

Greater Cambridge  
Mass Transit Options  
Assessment Report

Final Report  
January 2018

Greater Cambridge Partnership  
and Cambridgeshire and  
Peterborough Combined  
Authority

Our ref: 23201001





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Prepared by:

Steer Davies Gleave  
28-32 Upper Ground  
London SE1 9PD

+44 20 7910 5000  
[www.steerdaviesgleave.com](http://www.steerdaviesgleave.com)

Prepared for:

Greater Cambridge Partnership and  
Cambridgeshire and Peterborough  
Combined Authority

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## Executive Summary

### Study Context

Greater Cambridge is a thriving region. It is home to more than 288,000 people, a world-leading university and is one of the UK's most productive and dynamic economies. Cambridge acts as the heart of 'Silicon Fen', a world-renowned cluster of software, programming and life sciences firms, sustained by a highly-skilled workforce and close academic ties fostering a culture of innovation, collaboration and knowledge-sharing. Both Cambridge, and the wider region, continue to attract investment and talent from across the world. AstraZeneca, the world-leading pharmaceutical company, will open its global R&D and HQ at the Cambridge Biomedical Campus in 2018, creating up to 2,000 new jobs.

The Cambridgeshire & Peterborough Combined Authority (CPCA) and the Greater Cambridge Partnership (GCP) share an ambitious vision to build further on the region's transformational economic success over the last two decades – termed the 'Cambridge Phenomenon'. More than 33,500 new homes and 44,000 jobs are planned by 2030, with the potential, highlighted by the National Infrastructure Commission (NIC), for significant growth beyond this.

The CPCA highlight the imperatives of accelerating housing delivery and transforming transport connectivity to unlock constraints on growth and realise the ambition to double the area's economic output (measured by Gross Value Added, or GVA). Similarly, the NIC highlight the unrivalled economic potential of the Oxford – Milton Keynes - Cambridge corridor, but stress that poor transport connectivity and the slow rate of housing delivery places future growth at risk.



Source: <https://pixabay.com/en/united-kingdom-cambridge-university-2244622/>

Greater Cambridge's transport infrastructure currently acts to constrain growth, which must be overcome if the region is to fulfil its stated ambitions for sustainable long-term growth. Future employment growth is expected to be focused outside of the historic city core – in new 'city fringe' sites such as the Cambridge Biomedical Campus – which typically lack sufficient accessibility and capacity to connect them to potential workers and the city centre.



Cambridge's high-tech, high-skill economy also relies heavily on the productivity benefits that come from close proximity to one another (agglomeration benefits), and firms' ability to recruit workers across a wider labour market.

If Cambridge is to continue to grow, businesses within the 'Cambridge cluster' must be able to locate across a wider geography, yet still benefit from easy access to the region's innovative, skilled workforce and from close proximity to each other. Growth in 'satellite' communities at Cambourne, Bourn, Northstowe and Waterbeach, and in market towns such as Ely and Huntingdon, have the potential to spread the benefits of Cambridge's success across the wider region, tackling local deprivation and deliver tens of thousands of additional homes, but are predicated on significantly improved transport accessibility.

Several major transport schemes are currently planned or proposed, such as the A14 upgrade, while detailed plans for East West Rail and the Oxford – Cambridge Expressway are currently being developed which, if delivered, would transform east-west strategic connectivity in the 2020s. Public transport improvement corridors to Cambourne, Waterbeach and the South East Transport Corridor (A1307 Three Campuses to Cambridge) are planned, all of which will support efforts to improve transport accessibility, reduce congestion and promote growth.

However, committed and planned schemes alone fail to deliver the integrated, high-capacity, high-quality transport network required to support Cambridge's growth. Notably, they do not deliver the *seamless connectivity* required to facilitate growth, and fully address the congestion, poor connectivity and unreliable journey times that characterise many local journeys.

### Study Purpose and Approach

Mass transit could play an important role in delivering an integrated, high-capacity, high-quality transport network within Cambridge, which supports growth and allows the region to realise its full potential. Steer Davies Gleave was appointed by the CPCA and GCP to consider the case for a mass transit network within Greater Cambridge, including:

- the strategic context of growth, and emerging transport constraints;
- the geography of current and future travel demand, and how this relates to the key requirements of any future mass transit network;
- which mode or modes are best suited to a mass transit network within Cambridge; the overall case for mass transit, and next steps for the delivery of a mass transit network.

The approach to the study involved:

- Developing an objective and evidence-led approach to understand the problems, opportunities and key demand drivers that inform consideration of mass transit;
- Considering a range of different modes / concepts, and develop a shortlist of better performing options for more detailed consideration;
- Developing a Strategic Assessment Framework to assess shortlisted modal options, assessing how options perform against the study objectives, their demand and benefits potential, cost, affordability, value for money, deliverability and risk;
- Examining the potential for new and innovative transit technologies;
- Identifying potential funding sources, and developing recommendations and next steps.

Extensive engagement with key stakeholders formed a central element of the study. This provided a comprehensive understanding of the vision of key stakeholders for Greater Cambridge, and the role of Mass Transit, in order to understand their perspectives and gain specific insight, local knowledge and expertise that proved invaluable in guiding the study.

### Developing a Mass Transit ‘Concept’ for Greater Cambridge

Our review of the evidence base covered existing patterns of movements and constraints, the location and impact of future growth, and extensive engagement with stakeholders, and led to the development of a mass transit ‘concept’ for Greater Cambridge.

This concept identified the key attributes that a mass transit system should, *irrespective of mode*, seek to deliver. Our assessment of the planning capacity for a mass transit system considered the potential for significant growth beyond the current local plan period, and a substantial modal shift from car to public transport. This analysis suggested that any mass transit system should be designed with a planning capacity of 4,000 people per hour per direction per corridor (15,000 – 20,000 within the city centre tunnel), providing sufficient capacity for longer-term, aspirational levels of growth.

It demonstrated the need for a system which:

Delivers **high quality, high frequency, reliable** services, attractive to car users:

- World-leading user experience, with fully-segregated infrastructure, dedicated stops and real-time information

Delivers **maximum connectivity**, network coverage and reliable journey times:

- Directly linking all key destinations and corridors to one another
- Minimising the need to interchange

Provides sufficient **capacity for growth**, and to support Transit Oriented Development:

- A planning capacity of 4,000 people per hour per direct per corridors (15,000 - 20,000 through the City Centre core)

Is **flexible to adapt** for the future:

- Responsive to technological advances as they develop and become commercially available
- Providing capacity for growth, with a network that can be developed incrementally enabling operation to be scaled to support and accommodate future growth
- Planned for autonomous operation, but can accommodate driver-operated services in the short term

Utilises **emerging technology**, including connected and autonomous vehicles:

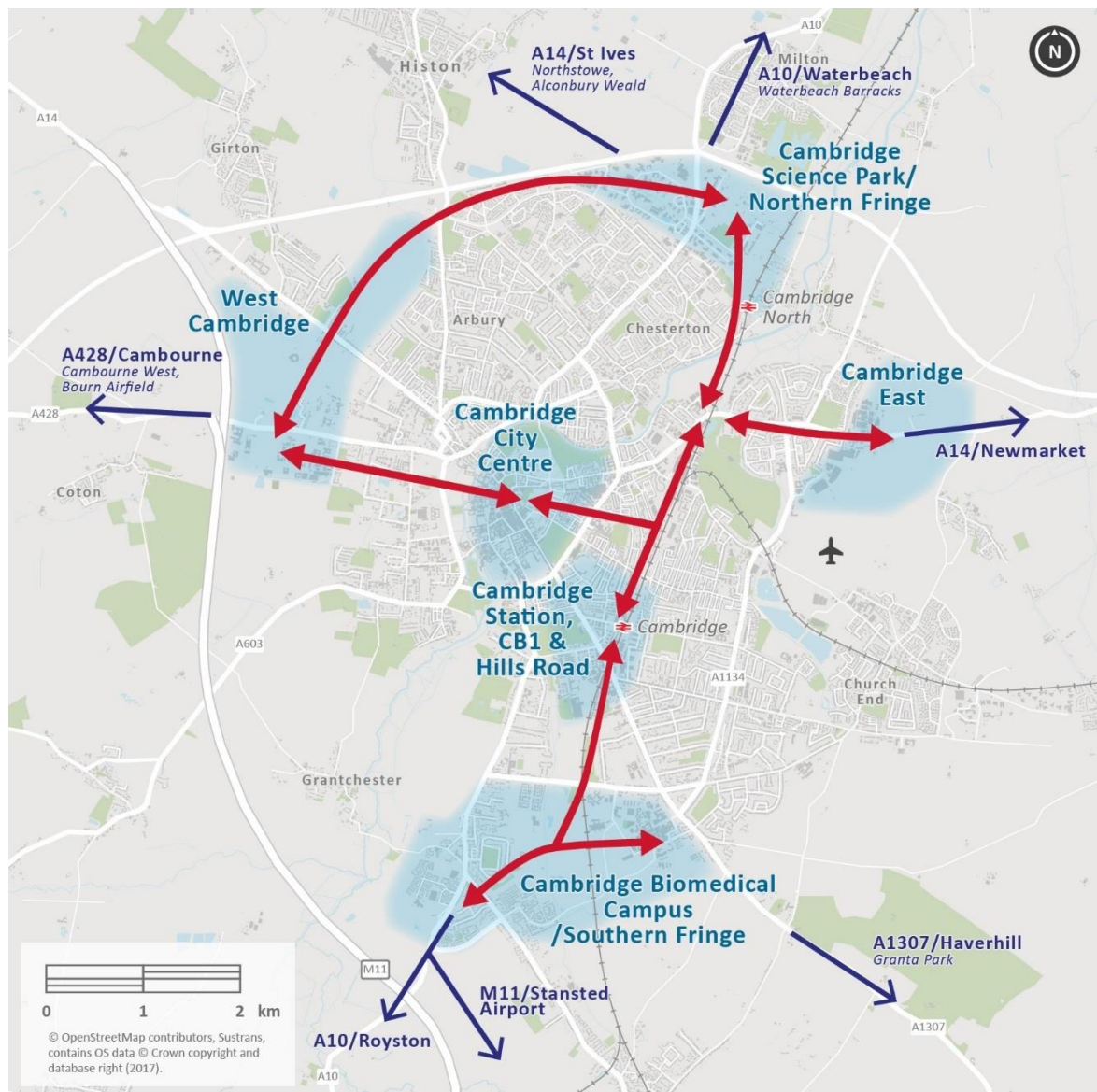
- Huge opportunity for Cambridge to be a ‘city of firsts’ in developing a high quality, high capacity automated mass transit system.

Represents **value for money, and is affordable and deliverable**.

Securing a largely **segregated alignment**, although challenging, was considered essential to deliver the principles above, and deliver the reliability expected for a mass transit system. Constraints imposed by Cambridge's historic streetscape, combined with the city's aspirations for growth, point towards the case for an integrated mass transit system, including sections of tunnel, which provides an extensive, frequent and reliable transport network for Greater Cambridge.

Based on the above principles, we developed a concept network. This was designed to address the guiding principles outlined above, whilst connecting all key destinations and development sites within Cambridge to each other, and the radial corridors from the city, as outlined in Figure 1.

**Figure 1: Proposed Mass Transit Network Schematic**



## Option Generation and Sifting

Our assessment considered a ‘long list’ of several mass transit technologies which could be suitable for a future mass transit system in Cambridge:

- | <b>‘Traditional’</b>               | <b>‘Emerging’</b>                      |
|------------------------------------|--|
| • Rail Based Metro                 | • Ultra Light Rail (ULR)               |
| • VAL (Véhicule Automatique Léger) | • Personal Rapid Transit (PRT)         |
| • Light Rail Transit (LRT) / Tram  | • Autonomous and driverless technology |
| • Bus Rapid Transit (BRT)          | • Affordable Very Rapid Transit (AVRT) |
| • Monorail                         |  |
| • Gondola / cable car              |  |
| • Kerb / other guided bus          |  |

Options were then sifted on their ability to meet the required planning capacity (4,000 people per hour per direction), and their likely deliverability, practicality and acceptability within Greater Cambridge. From this, a shortlist of modes was developed.

## Shortlisted Options

Three options were therefore shortlisted for a Cambridge mass transit system. These were:

- **Light Rail Transit (LRT)**, based on the Cambridge Connect concept developed by Dr Colin Harris. LRT would operate as a typical ‘light rail’ network, similar to the Manchester Metrolink, with trams with a capacity of approximately 200 passengers operating at least every ten minutes along each route. Steel rails and associated power infrastructure (typically overhead wires, but could be battery operated in sensitive areas) would be required along the length of the network.
- **Affordable Very Rapid Transit (AVRT)**, which is based on the concept advanced by Professor John Miles. AVRT is an innovative approach to use emerging technologies aiming to deliver a more cost-effective mass transit system within smaller cities such as Cambridge where construction of a traditional metro network may not be considered viable. It consists of small rubber-tyred vehicles (shown in Figure 2, each vehicle would have a capacity of approximately 40 passengers) operating as a high-speed shuttle (up to 120 mph) in small single-bore tunnels on a normal paved surface. Services would operate autonomously as a series of simple end-to-end shuttles, with interchange stations enabling passengers to transfer between shuttle services. Services would operate at high frequencies of 25 vehicles per hour.
- **Cambridgeshire Autonomous Metro (CAM)**, an option developed to utilise emerging driverless and connected technology and deliver the core outputs (quality, connectivity, capacity) outlined above. The concept employs elements of both LRT and AVRT. Specifically, it seeks to achieve the network coverage and connectivity of the Cambridge Connect LRT proposal, while utilising many of the technological features of AVRT. The CAM concept also includes tunnelling to overcome the key constraint within the city – in common with both LRT and AVRT options. Vehicles would offer a level of ride quality and comfort equivalent to that of LRT and be electrically-operated through battery operation. It would operate using bespoke rubber-tyred articulated vehicles (shown in Figure 3), with a capacity of 100 – 250 people, dependent on the chosen vehicle and demand requirement.
  - CAM could be either operated with a driver, or as technology matures, fully autonomously, using guidance technologies such as LIDAR.

- CAM would combine the use of 49km of new and proposed segregated infrastructure with existing segregated infrastructure to create a c. 75km fully segregated network, with the capability for services to extend beyond this, increasing network coverage to 90km+. Incremental segregation priority measures could be developed as future growth and congestion required.

The aim was to develop options capable of serving the wider Greater Cambridge area. However, we were also mindful of the fact that mass transit systems typically operate in urban areas, where demand levels are higher and can support the cost of implementing and operating a mass transit system. Accordingly, for LRT and AVRT both a 'city' and 'regional' variant was considered, serving the city and the wider corridors respectively. For 'city' variants access to mass transit from radial corridors would be provided via P&R and feeder services. CAM was developed as an option to provide regional coverage, whereby new and existing segregated infrastructure would facilitate the operation of direct services to all key radial corridors, without the requirement to interchange.

Table 1 summarises each option, including their attributes and costs.

**Table 1: Summary of Shortlisted Options**

Option	Description	Capital Cost (indicative)
LRT City Network	<ul style="list-style-type: none"> <li>• 42km network, with fixed track infrastructure</li> <li>• Based on Cambridge Connect</li> <li>• Corridors served via P&amp;R and bus feeders</li> </ul>	£2.8bn
LRT Regional Network	<ul style="list-style-type: none"> <li>• 90km network, with fixed track infrastructure</li> <li>• Based on Cambridge Connect proposal</li> <li>• Direct services to hinterland locations</li> </ul>	£4.5bn
AVRT City Network	<ul style="list-style-type: none"> <li>• 15km network, entirely new infrastructure</li> <li>• Based on John Miles proposal</li> <li>• Single or twin-bore tunnel options</li> <li>• Corridors served via P&amp;R and bus feeders</li> </ul>	£1.1 - £1.7bn (Dependent on single or twin-bore)
AVRT Regional Network	<ul style="list-style-type: none"> <li>• 56km network, entirely new infrastructure</li> <li>• Based on John Miles proposal</li> <li>• Twin-bore option to provide required capacity</li> <li>• Direct services to hinterland locations</li> </ul>	£2.1bn
Cambridgeshire Autonomous Metro (CAM) – Regional Network	<ul style="list-style-type: none"> <li>• 49km new infrastructure, of which: <ul style="list-style-type: none"> <li>• 24km new segregated infrastructure in Cambridge (including up to 6km tunnel)</li> <li>• 25km of planned / proposed segregated links</li> </ul> </li> <li>• Provides a 75km segregated network through the use of existing segregated infrastructure (such as Cambridge North &lt;&gt; St Ives)</li> <li>• Direct services to hinterland locations</li> <li>• Greater flexibility to serve regional destinations through shared running (e.g. to Haverhill or St Neots) if required, extending network to 90km +</li> </ul>	£1.5 - £1.7bn (Dependent on level of tunnelling required).

Note: Costs for CAM include all new segregated infrastructure and costs of planned/ proposed infrastructure.



**Figure 2: Illustration of Potential AVRT Vehicle**



**Figure 3: Illustration of CAM Vehicle**



## Strategic Options Assessment

The strategic options assessment sought to address two questions. First, to what extent does the option deliver against the key requirements identified for a mass transit system in Greater Cambridge. Second, is the option viable in terms of value for money, affordability and deliverability. The approach assessed each option against several key criteria, including:

**Table 2: Summary of Option Assessment**

Criteria	Description
Transport Outputs and Benefits	<ul style="list-style-type: none"> <li>What are the core transport benefits that support growth across the wider region of each option?</li> <li>Network coverage, frequency, quality, journey times, reliability, interchanges, accessibility</li> </ul>
Capital and Operating Costs	<ul style="list-style-type: none"> <li>What are the costs to construct the system and operate it on an ongoing basis?</li> </ul>
Likely Demand Potential	<ul style="list-style-type: none"> <li>Considering the attributes and transport outputs of the system, and the extent of network coverage, how much demand is each option likely to attract?</li> </ul>
Affordability and Value for Money	<ul style="list-style-type: none"> <li>Are the options likely to represent VfM under current government funding criteria?</li> <li>Are they likely to cover their operating costs in fares or receive an ongoing subsidy?</li> </ul>
Deliverability	<ul style="list-style-type: none"> <li>What are the key risks associated with the deliverability of each option?</li> </ul>

### Transport Outputs and Benefits

Transport outputs refer to the benefits of each option ‘on the ground’, such as the capacity, connectivity and accessibility they deliver. These typically determine the overall ‘attractiveness’ of the system (and hence the level of demand), and are in turn based on the overall coverage, frequency, quality of service, degree of interchange, reliability and journey times offered by the mass transit system in question.

Table 3 below summarises our assessment of the transport benefits of each scheme option:

**Table 3: Summary of Assessment of Transport Benefits**

	LRT - City	LRT – Regional Network	AVRT - City	AVRT - Regional	Cambridge Area Metro
Network coverage	✓✓	✓✓✓	✓	✓✓	✓✓✓✓
Route flexibility	✓✓	✓✓	✓	✓	✓✓✓
Frequency	✓✓	✓✓	✓✓✓	✓✓✓	✓✓
Journey time / reliability (in-vehicle)	✓✓	✓✓	✓✓✓✓	✓✓✓✓	✓✓
Interchange (minimised)	✓✓	✓✓✓	✓	✓	✓✓✓✓
Accessibility (no. stops served)	✓✓✓	✓✓✓	✓	✓	✓✓✓
Quality	✓✓✓✓	✓✓✓✓	✓✓	✓✓	✓✓✓

Overall, CAM would perform strongly across a range of transport criteria, broadly equivalent or better than LRT, offering:

- extensive network coverage, and greater flexibility, than the other options due to the ability to utilise existing segregated infrastructure and operate on-street if required;

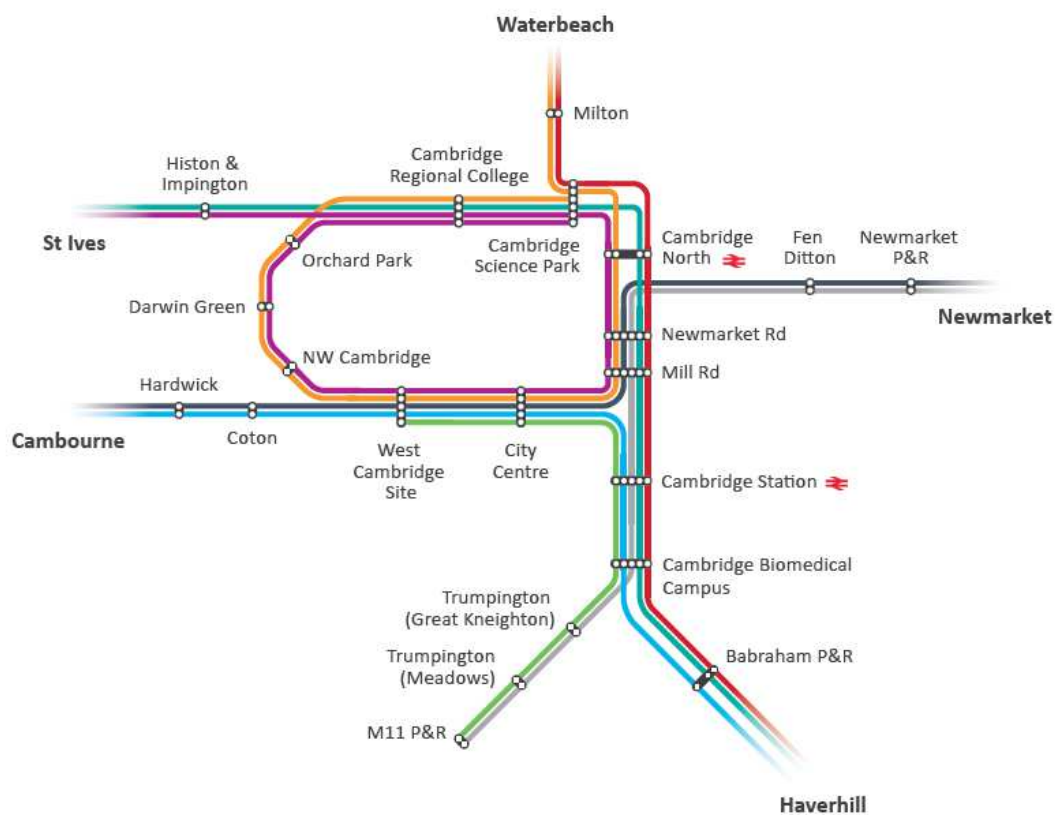


- a likely higher frequency service than LRT, due to the use of smaller vehicles;
- fast, reliable journey times, due to a largely segregated alignment;
- reduced need for interchange due to a more expansive network than other options;
- a service quality at least equivalent to LRT.

LRT would also offer a high-quality, frequent service, although a less expansive ‘city’ network would require interchange for some journeys (e.g. St Ives to Cambridge), although this could be mitigated by complementary services and infrastructure (such as bus feeders and P&R sites).

AVRT would be less attractive, since faster journey times are counteracted by limited network coverage (only 5 stops on the city network) and the increased requirement to interchange. Ride quality is also uncertain, due to the smaller vehicles and rapid acceleration.

**Figure 4: Illustrative CAM Network**



### *Likely Transit Demand*

We have not undertaken demand modelling and forecasting as part of this strategic assessment. However, the comparative assessment of transport outputs / benefits provides a basis for the relative demand potential for each mode. As such, LRT and CAM have the potential to deliver the greatest benefits, and attract more demand, than AVRT. We would expect that both LRT and CAM would attract a similar proportion of current and future demand along any given corridor, assuming they serve the same key destinations.

### *Value for Money*

Promoters of transport schemes are typically required to demonstrate that their scheme would deliver ‘value for money’ (VfM) – in broad terms that the monetised benefits of the scheme are significantly greater (at least 1.5 times) the scheme costs. The fundamental drivers of the VfM performance are the scheme costs (in particular capital costs) and the monetised transport benefits of the option.

*In comparative terms*, CAM represents the best value for money (VfM) of any option, delivering comparable transport benefits to LRT at a substantially lower cost (around a third of the capital costs of a regional LRT network). When compared to AVRT, our assessment is that CAM would deliver significantly greater benefits than AVRT at a cost broadly equivalent to the AVRT city network, and lower than AVRT costs for a regional network.

We assessed whether LRT (as the other option that performed well across the range of transport outputs and benefits) has the potential to deliver value for money in *absolute terms*. Our benchmarking of Cambridge LRT options against UK and international comparators concluded that a Cambridge-based LRT network would not have the critical mass or density of demand to support an LRT network, even taking account of the substantial growth potential of the region.

It is not possible at this early stage to state definitively that the CAM option would deliver value for money (based on meeting thresholds based on current DfT guidance). However, we conclude that of the options assessed, CAM is the only one with a realistic prospect of achieving value for money. The tunnelled section is the primary cost driver, but also the element of the system that would help deliver the greatest benefits in terms of:

- Significant journey time savings and reliability benefits, especially for cross-city and orbital trips which currently require interchange, due to the connectivity and segregation delivered by the city centre tunnel;
- There is a strong argument that without a mass transit scheme (or comparable project to deliver a significant increase in transport capacity) that the economic potential of Greater Cambridge (in terms of additional jobs and development) will not be realised, representing a significant ‘loss’ in future Gross Value Added.

### *Ongoing Affordability*

Proposed schemes are also required to be affordable on an ongoing basis, and must either operate at a surplus (with no ongoing subsidy) or if not, that any operating deficit is funded locally. DfT does not provide ongoing subsidies for new public transport infrastructure, except in rare circumstances.

Considering the expected operating costs of a Cambridge LRT network, it is highly unlikely that the level of demand it is likely to generate is commensurate with operating without a subsidy, which would need to be funded locally. Most UK LRT networks (despite serving denser, more populated areas than Cambridge) receive subsidy; the 80km Tyne-and-Wear Metro receives £25 million of annual support, despite supporting a level of patronage of 40 million journeys annually, significantly greater than that expected for a ‘regional’ Cambridge LRT.

Whilst it is not possible to state definitively at this stage, we would expect CAM to operate at a surplus. This is due to a lower operating cost per vehicle kilometre (which could be further reduced were the system to become driverless), and a greater flexibility to match service levels (the core driver of operating costs) to demand, at different times (e.g. off-peak), on

different corridors, and over time. Reflecting the uncertainty in AVRT technology, we have not considered the likely operating costs and ongoing affordability of the AVRT options.

### *Deliverability*

Reflecting the early stage of scheme development, there are significant risks associated with each scheme option. We have sought to identify ‘show-stopper’ risks which could render an option undeliverable.

While CAM would be a large and complex project to develop and implement, there are no ‘showstopper’ risks identified at this stage. Our view is therefore that CAM clearly represents most deliverable option. There is a high risk that LRT and AVRT options would not represent value for money (and hence receive scheme funding), and that any LRT or AVRT ‘regional’ scheme will be unaffordable on an ongoing basis due to the high level of operating subsidy required.

Our assessment of the deliverability risk (red = high risk) of each option is summarised in Table 4 overleaf.

**Table 4: Summary of Deliverability Risks**

	LRT - City	LRT – Regional	AVRT - City	AVRT - Regional	CAM
Technical Feasibility					
Technology					
Value for Money					
Affordability					
Powers / consents / legislation					
Stakeholder / public acceptability					

### *Option Assessment Summary*

- CAM offers the potential to deliver the capacity, quality and coverage required to support wider outcomes related to housing growth, jobs and GVA
- CAM could deliver similar benefits at a substantially lower overall cost than LRT, and hence represents better value for money and affordability. CAM would deliver greater benefits than AVRT at a similar or lower cost.
- The concept utilises emerging technology, including connected, autonomous / driverless vehicles – a great opportunity for Cambridge to be a ‘city of firsts’ in developing a high quality, high capacity, world-class automated mass transit system
- It could deliver transit-oriented development, and utilise a range of local funding mechanisms, including land value capture, to support the delivery of the scheme

### **Recommendations and Conclusions**

This assessment has identified CAM as the best option to take forward for further development. The central finding is that CAM has the potential to deliver the capacity, connectivity and accessibility to support sustainable long-term growth, and deliver wider outcomes such as the delivery of housing, supporting jobs and increasing productivity.

The next stage of work would be to develop the CAM concept to a greater level of detail, informing the development of a Strategic Outline Business Case, in line with Department for Transport guidance. This will set out the strategic case for the scheme in greater detail, and assess the value for money, affordability and deliverability of the CAM concept.

Consideration of how the development of the network would be phased, including the delivery of the tunnelled elements, and how autonomous technology could be rolled out, are also included in this stage.

#### *Funding*

Any scheme would need to be funded through a combination of local and national funding. Our initial analysis suggests that there is significant potential for the scheme to secure local funding contributions and would, subject to meeting value for money criteria, also be eligible for Central Government funding (potential funding could come from the Department for Transport, Ministry of Housing, Communities & Local Government and technology funding administered by Innovate UK). More innovative funding options, such as new or amended land-value capture mechanisms (as proposed by the NIC), could also be adopted if enabled by Central Government legislation.

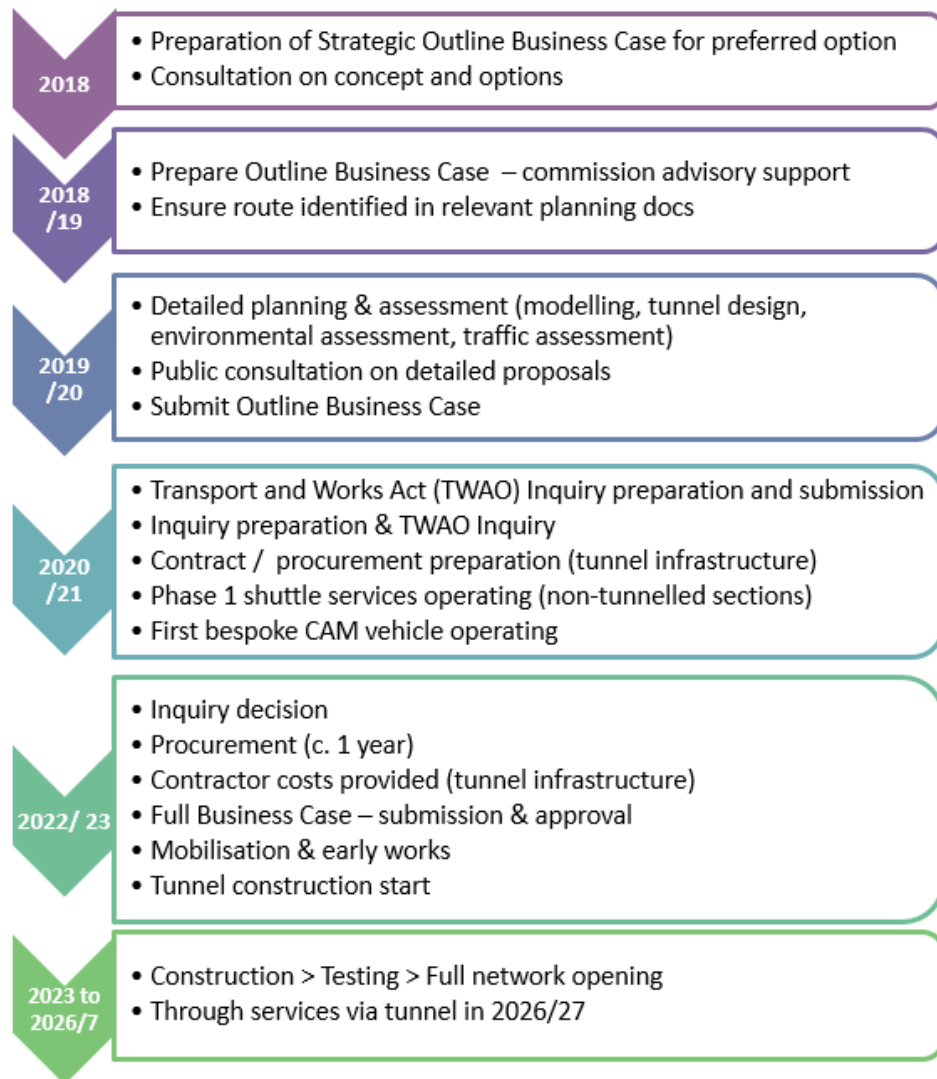
#### *Timetable*

An indicative timetable for the development and implementation of CAM is set out in Figure 5. The programme assumes that the detailed design, planning and powers would be focused on the new bespoke segregated infrastructure (including the tunnel) while the securing of segregated alignments on planned / proposed routes (e.g. to Cambourne, Waterbeach) would be progressed as separate projects. This reduces planning risk / dependency, and enables planned infrastructure to come forward in advance of the tunnel.

While the planning and delivery of parts of the overall segregated CAM network can be progressed separately, it will be imperative that the overall strategic case for CAM is made at

the network level, and takes account of wider complementary planned transport initiatives (e.g. demand management).

Figure 5: Indicative Timescale for Delivery



# 1 Introduction

- 1.1 Steer Davies Gleave (SDG) has been jointly commissioned by Greater Cambridge Partnership (GCP) and the Cambridgeshire and Peterborough Combined Authority (CPCA) to assess and develop the case for a rapid transit network within Cambridge and the surrounding region.

## **Strategic Context**

- 1.2 Our context for the consideration of mass transit options within Greater Cambridge is a desire to build on the recent successes of the Greater Cambridge economy, and support the region's untapped potential for economic growth, significant housing delivery and the creation of tens of thousands of new jobs.
- 1.3 Cambridge is a world-renowned city in the East of England, home to approximately 130,000 people. The city is home to a world-leading university and a leading cluster of software, programming and life science firms known as 'Silicon Fen', competing on a global stage. Recent years have seen unprecedented investment with, for example, AstraZeneca, one of the world's leading pharmaceutical firms, choosing the Cambridge Biomedical Campus to locate its global headquarters and R&D centre. There have been major new housing developments at Trumpington, West Cambridge and Cambourne – the latter one of the fastest growing towns' in Europe – which have delivered thousands of new homes over recent years.
- 1.4 The CPCA, with Cambridge at its heart, is led by Mayor James Palmer. The CPCA has ambitions to double the size of the local economy, enhance connectivity and continue to develop the regions' 'knowledge economy' on the global stage. The Greater Cambridge City Deal, overseen by the GCP, is expected to facilitate 44,000 new jobs and 33,500 new homes by 2031, with large new settlements outside the city at Cambourne / Bourn Airfield, Waterbeach and Northstowe.

## **The Role of Mass Transit**

- 1.5 Cambridge's economy attracts commuters from across a wide region encompassing 'city fringe' areas, 'satellite' settlements such as St Ives and Cambourne, and market towns such as Ely, Newmarket, St. Neots and Huntingdon. Rapid growth and new development within Cambridge – combined with an increasingly dispersed labour market catchment – underlines the need for a reliable, high capacity and high-quality transport network connecting people, jobs and services.

## **Proposed Transport Interventions**

- 1.6 Several transport schemes have been developed and proposed across the region in recent years, delivering improved connectivity, supporting growth and alleviating traffic congestion. The Cambridge Guided Busway is the longest kerb-guided busway in the world, connecting the

City Centre and Cambridge Station to Histon, St Ives, Trumpington and the Cambridge Biomedical Campus, carrying 3.8 million passengers annually. Cambridge North railway station, located to the north of the city near the Cambridge Science Park, opened in early 2017, providing regular services to London and Ely.

- 1.7 Currently under construction, the A14 upgrade will deliver additional highway capacity towards St Ives and Huntingdon, and the committed duelling of the A428 between Cambourne and St Neots will deliver a significant enhancement in the region's strategic connectivity. The proposed Oxford to Cambridge Expressway and East – West Rail Link would, if implemented, transform east-west connectivity towards Bedford, Milton Keynes and Oxford. Several local schemes, designed to improve accessibility into Cambridge, are also under development by the Greater Cambridge Partnership:

- **Cambourne to Cambridge:** a new public transport route between Cambourne and Grange Road in Cambridge;
- **Western Orbital:** a new bus link parallel utilising the M11 between the North-West Cambridge site and the Cambridge Biomedical Campus;
- **South East Transport Corridor Study (A1307 Three Campuses to Cambridge):** improvements to the public transport, walking and cycling network between the Cambridge Biomedical Campus, the Babraham Research Campus and Haverhill; and
- **Milton Road/ Histon Road:** introduction of new bus lanes and segregated cycleways along Milton Road and Histon Road.

#### The Case for Mass Transit

- 1.8 While these schemes will deliver significant benefits to the region, delivering faster journeys and supporting economic growth, they do not, on their own, deliver **an integrated mass transit solution** that provides seamless connectivity between the City Centre, key development sites on the city fringe (such as the Cambridge Biomedical Campus) and the wider corridors in the region. They are unlikely to provide the required accessibility, and capacity, to support long-term aspirations for Greater Cambridge.

- 1.9 The proposed schemes under development do not penetrate the highly constrained city centre, which has limited capacity to accommodate additional bus services, and therefore do not provide 'last mile' connectivity. Cambridge and the wider region are therefore likely to require a mass transit scheme which delivers high capacity and high-quality connectivity, offering improved accessibility into and across the historic city centre core.

### Purpose of this Study

- 1.10 Steer Davies Gleave has been jointly commissioned by GCP and the CPCA to assess and develop the case, at a high-level, for a rapid transit network within Cambridge and the surrounding region.

- 1.11 The requirements of the study were to:

- Develop an objective and evidence-led approach throughout;
- To understand the problems, opportunities and key demand drivers that inform consideration of mass transit;
- To consider a range of different modes / concepts, and develop a shortlist of better performing options for more detailed consideration;



- To develop a Strategic Assessment Framework to assess shortlisted modal options. The framework is used to assess fit with objectives, demand and benefits potential, cost, affordability, value for money, deliverability and risk;
- To examine the potential for new / innovative technologies;
- Identify potential funding; and
- To develop recommendations and next steps.

1.12 A central element of the study was to engage with key stakeholders. This engagement provided an understanding of the vision that key stakeholders had for Greater Cambridge, and the role of Mass Transit, to understand their perspectives and gain specific insight, local knowledge and expertise that proved invaluable in guiding the study.

1.13 The study is a relatively high-level strategic assessment, and further development work will be required to take forward its recommendations.

## Report Structure

1.14 This report is formed of ten chapters, of which this chapter is the introduction. The rest of the report is structured as follows:

- **Chapter 2:** sets out the strategic context of the study and establishes the need for a mass transit system in Greater Cambridge;
- **Chapter 3:** sets out the key drivers of transport demand and implications for patterns of movement, both now and in future;
- **Chapter 4:** sets out the objectives for a mass transit scheme in Greater Cambridge;
- **Chapter 5:** describes an illustrative demand assessment to inform an assessment of the 'planning capacity' that a mass transit scheme should aim to deliver;
- **Chapter 6:** considers a range of mass transit options and potential technologies;
- **Chapter 7:** analyses which modes can achieve the objectives for mass transit in Greater Cambridge, condensing a long-list into a short-list of options;
- **Chapter 8:** provides more detailed analysis of the short-list using a strategic assessment framework;
- **Chapter 9:** provides recommendations for next steps; and
- **Chapter 10:** concludes the report.

## 2 Strategic Context

2.1 This chapter outlines the wider context to the study, establishing the ‘case for change’ including:

- the success of the Greater Cambridge economy;
- aspirations for future housing and employment growth;
- the key barriers which act to constrain this growth, including poor connectivity and housing unaffordability.

2.2 It also provides context on the wider political context, highlighting both the important role of transport infrastructure in facilitating growth, and how recent and currently-proposed transport investment in Greater Cambridge fails to provide the integrated, high capacity, high quality solution required to support the region’s long-term aspirations.

### **The Greater Cambridge Economy**

2.3 Greater Cambridge is a thriving region, home to more than 288,000 people, a world-leading university and a highly productive, dynamic economy. Cambridge acts as the centre of ‘Silicon Fen’, a leading global cluster of software, programming and life science firms, that sustain the regions’ high-tech economy and compete on a global stage. Historic Cambridge, together with the towns and villages of surrounding South Cambridgeshire, offer an outstanding quality of life which underpins the region’s success, and attracts talent from across the world. The University of Cambridge, ranked as one of the world’s top five universities, forms a central part of the city’s highly-skilled economy, driving innovation and stimulating start-ups amongst academics and post-graduates.

2.4 Both the region’s small scale and the extensive networks of academic staff, skilled workers and postgraduate students fostering a culture of co-operation, knowledge sharing and innovation, known as the ‘Cambridge Phenomenon’. Cambridge acts as the innovation capital of the country, with more patents per person than the next six cities combined<sup>1</sup>. Employment within professional, scientific and technical activities – including within knowledge-intensive sectors such as research and development, bioscience and technology – is more than double the national average<sup>2</sup>.

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<sup>1</sup> Centre for Cities, Cities Outlook 2014

<sup>2</sup> Business Register and Employment Survey, 2014

- 2.5 Cambridge's hi-tech economy is hence highly productive, with Gross Value Added per head of £45,000, considerably greater than the national average of £25,400<sup>3</sup>. High levels of productivity are reflected in the levels of pay: workers in Cambridge receive a median hourly pay of £14.50 per hour, 25% greater than the UK median of £11.60. 44% of the population hold an NVQ4 or above qualification, almost double the national average of 27%, with 34% holding degree-level qualifications (BA / BSc or higher), compared to the national average of 17%<sup>4</sup>. Employment within education directly – including that associated with the university – is 78% greater in Greater Cambridge and 148% greater within the city boundary than the England and Wales average<sup>5</sup>.
- 2.6 Recent economic success has been accompanied by rapid population growth in recent years. Between 2001 and 2016, the population of Cambridge proper grew from 110,000 to 132,000, and a further 26,000 within surrounding South Cambridgeshire<sup>6</sup>. Major new housing developments, such as Trumpington Meadows, have created attractive new communities on the 'city fringe' which offer an outstanding quality of life for local residents.

### Recent growth

- 2.7 Cambridge's skilled workforce, culture of innovation and high quality of life continue to attract both talent and investment from around the world. AstraZeneca, the world-leading pharmaceutical company, is expected to open in global R&D and HQ at the Cambridge Biomedical Campus in 2018, creating up to 2,000 new jobs. Combining world-class biomedical research, patient care and education on a single site, the Campus hosts an emerging cluster of biotech and life sciences firms, and is expected to become one of the leading biomedical centres in the world by 2020.

Figure 2.1: Future AstraZeneca HQ and global R&D centre



Source: Construction Enquirer

<sup>3</sup> Office for National Statistics, Regional GVA by Local Authority, 2015

<sup>4</sup> Office for National Statistics, 2011 Census

<sup>5</sup> Business Register and Employment Survey, 2016

<sup>6</sup> Office for National Statistics, Mid-Year Population Estimates, 2016

- 2.8 Cambridge Ahead, a local business and academic group, indicate that in the year to 2016, both turnover and employment at Cambridge companies increased by more than 7%, with the number of firms with their home base within 20 miles of Cambridge growing by more than 2,500, reflecting the region's continued success. Turnover and employment within the life sciences sector grew by 32.1% and 10.5%<sup>7</sup>, reflecting the region's strengths in this rapidly emerging industry. Overall, the 'AstraZeneca effect' is expected to add £16.1 billion to the city regions' turnover, with an additional 60,100 jobs<sup>8</sup>.
- 2.9 Between 2010/11 and 2015/16, the turnover of Cambridge companies grew by 7.5% p.a., and employment by 6.6% p.a., demonstrating the region's sustained growth. Cambridge Ahead note that *"the growth of 7% per annum, if sustained and compounded over 10 years, will result in growth of 97%, essentially a doubling of where we were in 2011"*, underlining the need to sustainably plan and manage growth to maintain Cambridge's success, and maintain the quality of life of its residents.

### Vision for Growth

- 2.10 Policymakers and businesses within Greater Cambridge have an ambition to ensure the region continues to grow and prosper, and to cement its position as a global leader in research, technology and life sciences. Cambridge's potential – and importance to the UK economy – is recognised at a national level, with the National Infrastructure Commission recognising both the region's success and its potential for growth.
- 2.11 It highlights the ability for the Oxford – Milton Keynes – Cambridge corridor to become a world-renowned centre for science, technology and innovation, but stresses that a lack of housing and connectivity are putting future success at risk:

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*"Towns and cities across the [Cambridge – Milton Keynes – Oxford] corridor are amongst the most successful and fastest growing in the UK, making a substantial, and increasingly important, contribution to UK income and to national tax revenues. The success of these places matters, not just to those who live and work in the corridor, but to national prosperity"* National Infrastructure Commission, November 2016

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- 2.12 The Greater Cambridge Partnership, the Greater Cambridge Greater Peterborough Local Enterprise Partnership and the Cambridgeshire & Peterborough Combined Authority provide the funding and mechanisms to unlock growth, and ensure that the key barriers to growth are overcome, whilst the NIC also plays a role in shaping the region's future growth.
- 2.13 Figure 2.2 summarises the local institutional structures with responsibility for the planning and delivery of infrastructure.

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<sup>7</sup> Cambridge Ahead, "Latest data from Cambridge Ahead reveals unabated growth of Cambridge companies", 2017

<sup>8</sup> Ibid

Figure 2.2: Local Structures within Greater Cambridge

 <b>CAMBRIDGESHIRE &amp; PETERBOROUGH</b> COMBINED AUTHORITY	 <b>GREATER CAMBRIDGE / GREATER PETERBOROUGH</b> ENTERPRISE PARTNERSHIP	 <b>GREATER CAMBRIDGE</b> PARTNERSHIP
<ul style="list-style-type: none"> <li>The Authority is led by a Mayor James Palmer, who was elected on 5th May 2017.</li> </ul>	Business-led Partnership responsible for promoting developing economic priorities and promoting economic growth	<ul style="list-style-type: none"> <li>Partnership of Cambridgeshire County Council, Cambridge City Council, South Cambridgeshire District Council, Greater Cambridge Greater Peterborough LEP and the University of Cambridge.</li> </ul>
<b>Devolution Deal funding:</b> <ul style="list-style-type: none"> <li>£100m housing and infrastructure fund</li> <li>£20m pa of 60% capital and 40% revenue for 30 years</li> <li>£70m housing need fund</li> </ul> Mayor to <b>control transport budget</b> , management of Key Route Network and strategic planning with infrastructure fund	<b>Administers £150m Growth Deal Funding to:</b> <ul style="list-style-type: none"> <li>Drive innovation and business growth</li> <li>Support housing delivery</li> <li>Invest in skills and infrastructure</li> <li>Fund transport improvements</li> <li>Develop the area's enterprise zones</li> </ul>	Delivery of <b>City Deal funding</b> of transport infrastructure to boost economic growth <ul style="list-style-type: none"> <li>£100m until 2020</li> <li>Further £400m if initial investments are successful</li> </ul>

### Cambridgeshire and Peterborough Combined Authority

- 2.14 The Cambridgeshire and Peterborough Combined Authority forms the regional body responsible for newly-devolved powers from Central Government. Led by a directly-elected mayor, James Palmer, its key ambitions include:

- doubling the size of the local economy and Gross Value Added;
- accelerating house delivery to meet local needs, with 72,000 new homes across the Combined Authority area;
- providing world-class transport and digital connectivity, fit for the 21<sup>st</sup> century;
- investing in skills, and providing the UK's most technically-skilled workforce;
- boosting the region's international recognition for its knowledge-based economy, including in life sciences and information and communication technologies; and
- improving local quality-of-life by tackling areas suffering from deprivation.

- 2.15 The Cambridgeshire and Peterborough Devolution Deal, published in March 2017, sets out significant new funding and devolved powers to achieve their ambitions, including a 30-year, £600 million investment fund to grow the local economy, £170 million for new homes and new powers over transport, planning and skills. It recognises that transport connectivity plays a key role in facilitating these ambitions.

### Greater Cambridge Greater Peterborough Local Enterprise Partnership

- 2.16 The Greater Cambridge Greater Peterborough (GCGP) LEP is a business-led partnership responsible to supporting economic growth across the wider region. It administers approximately £150m of Government 'Growth Deal' funding, supporting a range of transport, skills and economic support interventions across the wider region, stretching from Kings Lynn to Bury St Edmunds, Stansted and Huntingdon.

- 2.17 GCGP LEPs' ambitions include:

- Becoming the UK's exemplar area for digital connectivity;
- Removing skills barriers to facilitate continued growth;
- Delivering a growth hub to support business growth;
- Creating a transport network fit for the future;
- Facilitate the creation of additional incubator and innovation space;

- Support the continued development of the Alconbury Weald Enterprise Campus.

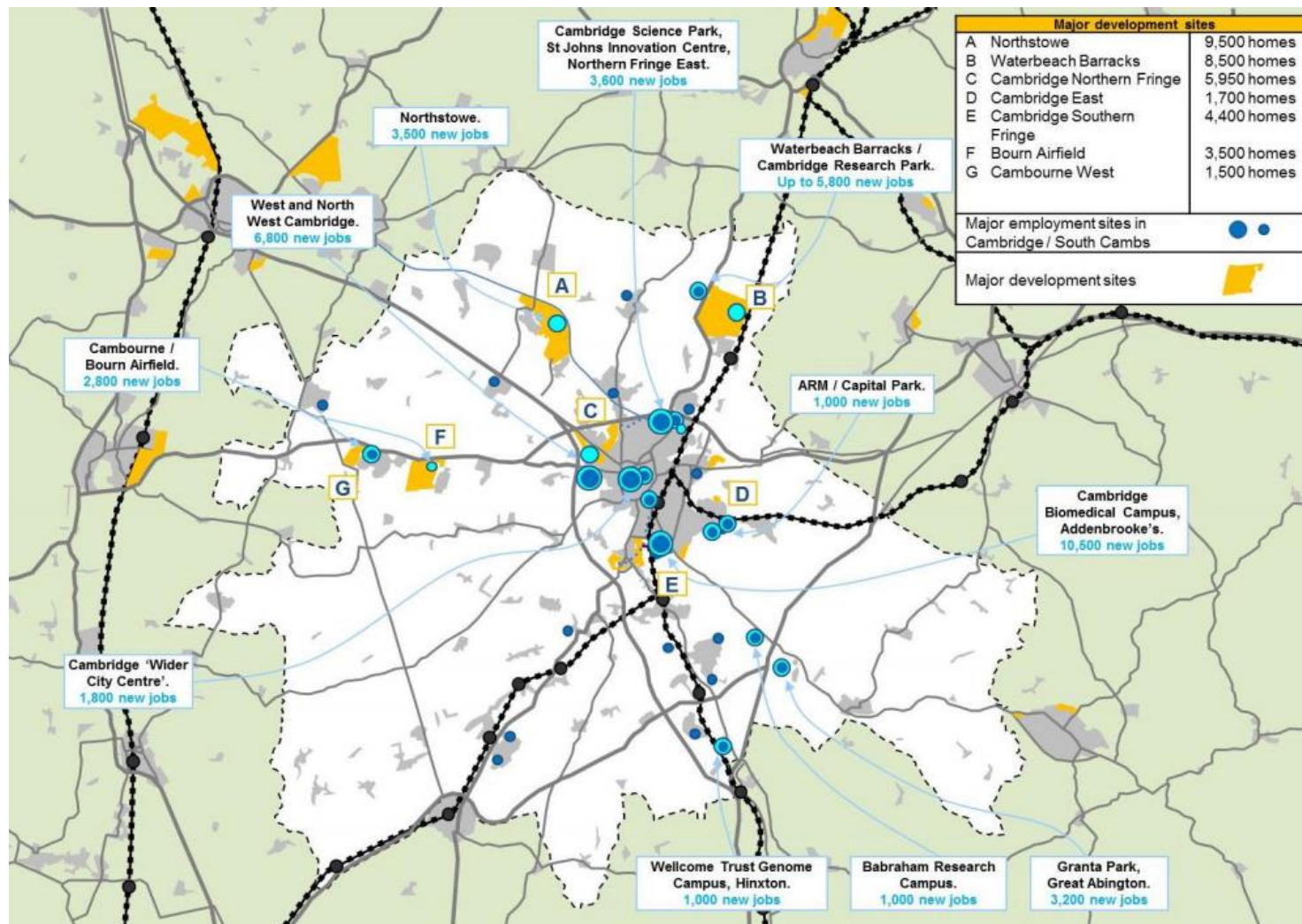
Projects supported by the LEP include investment in the Cambridge Biomedical and Haverhill Innovation Centres, upgrades to the A47 and Ely Southern Bypass, and new academies and educational colleges focusing on specific skills in construction and agri-tech.

### **Greater Cambridge Partnership and the City Deal**

- 2.18 The Greater Cambridge Partnership was established as the local delivery body of the City Deal, intended to coordinate a response to the shortage of housing threatening future economic growth. The GCP covers the area defined by the Cambridge and South Cambridgeshire local authorities, and its key aims include:
- accelerated delivery of 33,500 new homes;
  - creation of 44,000 new jobs;
  - provision of £1bn of local and national public sector investment, enabling an estimated £4bn of private sector investment in the Greater Cambridge area;
  - delivering a new governance arrangement, joint decision making and the framework, funding and assurance to enable growth to take place.
- 2.19 The City Deal outlines how the Greater Cambridge area can grow physically to enable economic growth, through a spatial focus on key economic hubs such as Cambridge City Centre, the Science Park, the University of Cambridge's west and north-west sites and the emerging Addenbrookes' Biomedical Campus. The City Deal includes priorities around enhancing connectivity and offering a high quality of life, which will underpin the area's attractiveness and success.
- 2.20 Figure 2.3 shows the areas identified for major housing and employment growth under the City Deal. Further detail on proposed development both within Cambridge, and the wider corridors, is presented in Chapter 3.



Figure 2.3: Greater Cambridge City Deal – areas for proposed housing and employment growth





## National Infrastructure Commission

- 2.21 The National Infrastructure Commission (NIC), responsible for advising HM Government on the pressing infrastructure challenges facing the UK, recently identified the massive potential for the Oxford – Milton Keynes – Cambridge corridor to become a single, world-renowned centre for science and innovation. Stressing how the region could become the UK’s ‘Silicon Valley’, it highlighted Cambridge’s unique assets including a concentration of highly-skilled workers, globally competitive business clusters and world-leading universities and research institutes – but that a lack of housing and poor connectivity is putting growth – and future success – at risk:

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“This corridor is a national asset, that competes on the world stage and can fire the British economy – but only with an integrated and ambitious strategy to deliver new homes, connectivity and opportunities can it realise its full potential” *National Infrastructure Commission*

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- 2.22 The Commission’s central finding was that rates of house building within the corridor need to double if the region is to achieve its economic potential, with up to a million new homes by 2050 in well-designed, liveable and connected communities which enhance the region’s quality of life. It is judged unlikely that this level or quality of development can be delivered if growth is focused exclusively on the fringes of existing towns and cities, or through small garden towns – instead, Government and local authorities need to plan and deliver large new settlements and major urban extensions, including the first new towns in over a generation.
- 2.23 The Commission identifies that this requires national leadership combined with support from local communities, and stresses the need for an integrated strategy for housing, jobs and infrastructure to ensure the significant potential for the region is realised, including:
- Local and regional leadership to create effective joined-up strategies, including across administrative borders;
  - new investment in strategic east-west transport infrastructure, including East-West Rail and the Oxford – Cambridge Expressway, to unlock the development of ambitious new and expanded settlements; and
  - a local commitment to accelerate house building, in return for certainty over enabling infrastructure and the freedoms and resources required to shape growth in a way that enhances quality of life for residents.
- 2.24 The NIC recognises the need for greater private sector and local funding contributions – including through streamlined land-value capture mechanisms – to enable the delivery of these schemes, reflecting the benefits that these parties gain from new infrastructure. New statutory development corporations should be able to assemble the land required for new settlements at existing ‘no-scheme’ values, including through compulsory purchase mechanisms, to ensure that the value of public investment is maximised, and a more flexible approach to the Community Infrastructure Levy and Section 106 agreements adopted.

- 2.25 Government and local policymakers should work *in partnership* to implement measures to increase certainty on the delivery of growth enabling infrastructure, including:
- establishing indicative, long-term pipelines of strategic national and local infrastructure investments, conditional upon housing delivery and supported by firm financial commitments, by 2020;
  - developing robust and credible transport plans to enable the development of the corridors' key towns and cities by mid-2019, providing a firm basis for long-term growth and investment, and including plans for significantly upgraded public transport, integrated transport hubs and the provision of safe cycling infrastructure.
- 2.26 Ultimately, local areas must be given the **certainty, freedom and resources** to create well-designed, well-connected new communities, and in doing so fully realise their potential.
- 2.27 The NIC work highlights the need to joint transport and spatial planning approaches to be developed at a corridor and local level, for which Mass Transit has the potential to play an integral role.

## Challenges to Growth

- 2.28 Future growth is therefore not certain – it is dependent on a comprehensive, integrated strategy to tackle the high cost of housing, poor connectivity and worsening congestion – as recognised by the NIC, the GCP and the CPCA.

### Transport Connectivity and Capacity

- 2.29 Cambridge benefits from an extensive transport network, including connections to the strategic highway network, rail services to London, East Anglia and the West Midlands and a local and regional bus network. However, connectivity within the city itself is limited, with key road corridors suffering from slow, unreliable journey times. Good bus accessibility is limited to the City Centre, with other employment hubs such as the Cambridge Science Park suffering from limited public transport accessibility. Such sites are heavily reliant on commuting by private car, which places increasing pressure on the highway network.
- 2.30 Much of Cambridge's future growth is expected to be disproportionately concentrated on the city's 'fringes', either at large employment hubs such as the Cambridge Biomedical Campus, or new communities at North West Cambridge, Cambourne or Waterbeach, placing new requirements and challenges on the transport network. New commuting patterns are likely to place greater importance on orbital connectivity and trips across the region, rather than simply radial access to the City Centre. Much of the city's existing transport network is poorly configured for such future trips, with commuting over longer distances by public transport being often slow and challenging.
- 2.31 Both the highway and bus networks suffer from limited capacity, which is unlikely to be able to cater for significant increases in traffic volumes without worsening congestion or lengthening journey times. Chronic congestion is already commonplace within the city, with common journeys – such as the City Centre to Cambridge Station – often faster on foot than by car or bus. Traffic congestion is expected to worsen in future without investment, which limits accessibility, worsens air quality and fundamentally undermines the high quality of life the city offers.

- 2.32 Businesses in Cambridge’s high-tech, high-skill economy rely on the productivity – or agglomeration – benefits that come from close proximity to one another and the ability to recruit workers from wide labour markets who fit their exact skills requirements. If Cambridge is to continue to grow, businesses within the ‘Cambridge cluster’ will be required to locate across a wider area, yet if poor accessibility reduces the productivity benefits of locating in Cambridge, this will threaten the region’s competitiveness and the potential for growth.

#### **Housing Delivery**

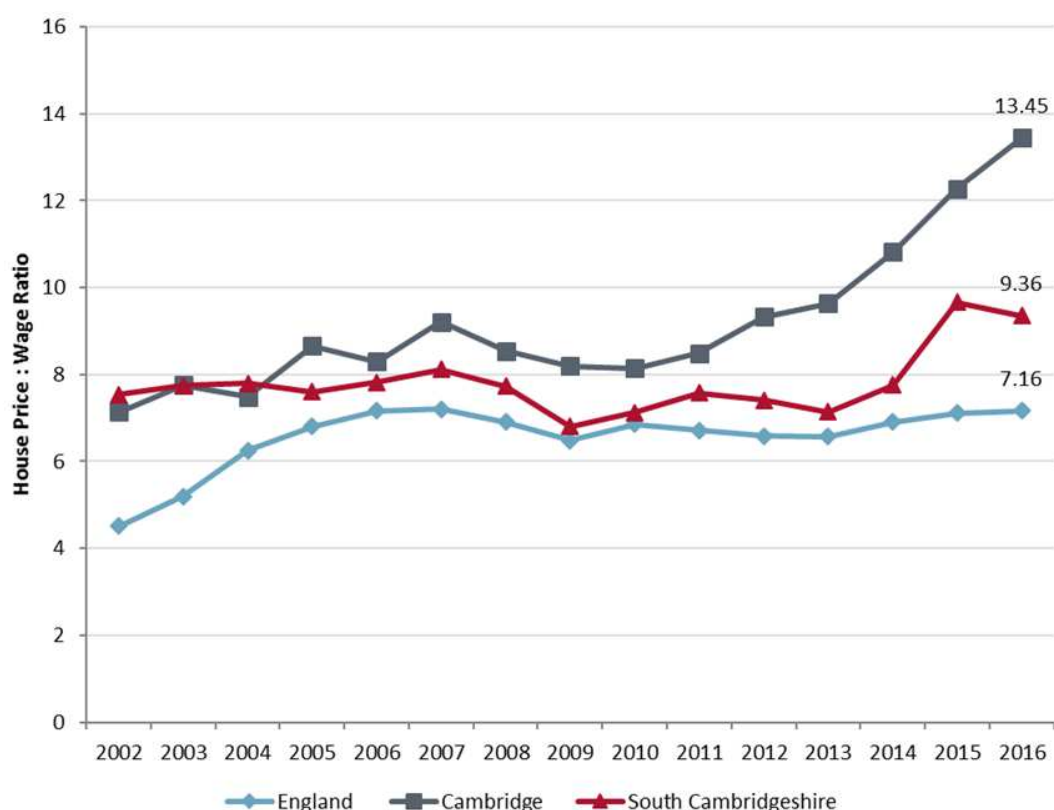
- 2.33 Sustained population and employment growth has also led to a housing shortage within Cambridge, with high house prices and low levels of housing affordability. Cambridge is frequently ranked as the one of most unaffordable places to live within the UK, with an average house price of £397,000 – nearly double the UK average of £223,000, and approximately 13 times local earnings. It is only becoming more unaffordable as the ratio between the median house price and median wage continues to grow, as shown in Figure 2.4.

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“Housing in and around the city remains unaffordable for many employees, particularly those on lower pay ... Many workers have sought housing in the more affordable towns and villages further away from the city, but this has put stress on the transport network leading to slower than average journeys and congestion in the city.” Greater Cambridge Partners, response to NIC Call for Evidence, November 2016

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- 2.34 Cambridge’s high housing costs places sustained growth at risk, increasing costs for businesses and diminishing their ability to attract and retain staff – including mobile talent and those on above-average incomes. The University of Cambridge, for example, frequently reports difficulties in housing support staff, post-graduates and academics, who can be forced to spend more than half their salaries on rent.

**Figure 2.4: Median house price: median wage ratio in Cambridge, South Cambridgeshire and England**

Source: Office for National Statistics, House Price Statistics for Small Areas (annual data for year ending Q3)

- 2.35 Poor infrastructure limits the ability for the region to grow. Many large development sites outside the city 'fringe' and Green Belt, such as former MOD sites such as RAF Wyton or urban extensions, require substantial infrastructure investment to connect them to existing settlements, and make them attractive places to live.
- 2.36 Without investment in better strategic and regional transport links, which provide opportunities for sustainable communities focused around transport hubs, there is a real danger that housing delivery will fall short of the Local Plan proposals, and seriously constrain the regions' economy.

#### **Inequality and opportunity**

- 2.37 Limited connectivity across the region also acts to limit opportunities for less prosperous districts within Greater Cambridge, and the surrounding region. While Greater Cambridge is one of the UK's most productive and successful regions, it retains pockets of deprivation, with limited labour market opportunities and higher levels of unemployment. Districts in Huntingdon fall within the most 20% deprived of communities in the country, yet are located less than 20 miles from Central Cambridge.
- 2.38 Large developments across the region such as Alconbury Weald can help to deliver local jobs for deprived communities, but these are predicated on good regional connectivity to the people and markets within Cambridge. Failure to invest in improved connectivity could therefore result in both an increasingly 'overheated' Cambridge economy, with worsening congestion, high housing costs and a poorer standard of living, but also lost opportunities elsewhere in the region which remain disconnected from the region's success.

## Planned & Proposed Future Transport Investment Priorities

- 2.39 Reflecting the importance of transport connectivity to the region's success, several major transport schemes have been committed to, and recently delivered, across the region.

### Strategic Transport Investment

- 2.40 Several large highway schemes are also either under development or construction. Currently under construction, the £1.5bn upgrade of the A14 between Cambridge and Huntingdon will provide extra capacity and relieve congestion on one of the UK's most congested trunk roads. Proposals for the dualling of the A428 between Cambourne and St Neots are currently subject to consultation, and construction has recently commenced on the Ely Southern Bypass.
- 2.41 Proposals for a new Expressway between Oxford, Milton Keynes and Cambridge, together with the Central Section of East-West Rail, are also under development by the Department for Transport. Whilst at an early stage, these projects have the capability to radically transform travel across the wider region and the Oxford – Cambridge corridor, supporting housing growth, relieving congestion and expanding labour market catchments.

### Local Connectivity

- 2.42 Cambridge's Guided Busway – the longest of its type in the world, opened in 2011. This connects the City Centre and Cambridge Station to Histon and St Ives to the north-west, and Trumpington and the Cambridge Biomedical Campus to the south, carrying approximately 3 million passengers a year<sup>9</sup>. Cambridge North railway station, located to the north of the city in close proximity to the Cambridge Science Park, opened in early 2017, with services to London and Ely.
- 2.43 Cambridge South railway station is a proposed new station directly serving the Cambridge Biomedical Campus, which will cater for local workers and provide improved access to London. It is currently being developed jointly by DfT, CPCA, GCP and AstraZeneca.
- 2.44 While the CPCA's responsibilities extend beyond the geographical reach of this study, it is also currently promoting and/or developing a number of strategic transport initiatives which directly affect the Greater Cambridge area, including:
- A10 Upgrade: major improvements to the A10 corridor between Cambridge and Ely; and
  - M11 Extension: an extension of the M11 north of Cambridge to the A47.
- 2.45 Within Cambridge, several new mass transit links are also currently under development by the GCP:
- Cambourne to Cambridge: a new public transport route between Cambourne and Grange Road in Cambridge;
  - Western Orbital: a new parallel bus link utilising the M11 between the North-West Cambridge site and the Cambridge Biomedical Campus;
  - South East Transport Corridor Study (A1307 Three Campuses to Cambridge): improvements to public transport with possible new public transport routes, walking and cycling network between the Cambridge Biomedical Campus, the Babraham Research Campus and Haverhill;
  - Milton Road: introduction of new bus lanes and segregated cycleways;

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<sup>9</sup> Data provided by Stagecoach, current operator of Cambridge Guided Busway.

- Histon Road: bus priority measures such as bus lanes, smart signals and side road closures to reduce delays caused by signals and improve reliability;
- Rural Travel Hubs: bespoke rural transport interchanges, currently being piloted in South Cambridgeshire, to better connect residents with public transport and cycling/walking routes with the aim of reducing private car journeys into Cambridge from rural villages;
- ‘Greenways’: commuter cycle routes from surrounding towns and villages within a ten-mile radius; and
- Improved cycle infrastructure within the city such as the Chisholm Trail linking both rail stations and the Cambridge Biomedical Campus.

## Consideration of Mass Transit

- 2.46 While these schemes will deliver significant benefits to the region, delivering faster journeys and supporting economic growth, they do not deliver, in themselves, an **integrated mass transit solution** that provides seamless connectivity between the City Centre, key development sites on the city fringe (such as the Cambridge Biomedical Campus), and the wider corridors in the region.
- 2.47 Greater Cambridge requires a transport system offering high quality, high volume and reliable services connecting housing and economic growth zones in order to support the growth aspirations for Greater Cambridge. Combined with the desire to achieve modal shift away from private car, this points towards the consideration of mass transit. This fits with the economic, social and environmental goals of the CPCA and the GCP, facilitating increased housing development and supporting sustainable, inclusive economic growth, without harming the area’s excellent quality of life.
- 2.48 Such a system would have to be sufficiently attractive in terms of routing, journey time saving and comfort to provide for new demand and encourage modal shift of existing journeys, as well as being financially viable. Two key considerations include:
- **Providing ‘last few mile’ connectivity:** Journeys within Cambridge, including those served by existing and proposed busway links to St Ives and Cambourne, suffer from slow journey times, limited capacity and congestion in the City Centre, together with poor onward connectivity to ‘city fringe’ destinations. For example, the proposed Cambourne – Cambridge busway will deliver faster, more reliable journey times from Cambourne to Grange Road, but suffer from ‘last mile’ congestion in the final leg into the City Centre, and providing limited onward connectivity to sites such as the Cambridge Biomedical Campus, requiring an interchange in the City Centre.
  - **Constraints in the City Centre:** improving connectivity into the City Centre, such as through additional bus priority measures, is extremely challenging due the constraints posed by the historic streetscape. Narrow roads lined with historic, listed buildings limit the ability to create segregated space for public transport, and thereby point towards a tunnelled solution to provide the required capacity, journey times and reliability, as outlined further in Chapter 3.
- 2.49 Greater Cambridge’s ambitions for growth, together with these constraints, point towards the strong case for an **integrated mass transit network**, including short sections of tunnel where required, to provide the required **accessibility**, **capacity** and **reliability** to support economic growth.

## How Mass Transit Could Support the Wider Economy & Housing Delivery

- 2.50 Efficient transport networks are vital in not only connecting workers to jobs, but also in maintaining the region's outstanding quality-of-life, and enhancing its competitiveness and attractiveness for investment. Businesses rely on transport accessibility to connect them to their employees, clients and markets, but also to support the dense concentration of firms and workers that underpins Greater Cambridge's success.
- 2.51 Any mass transit solution within the region would be expected to support economic growth, and help Greater Cambridge's reach its economic potential. This section explores the specific mechanisms through which mass transit would be expected to benefit the wider Greater Cambridgeshire economy.

Figure 2.5: Linkages between transport and economic performance



### Agglomeration / Proximity Effects

- 2.52 Closer concentration – or *agglomeration* – of firms, skilled workers and academics improves the productivity of all parties since they collectively benefit from each other's' innovation, ideas and creativity. Start-ups, for example, can rapidly develop with just a few skilled staff, benefitting from a culture of knowledge-sharing and a dense labour market of skilled workers.
- 2.53 Cambridge's national and international competitiveness is based on this 'cluster effect', whereby the *benefits* for firms (such as AstraZeneca) of being located close to research institutions, deep labour markets and other firms outweighs the *costs* of higher rents, higher housing costs and congestion. Indeed, these productivity benefits explain in large part why economic activity (in particular high-value, high-skill jobs) tend to cluster within large, dense urban areas. However, these costs increasingly act as a barrier to further growth, undermining the benefits of closer economic concentration, and limiting inward investment.
- 2.54 Such agglomeration effects are highly dependent on temporal proximity to one another, and hence a region's transport infrastructure. Productivity effects decay rapidly with increasing travel time, with the greatest agglomeration benefits coming from short journeys within urban areas. Technology firms, for example, tend to 'cluster' on specific sites such as the Cambridge Science Park, despite the higher rents, while other sites with poorer connectivity have significant vacant office space. As Greater Cambridge's economy expands, firms will inevitably locate over wider geographies, such as at Cambridge Research Park (in Waterbeach), at Granta Park or at the Alconbury Science Campus. Rapid, high frequency transport connections will therefore be vital to ensure that firms can both expand and benefit from the close proximity to each other that underpins their success.



- 2.55 Mass transit connectivity between these areas and existing businesses and institutions in and around Cambridge will therefore make investing and locating in the entire region more attractive. This, in turn, can reinforce and expand Cambridge's unique concentration of skilled workers and high-value firms, and help to avoid 'pricing out' new jobs with higher rents, congestion and housing costs. It will also ensure that *all* jobs benefit from increased 'effective density' (the measure of agglomeration) and hence productivity.

#### **Expanding Labour Markets**

- 2.56 Businesses within the most productive, high-value sectors of the economy – such as research and development or computer programming – also tend to require staff that meet their precise skills requirements, with specific experience, qualifications and know-how, to ensure their success. Staff are typically a Cambridge firms' greatest, most important asset, and underpin a firm's success. Provision of a transport network that successfully connects such workers to jobs is therefore vital for ensuring firms can recruit the staff they require, and continue to grow.
- 2.57 Poor transport therefore acts as a barrier to growth, reducing the size of the labour market, threatening growth and hence the overall success of Cambridge's high-value, tech economy. Improved transport helps the efficient functioning of the labour market through both increasing the overall supply of workers within a given commuting catchment and secondly helping to moderate house price growth through unlocking housing delivery and expanding the commuter catchment – thereby making it more affordable for workers to live closer to their place of work. Mass transit can thereby contribute towards making Greater Cambridge more attractive as a location to live and work, and hence supporting its continued growth.

#### **Direct productivity impacts**

- 2.58 Time spent travelling is often, at least in part, wasted, representing a clear productivity cost to firms. Faster journeys represent additional time that could be spent working, can generate direct savings from reduced fuel and vehicle operating costs, and thereby allow firms to become more efficient and more competitive.
- 2.59 Mass transit can play direct role in making business more competitive (easier to get to meetings, supporting business to business activity). Mass transit can provide the local linkages that, in turn, provide better overall connectivity to key gateways, such as Stansted and Heathrow Airports, major markets such as London and key strategic economic corridors such as the Oxford – Cambridge corridor. Indeed, the NIC stress the importance of enhanced local connectivity in delivering the potential of the Oxford – Milton Keynes – Cambridge corridor.
- 2.60 Mass transit can deliver 'second order' benefits through modal shift and congestion reduction which improves journey times and reliability for all road users, including commuters, businesses and freight traffic, delivering further economic productivity benefit through direct savings to businesses. Faster journeys therefore act to maximise the overall competitiveness and productivity of the Greater Cambridge economy, helping to attract investment from elsewhere.

#### **Transport and Social Factors**

- 2.61 Residents expect a transport network which connects them to jobs, friends, family and leisure destinations, from local trips to work or a meal out or longer trips to leisure destinations or university, either in the UK or abroad. Delivering a network which efficiently caters for this

wide variety of trips is essential to Greater Cambridge's offer, and attracting and retaining highly-skilled, globally mobile talent to settle in the region.

- 2.62 Greater Cambridge's transport network currently only partly provides the connectivity and capacity that people expect. Mass transit can help tackle the time wasted in traffic congestion and the limited public transport connectivity which currently undermines the attractiveness of the region and exacerbates the shortage and cost of housing, thereby improving local quality-of-life and helping the region realise its' true potential.

## 3 Key Destinations, Opportunity Areas and Constraints

3.1 This chapter summarises the economic geography of Greater Cambridge. It considers the key destinations and employment hubs within the region, their growth aspirations and travel patterns, in order to:

- understand the key trip destinations within Greater Cambridge, which any future rapid transit network would be expected to serve;
- understand the magnitude and geography of future growth, which is likely to shape the demand and requirements for a rapid transit system;
- assess the geography and magnitude of travel demand into Cambridge city; and
- consider the constraints to the ability of the current network to accommodate demand growth, both in the short and longer-term.

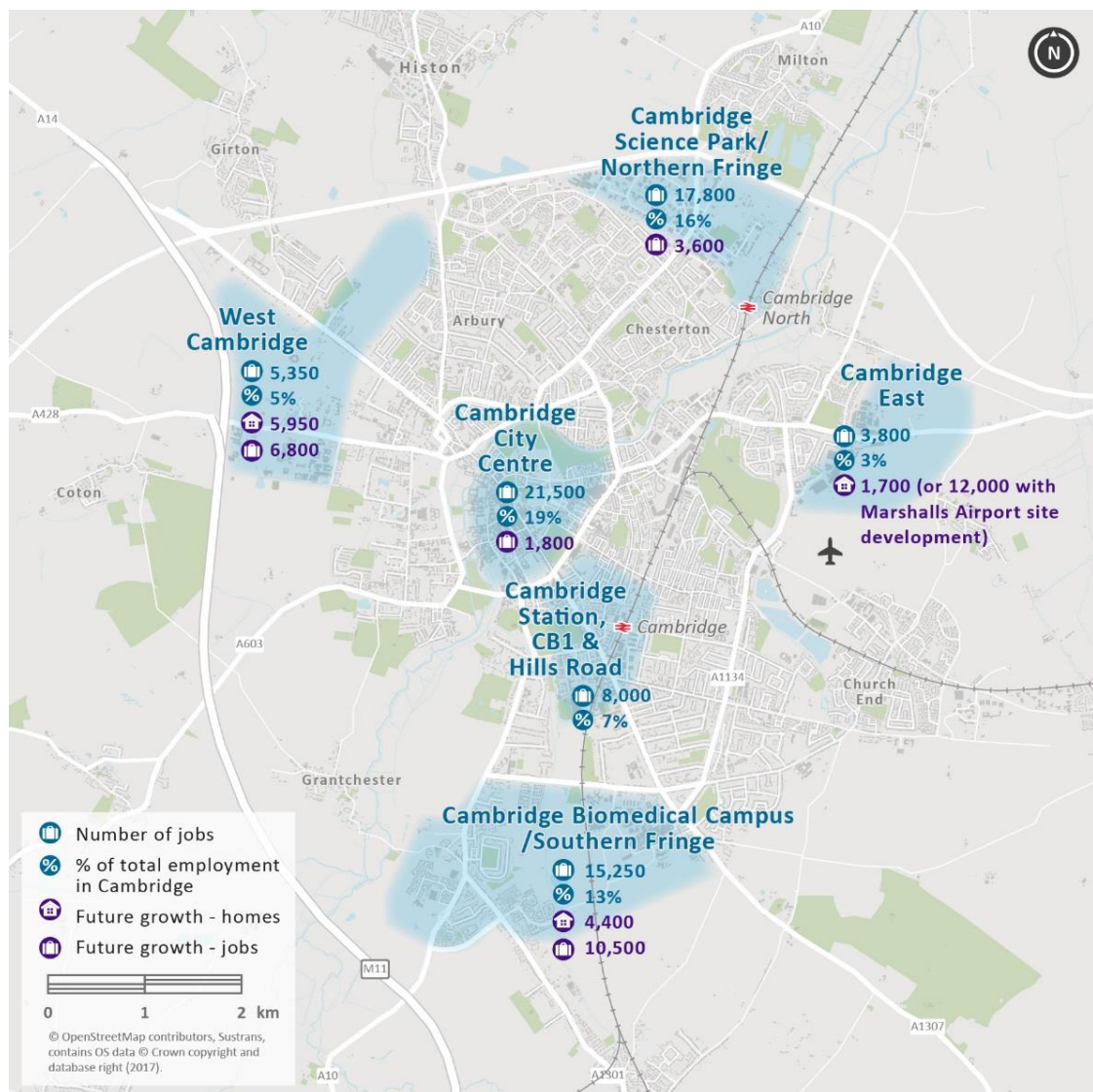
### **Key Destinations – Cambridge City / Urban Area**

3.2 Several districts within Cambridge act as key employment hubs, leisure destinations and educational centres, which generate significant transport demand and are expected to grow over the coming decades. Any rapid transit network would hence be expected to serve trips to and between the following ‘key destinations’:

- Cambridge City Centre;
- Cambridge Station, CB1 and Hills Road;
- Cambridge Biomedical Campus and ‘Southern Fringe’;
- Cambridge Science Park and ‘Northern Fringe’;
- Cambridge West; and
- Cambridge East.

3.3 Collectively, these sites in Cambridge account for 63% of all jobs within the Cambridge urban area, and 40% of all jobs within Greater Cambridge. Future employment growth is expected to be disproportionately located at these sites, which benefit from firm proximity, agglomeration and good labour market accessibility – vital to the success of Cambridge’s economy.

3.4 These ‘key destinations’ are summarised in Figure 3.1 overleaf.

**Figure 3.1: Key Destinations within Cambridge, and future growth aspirations**

### Cambridge City Centre

- 3.5 Cambridge City Centre acts as the heart of the city, forming the economic and culture core of Greater Cambridge, and home to the historic university, a large retail core and a range of tourist destinations (such as Kings College Chapel). Employment within the City Centre retains an educational focus, and includes a significant proportion of the University of Cambridge's office and research space.
- 3.6 Much of the City Centre remains highly constrained, with limited opportunities for redevelopment or significant employment growth. Recent employment growth within Cambridge city, especially within 'hi-tech' sectors such as life sciences has instead been focused elsewhere in the city, such as at the Cambridge Science Park, although there remain smaller opportunities for growth on the Old Press / Mill Lane site and at the Grafton Centre / Fitzroy Street.

### **Cambridge Station, CB1 and Hills Road**

3.7 Cambridge Station, CB1 and Hills Road includes the corridor radiating from the City Centre to Cambridge station, and retains elements of a High Street offer, together with significant office space. While the district (especially surrounding the station) has been neglected in the past, it is undergoing a mixed-use redevelopment, known as CB1, including:

- 330 new residential units, 1,250 student dwellings and a new hotel;
- 60,000 m<sup>2</sup> of new office and retail floor space, with occupants including Microsoft;
- A new station square, bus stops and a station cycle park and expanded concourse.

3.8 Completion of the CB1 development will limit the potential for future large-scale development station, although under the Local Plan there are proposals for continued incremental development along the Hills Road corridor, together with mixed-use redevelopment of the Clifton Road Industrial Estate, with approximately 550 new homes.

### **Cambridge Biomedical Campus and ‘Southern Fringe’**

3.9 The Cambridge Biomedical Campus and ‘Southern Fringe’ is home to Addenbrookes’ Hospital, Cambridge University Hospital, the Medical Research Council Laboratory of Molecular Biology, and the future global HQ and R&D centre of AstraZeneca. It forms one of the world’s leading clusters of life sciences, medical research and health innovation firms. Similarly to the Cambridge Science Park, it relies fundamentally upon the agglomeration benefits arising from the clustering of a large concentration of similar firms, access to a highly skilled labour market, and close ties to academic institutions.

3.10 The Biomedical Campus is currently expanding rapidly, and will be the new home of Papworth Hospital, the new global HQ and R&D centre of AstraZeneca, the new global HQ for Abcam as well as a large volume of new laboratory, research and educational floorspace. Outline planning has recently been granted for Phase 2 of the Campus, involving 75,000 sq. m of additional research and development floorspace.

### **Cambridge Science Park and Northern Fringe**

3.11 The Northern Fringe forms the area to the north of Cambridge, immediately south of the A14 and the Milton Interchange, and adjacent to Cambridge North station. It is home to the Cambridge Science Park and Cambridge Business Park, together with a large cluster of IT, programming and software development firms, and forms one of Europe’s longest-serving and largest centres for commercial research and development. Similarly to the Biomedical Campus, it relies heavily on the productivity benefits arising from a large concentration of software, programming and technology companies.

3.12 Significant growth is expected within the Northern Fringe, with an estimated 36,000 additional jobs by 2031 under the City Deal. Redevelopment of the 36-acre Chesterton Sidings, known as the CB4 development and at an early planning stage, is expected to include 121,000 sq. m of office floorspace and residential / student accommodation<sup>10</sup>. Land currently occupied by a sewage works could, in the longer term, also be released for redevelopment, and is currently subject of a bid to the Ministry of Housing, Communities and Local Government for Housing Infrastructure Fund (HIF) funding. Overall, this could release a further 118-acres of land, potentially delivering more than 7,000 new homes and 30,000 new jobs. Both the Cambridge

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<sup>10</sup> <http://www.brookgate.eu/cb4-cambridge>

Science Park and Cambridge Business Park are comparatively low-density in nature, and site densification could deliver significant additional office space.

### **Cambridge West**

- 3.13 Cambridge West includes the West Cambridge Site, home to significant University research, laboratory and teaching space, and new housing developments at North West Cambridge and the National Institute of Bothy Site (NIAB).
- 3.14 6,800 new jobs and 5,950 new homes are expected to be delivered in the area by 2031, with West Cambridge continuing to grow rapidly, with a masterplan for up to 250,000 sq. m of floorspace and a focus on occupiers with strong links to the University. Construction has recently begun on 3,000 new homes at the North West Cambridge Development, with a focus on affordable housing for university post-graduates and key workers, with planning at an earlier stage for development of the NIAB site, known as Darwin Green.
- 3.15 Additional developments at Bourn Airfield and Cambourne, located to the west of Cambridge, are discussed in Para 3.21.

### **Cambridge East**

- 3.16 Cambridge East represents the area stretching along Newmarket Road east of the Cambridge – Ely railway, including Cambridge Airport. Up to 1,700 new homes are proposed under the City Deal, including the Wing development of a new community of up to 1,300 homes between Newmarket Road and High Ditch Road, with construction expected to commence in 2019.
- 3.17 Land at Cambridge East was previously taken out of the Green Belt in the late 2000s, as part of proposals for a major new urban extension to the city, dependent on relocation of Marshall Group to an alternative airport site. While Marshalls have no current plans to relocate, the site is safeguarded for longer-term development post-2031, and could accommodate 10,000 – 12,000 homes in the longer term.



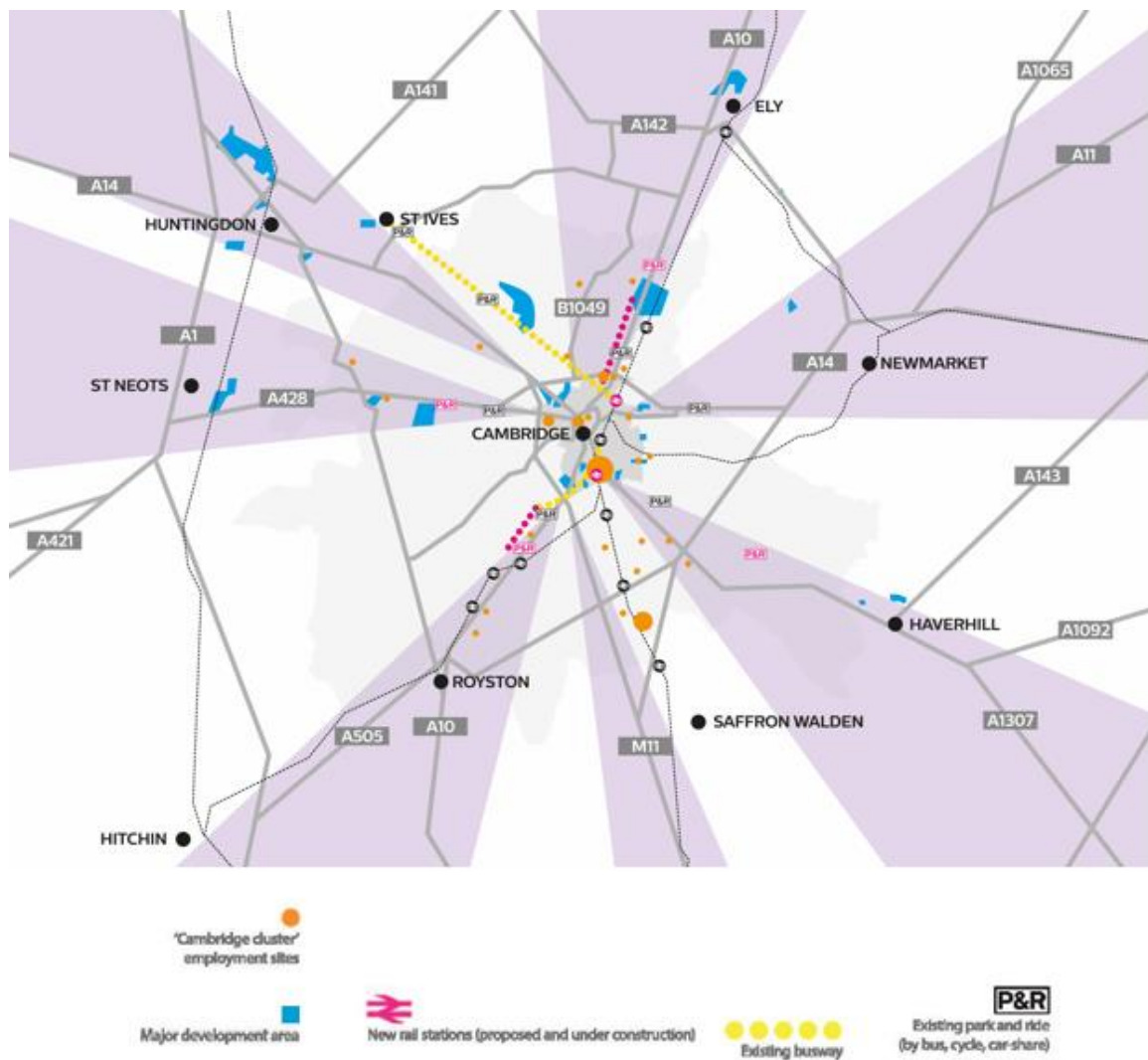
## Key Corridors

3.18 Growth within Greater Cambridge is also expected to be spread across the region, including along seven corridors radiating from Cambridge, outlined in Figure 3.2. These include:

- **A14 North West**  
Northstowe, St Ives and Huntingdon;
- **A428 West**  
Cambourne and St Neots;
- **A10 South**  
Royston and Hitchin;
- **M11 South**  
Saffron Walden and Stansted;
- **A1307 South East**  
Babraham and Haverhill
- **A14 East**  
Newmarket, Bury St Edmunds and Mildenhall;
- **A10 North**  
Ely.

3.19 Ensuring that economic growth and opportunity are not simply confined to Cambridge but spread across the seven corridors is a key objective of both the CPCA and GCP. Spreading the benefits of Cambridge's success will not only help tackle deprivation elsewhere, but help relieve the Cambridge housing and employment market, and thereby ensure the regions' long-term growth.

Figure 3.2: Key Growth Corridors from Cambridge



### Corridor growth

- 3.20 Several major developments are therefore planned across the corridors, which will:
- Provide additional housing to support the regions' growth, and tackle housing unaffordability;
  - Create additional jobs, especially in distribution and 'back office' service sectors which facilitate the success of the high-tech Cambridge economy; and
  - Ensure that economic opportunities are spread across the entire region, not simply within Cambridge itself.
- 3.21 Under the Cambridge and South Cambridgeshire Local Plans, approximately 15,000 new homes are proposed within new settlements and villages in South Cambridgeshire outside of the 'city fringe'. Major developments across the wider region include:
- **Northstowe New Town**, located on the A14 corridor seven miles north-west of Cambridge, will include up to 10,000 homes and 3,500 new jobs in a new town on a former airfield, including a new town centre, schools and community facilities. It will be linked to Cambridge directly via the Guided Busway, and new link roads to the A14;
  - **Waterbeach Barracks**, located on the A10 corridor approximately six miles north of Cambridge, is a mixed-use development of a former MOD site, expected to include 8,500 new homes, dualling of the A10 to Milton Interchange, a new public transport corridor to Cambridge and relocation of Waterbeach station. Together with expansion of the Cambridge Research Park, it is expected to generate up to 5,800 new jobs;

Figure 3.3: Waterbeach Barracks development



- **Cambourne West and Bourn Airfield**, located on the A428 corridor, is expected to deliver 5,000 new homes and up to 2,800 new jobs on a disused airfield and expansion of the existing new town. It will be connected to Cambridge by a proposed public transport corridor to Grange Road, the existing dual carriageway A428, and will also be served by the dualling of the A428 to the east, improving links to the A1 and the wider strategic road network;
- **Alconbury Weald**, located to the north of Huntingdon on the A14 corridor, is expected to deliver 5,000 new homes on a former RAF site, together with significant employment growth within the Alconbury Enterprise Campus, supported by Enterprise Zone status. This will include flexible research and development, office and production space, including for small start-up firms, with substantial business rate reductions from Government to encourage development;
- **Ely North**, located on the A10 corridor approximately 17 miles north of Cambridge, is expected to include 3,000 additional homes as part of an urban extension of the town;
- **St Neots East**, located on the A428 corridor, will include 3,700 new homes in an urban extension of the town, in close proximity to St Neots railway station and the duelled A428; and
- Expansion of the **Wellcome Trust Campus** in Hinxton, the **Babraham Research Campus** and **Granta Park** in Great Abingdon, all located on the M11 / A1303 corridor to the south east of Cambridge, have the potential to deliver up to 5,200 jobs between the sites, with a focus on scientific, research and pharmaceutical firms.

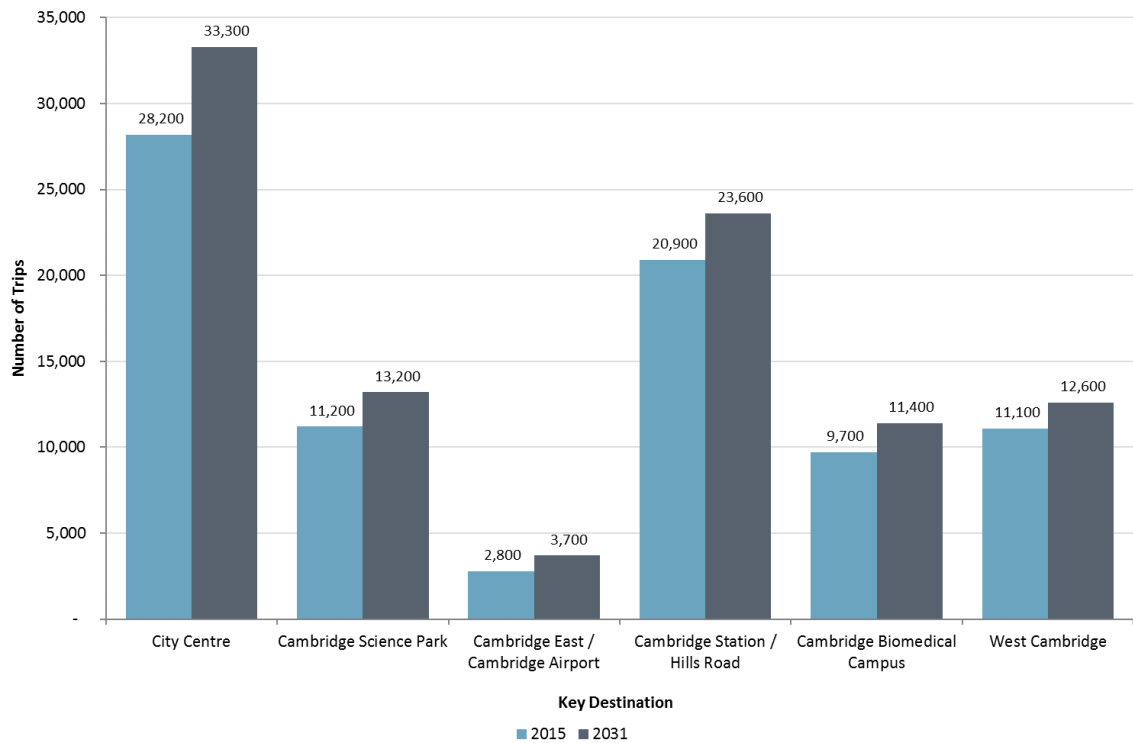
## Travel Demand

- 3.22 Each of the key destinations therefore attracts a significant volume of travel demand, spread across a range of modes, which could justify the provision of a rapid transit network.
- 3.23 83,900 trips are made to one of the 'key destinations' during the three-hour morning peak (of which 47,300 are made by non-active means), as outlined in Figure 3.4. This also outlines the predicted growth in trips from 2015 to 2031, assuming delivery of growth in line with the Cambridge and South Cambridgeshire Local Plans, and based on outputs from the Cambridge Sub Regional Transport Model 2 (CSRM2).

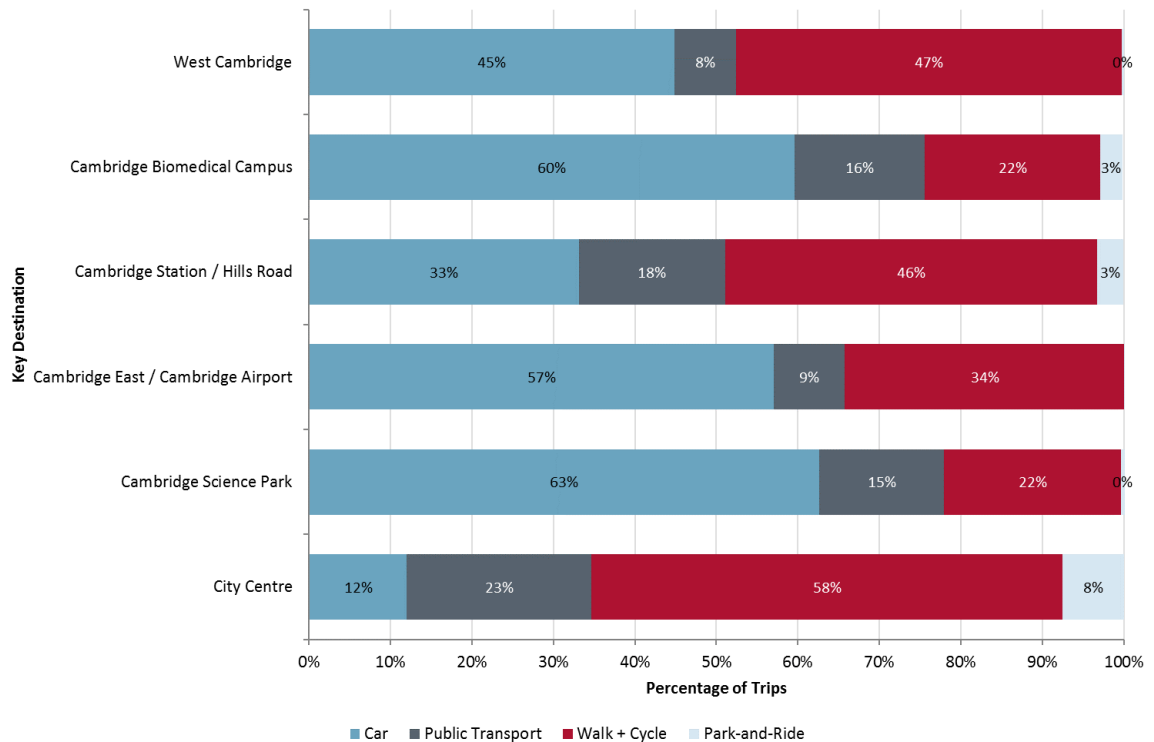
### Modal share

- 3.24 Active travel (walk and cycle) accounts for approximately 44% of all trips, significantly higher than comparable towns and cities in the UK, reflecting Cambridge's small geographic size and 'cycling culture'. Highway trips typically account for the majority of trips to 'fringe' employment sites (such as the Science Park and Cambridge Biomedical Campus), reflecting both their highway accessibility to the A14 / M11 / A11, and their limited public transport accessibility.
- 3.25 The mode shares are shown in Figure 3.5. Public transport accounts for only 17% of all trips to the 'key destinations', with a further 4% of trips made by Park-and-Ride, concentrated on trips to / from the City Centre. Any future rapid transit network would be expected to capture a significant proportion of these trips, together with modal shift from highway, in order to represent value for money.

**Figure 3.4: AM peak (3-hr) trips to each 'key destination', all modes including active, CSRM2**



**Figure 3.5: AM peak (3-hr) mode share to each 'key destination', 2015**



### Trip geography

- 3.27 Reflecting the strength of the Cambridge labour market, and the volume of in-commuting, the city has an **extensive geography of long-distance commuting**. Approximately 37,500 trips to the ‘key destinations’ originate from outside Cambridge in the 3-hour AM peak, with 30% of trips to the City Centre originating from outside the Cambridge local authority boundaries, including 15% from South Cambridgeshire and 15% from elsewhere (such as Huntingdon, Newmarket or London).
- 3.28 This proportion of commuting trips originating from outside the city is significantly greater for the ‘fringe’ employment sites, such as the Science Park and Biomedical Campus, where future growth is expected to be focused. 59% of trips to the Science Park originate from outside of Cambridge city, with 29% from outside Cambridge and South Cambridgeshire; similarly, 46% and 17% of trips to South East Cambridge (including the Biomedical Campus) originate from outside Cambridge and outside Cambridge and South Cambridgeshire respectively.
- 3.29 Additional employment growth at the city fringe is likely to be accompanied with increased commuting from outside the city, especially considering the geography of housing growth outside the city in new and expanded settlements at Waterbeach, Northstowe and Cambourne. This underlies the need for an **efficient, high capacity transport network** to connect future employment and housing sites.
- 3.30 Trips to and within Cambridge are also **highly dispersed**, reflecting the polycentric nature of the region and the ‘key destinations’, with only 19% of employment within the Cambridge urban area located within the City Centre. Considering public transport demand along the Cambridge Guided Busway corridor, for example, only 32% of public transport demand to the Cambridge urban area from Histon, Longstanton, St Ives and Huntingdon is to the City Centre, with 11% of trips to the Science Park, ~ 25% to the area surrounding the station and 20% to South East Cambridge (including the Biomedical Campus).
- 3.31 With future growth expected to be focused on the ‘city fringe’, and outside of the historic City Centre, such dispersed trip patterns are likely to increase in future, despite the typically poor current public transport accessibility to ‘fringe’ sites. This underlines the need for both improved connectivity to these sites, but also a **transit network which is sufficiently flexible to serve a range of different destinations**, at appropriate frequencies, in order to be attractive to users and generate sufficient patronage to be viable.

### Transport Constraints

- 3.32 Paragraphs 3.2 to 3.21 identify the strategic rationale for a mass transit network within Greater Cambridge, including the need to improve ‘last few mile’ connectivity. Constraints within the City Centre limit the ability to adopt a more *incremental* approach – such as through continued expansion of the bus network, increased provision of Park-and-Ride and supporting increased walking and cycling, and instead point towards a more radical approach for supporting growth and addressing Cambridge’s transport challenges.

#### City Centre Bus Accessibility

- 3.33 Currently, approximately 100 buses operate per hour through the City Centre, including conventional city bus services and limited-stop guided bus and Park-and-Ride services. Cambridge’s bus network is overwhelmingly focused on the City Centre, with every high-frequency route passing through it, with the only other public transport option provided by rail services to Cambridge station, a twenty-minute walk to the south.



- 3.34 Housing and employment growth (largely focused in Busway corridors) and targeted modal shift could result in a more than doubling of current bus demand. Even with a significant reduction in car trips throughout Cambridge, and car restraint, the **effective capacity of bus services and their routes cannot accommodate this level of growth**, based on current bus routings due to the constrained city centre street layout. This also inhibits the ability to operate buses along key desire lines (such as from the City Centre west towards Grange Road / Cambourne). Some of these constraints are highlighted below.

*Magdalene Street / Magdalene Bridge*

- 3.35 Many bus services to the north and west of the City, including the proposed public transport corridor to Cambourne, operate via Magdalene Street (shown in Figure 3.6) at the northern edge of the City Centre. This is a narrow street, only sufficiently wide for one vehicle at a time, with narrow pavements and adjacent to numerous historic, listed buildings and Magdalene College. It forms the key access route into the City Centre to the north and north-west, including for cyclists, taxis and delivery vehicles, and is frequently congested, in part due to close proximity to a junction with the inner ring road.

Figure 3.6: Magdalene Street



Source: wfmillar, CC BY-SA 2.0

- 3.36 It is hence unlikely to be able to cater for a significant increase in bus flows, while the limited number of city centre access points also mean that reducing delivery traffic for increased bus services would be difficult to achieve.

*Lack of East / West connectivity*

- 3.37 Due to the north / south barrier created by the Cam and St John's, Trinity and Kings' Colleges, there is no vehicle route between the Silver St bridge to the south and Magdalene Bridge to the north (itself highly constrained).

*Suboptimal city centre routes*

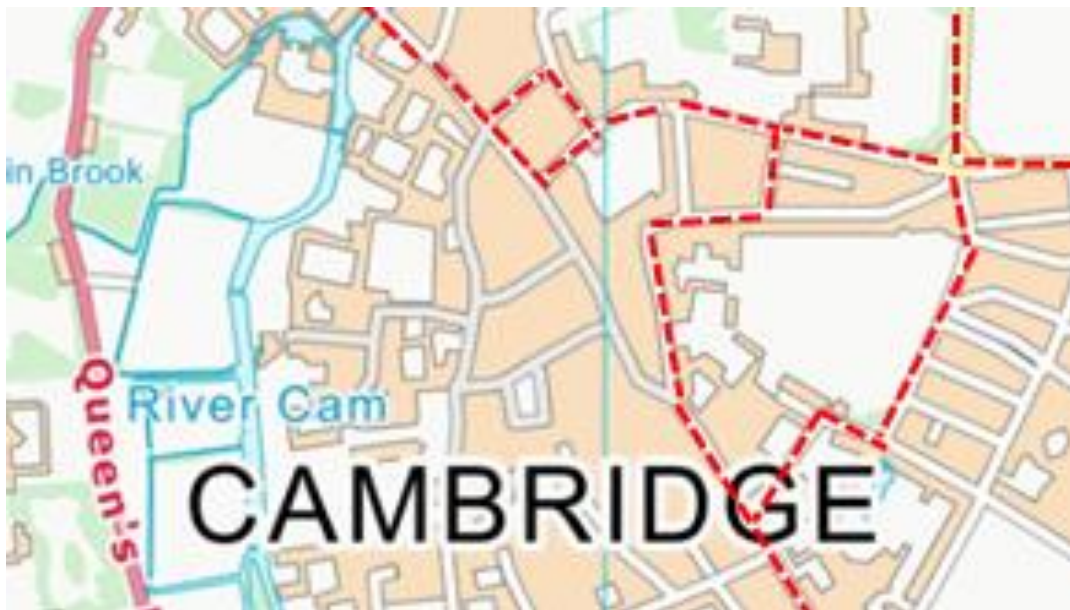
- 3.38 Figure 3.7 outlines the street pattern within Central Cambridge, and the routes currently taken by frequent bus services around the City Core. No bus services operate along the most direct routes through the City Centre, including along Sidney Street, St Johns Street, Trinity Street or



Market Street, due to the narrow roads, density of people and cyclists, and the part-pedestrianised layout.

- 3.39 Instead, services operate via Hobson Street / Manor Street or Emmanuel Street, lengthening journey times and resulting in buses stopping further from Market Square. These routes reduce the attractiveness of the bus network, especially for cross-city trips, and together with the stopping arrangements on Emmanuel Street and St Andrews St, and have a limited capacity to support additional buses.

**Figure 3.7: City Centre Bus Corridors**



*Congestion on routes to the City Centre*

- 3.40 All routes (except Newmarket Road) into the City Centre are two lanes (one in each direction), limiting the potential for any rapid transit route to be segregated from highway traffic, with many corridors suffering from chronic congestion. Combined with the absence of any viable alternative routes, this limits the ability for any future transit alignment to deliver faster journey times, and therefore be attractive to users and support Cambridge's growth.

*Summary*

- 3.41 Collectively, these barriers mean that it is unlikely that the City Centre can accommodate significant increases in bus throughput under the current bus network configuration, and any increase is likely to be accompanied by increases in journey times. While there are options for alternative bus network / service configurations, such as relocating services outside the City Centre core, there is a clear trade-off between the accessibility benefits of facilitating more services into Cambridge, and significant disbenefits associated with bus services serving stops located further from the City Centre.
- 3.42 Combined with the region's aspirations for growth, these constraints point strongly towards consideration of tunnelled solutions for a mass transit network.

## 4 Developing a Mass Transit Concept for Greater Cambridge

- 4.1 This Chapter considers the development of a concept for mass transit within Greater Cambridge, building on the opportunities and constraints for growth set out in Chapter 2 and 3. The focus is on developing an ‘output specification’ (in terms of capacity, connectivity, accessibility) of what any mass transit system, *irrespective of mode*, should seek to deliver in a Greater Cambridge context.
- 4.2 It sets out how our evidence-led approach points towards the development of a mass transit network, by summarising the regions’ growth aspirations, opportunities and constraints to demonstrate the case for a network which provides the enhanced connectivity and capacity to support long-term growth.

### Developing a Network Concept

- 4.3 Chapter 2 identified how Cambridge, and the surrounding region, is expected to experience significant housing and employment growth in the coming decades. This will place new and continued pressures and requirements on the local transport network, including:
- Improved accessibility to ‘city fringe’ employment hubs (such as the Science Park), many of which lack good regional and orbital public transport connectivity;
  - Supporting new housing development outside the City, together with a wider labour market catchment extending across seven radial corridors from Cambridge;
  - Providing sufficient capacity to cater for increased travel demand, and support a modal shift away from private car;
  - Deliver a transport system which supports economic agglomeration through providing connectivity across the region, upon which the future success of the ‘Cambridge Phenomenon’ relies, while maintaining and enhancing the regions’ excellent quality of life.
- 4.4 High levels of travel demand and the geography of commuting patterns, together with the constraints imposed by the historic city core, point to the development of a simple transit network. Benefits would arise both from journey time and reliability benefits, together with supporting development and growth within Cambridge and the wider region. This would be expected to connect the following key destinations and opportunity areas within Cambridge:
- |   |                                  |
|---|----------------------------------|
| • Cambridge City Centre                         | • Cambridge Station / Hills Road |
| • Cambridge Science Park                        | • West and North-West Cambridge  |
| • Cambridge Biomedical Campus / Southern Fringe | • Cambridge East / Airport       |

- 4.5 The network would enable these locations to be connected directly to each other, and to the seven radial corridors outlined in Chapter 3.
- 4.6 Securing a largely segregated alignment for the network, while challenging, is important to provide the network capacity, overall journey time and journey time reliability required. Sharing an alignment with traffic typically results in longer, less reliable journey times, and acts to limit the capacity available to mass transit, which reduces the overall attractiveness of transit and undermines the regions' image and future growth aspirations.
- 4.7 Chapter 3 outlines key constraints within Cambridge City Centre, which suggests the need for tunnelling in order to deliver a city centre alignment that provides the required journey time reliability and capacity for transit. Considering the likely high cost of a tunnelled solution, the length of tunnelling should be kept to a minimum to maximise the value for money of the scheme.
- 4.8 Similarly, to maximise the value for money of the transit network, any solution should make best use of existing and committed transit infrastructure, such as the existing Cambridge Guided Busway. Benefits for any transit network will be greatest where it delivers significant journey time and reliability savings and significantly enhances accessibility (such as providing a rapid, direct link between Cambridge West, the City Centre and Cambridge Station), rather than simply replacing or replicating existing segregated infrastructure.
- 4.9 Almost all the benefits and wider strategic case for a mass transit network arise from the overall connectivity enhancement, journey time reliability, accessibility and improved passenger experience that the system offers.
- 4.10 The network concept is therefore focused on what a mass transit system *could* deliver – in other words the transport outputs (improved connectivity, capacity, and accessibility) that support the wider aspirations for Greater Cambridge (including housing and employment growth, improved economic performance, quality of life and GVA). Detailed consideration of how different modal options support these transport outputs is set out in Chapters 6 to 8.

## Guiding Principles

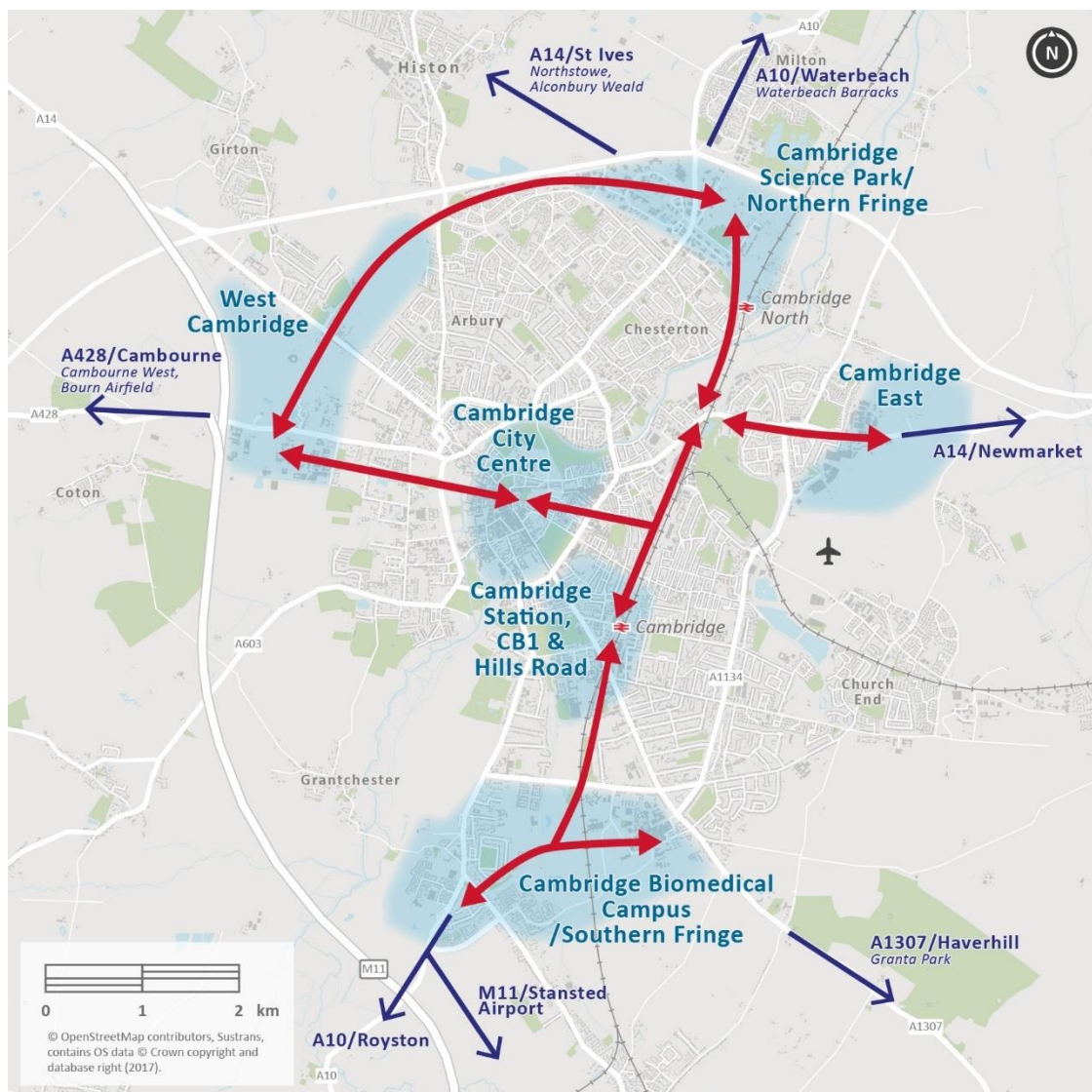
- 4.11 This therefore points towards the following key principles for the development of any network solution:
- Delivers **high quality, high frequency, reliable services**, attractive to car users. This entails a world-leading user experience, with fully-segregated infrastructure, dedicated stops and real-time information
  - **Maximise connectivity** to support growth across the region, support agglomeration and enhance Greater Cambridge's quality of life;
  - **Provide sufficient capacity** to accommodate future travel demand, and support modal shift away from private car;
  - **Zero-emission (at least in City Centre)** to ensure a sustainable solution which acts to improve Cambridge's air quality;
  - **Fully accessible** to provide improved accessibility for all;
  - Make **best-use of emerging technology and innovation** to provide intelligent mobility and maintain Cambridge's position as a 'city of firsts';
  - **Future proofed** in terms of technology and capacity, and with sufficient flexibility to expand incrementally to support growth in the decades ahead; and

- Must represent **value for money, be affordable and deliverable**, and likely to be supported by the public and stakeholders.

## Mass Transit Network Concept

- 4.12 Based on these principles, and the geography of Cambridge and the wider region, Figure 4.1 presents a summary of an indicative transit network for the region. This is informed by the evidence base presented in Chapters 2 and 3, and through our extensive engagement with key stakeholders. The development of the concept is therefore ‘objective-led’ and evidence-based. In addition, the Cambridge Connect and Cambridge Affordable Very Rapid Transit (AVRT) proposals, provided valuable insight and thinking on how a mass transit network could be developed, as do the ongoing GCP corridor studies. A detailed assessment of these and our ‘network concept’ is outlined in Chapter 8.
- 4.13 This network has been developed to provide **direct connectivity** between each of the ‘key destinations’ and corridors outlined in Chapter 2, thereby supporting future growth and greatly expanding the labour market catchments of each ‘outer’ employment hub (e.g. Cambridge Biomedical Campus), while minimising the length of tunnelling required.
- 4.14 This is illustrated in Figure 4.1, which shows where segregated routes would support fast and reliable connections into the city centre, and from the city-centre to the city-fringe (shown in blue) and beyond to the satellite centres (e.g. Cambourne, Waterbeach) and market towns (e.g. St. Neots, Newmarket).

Figure 4.1: Proposed Mass Transit Network Schematic



4.15 Key to the concept is the use of both the city centre tunnel and the segregated north-south axis as an enabler of **wider connectivity**, facilitating rapid cross-city and orbital trips for the first time which collectively act to transform connectivity across Cambridge and the surrounding corridors. For example:

- Trips between the Cambridge Science Park and Cambridge Station / Cambridge Biomedical Campus would be possible directly via a wholly segregated alignment, avoiding the need to run on-street via the congested City Centre as per current Busway services;
- Direct services would link West Cambridge to the Science Park, Cambridge Biomedical Campus and Cambridge East for the first time, avoiding the need to interchange;
- Services would operate in each of the key radial corridors serving: A14/ St. Ives, A10 Waterbeach, A14 / Newmarket, A3101 / Haverhill (Granta Park), A10 / Royston and A428 / Cambourne. Services could then operate onwards to respective market towns, and provide connectivity from each corridor to the city and across the city.
- Each corridor would benefit from direct, high frequency accessibility to not only the City Centre but also *all* key destinations and employment hubs, negating the current need for interchange and travel via the city centre for most trips;



- Rail trips from outside the region via Cambridge / Cambridge North station, and the proposed Cambridge South Station, would benefit from significantly improved ‘last mile’ access to Cambridge, largely avoiding the need for a lengthy walk or interchange with bus services to reach a final destination; and
- Park-and-Ride trips to Cambridge would benefit from a faster, more reliable journey to the City Centre, together with direct accessibility to other key employment hubs.

4.16 Collectively, the network and segregated alignments would be expected to generate significant journey time savings, improved reliability, and significant agglomeration and wider economic impacts through closer proximity of firms and workers. It has the potential to create a powerful image of Cambridge as a region investing in its future, with a high-capacity, high-quality transport network. Modal shift away from private car, together with a reduction in the number of buses operating within the City Centre, would improve air quality, reduce carbon emissions, and ensure that Cambridge continues to offer an excellent quality-of-life.

4.17 Full details of the proposed network, and an assessment of likely transit demand and potential costs and benefits are outlined in Chapter 8.

### Mass Transit within an Integrated Network

4.18 While the primary focus of this study is to consider a Mass Transit option, any Mass Transit solution would need to be developed and fully integrated with other transport and planning policies.

4.19 The consideration of Mass Transit is part of a wider ongoing and planned programme of initiatives being led by the CPCA and GCP. Mass transit is seen as a potential key element of the future regional transport network, but one which must be planned and integrated with other policies and proposals, such as:

- **Consideration of demand management** in the Cambridge urban area. Some form of demand management would support the transport planning rationale for Mass Transit, with any prospective charging regime more acceptable and potentially provide a valuable source of funding.
- **Integration with other public transport modes**, including:
  - City bus services. Mass transit would need to complement existing and future bus services. Network planning (across bus and mass transit) would need to ensure overall accessibility levels are maintained or enhanced across the network, including, for example, corridors within Cambridge city that may not be directly served by Mass Transit. Indeed, the modal shift and traffic reduction potential of Mass Transit provides the opportunity to enhance the quality of provision across the network.
  - Rail network and services, at all existing and proposed (e.g. Cambridge South) stations on the network.
- **First and Last Mile.** There would need to be consideration of ‘first and last mile’ connections to Mass Transit stops to maximise the connectivity benefits of the system and, consequently, improve the overall viability and attractiveness of the network. The overall system would utilise the concept of ‘intelligent mobility’ or ‘mobility as a service’, whereby information on travel options, payment and ticketing would be cross-modal (including car).



## 5 Planning Capacity for Mass Transit

5.1 This chapter considers the demand that a Greater Cambridge mass transit network should be designed to cater for, considering a range of future growth and modal shift assumptions. This analysis is used to:

- inform the planning capacity of the system, to ensure that the system can accommodate future growth and is sufficiently ‘future-proofed’ to cater for demand in the long-term;
- support the consideration of different mass transit options, to ensure that any solution provides a capacity commensurate with likely transit demand;
- inform whether the likely level of demand is likely to be sufficient to justify a mass transit options.

5.2 Successful mass transit systems rely on transporting large volumes of people along distinct corridors within a region or urban area, and hence require a certain level of demand to be viable. Key to developing the case for mass transit, and the most appropriate solution, is to understand the level of demand the system should cater for.

### Developing Demand Scenarios

5.3 Our approach does not seek to *forecast* the level of likely transit demand. Rather, it seeks to develop a range of *scenarios* for future travel demand to assess the *potential* volume of public transport demand under different assumptions regarding future housing and employment growth, total travel demand and modal share. Our analysis uses modelled demand from the 2015 base year Cambridge Sub Regional Model 2 (CSRM2)<sup>11</sup> as a starting point. This reflects the early stage of this study, and the lack of transport modelling of any proposed mass transit scheme.

5.4 Demand scenarios were based on existing (based on 2015 levels) ‘in-scope’ public transport demand and highway demand from the 2015 CSRM2 model for movements between each of the key corridors and the Cambridge urban area. The scenarios provide for an assessment the scale of future public transport demand based on a combination of:

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<sup>11</sup> The base level of public transport demand has been taken from the Cambridge Sub-Regional Model 2 (CSRM2), which provides a detailed, validated representation of base year (2015) demand. It represents the best assessment of current transport demand within the region for the purposes of this study. SDG has undertaken high-level sense checking of demand on the guideway corridor, to ensure that modelled demand provides a good representation of actual demand.

- **Growth in housing and jobs.** We have considered growth based on:
  - ‘Local Plan’ growth up to 2031, which forecasts 33,500 additional dwellings between 2011 and 2031 within Cambridge and South Cambridgeshire. This is expected to increase the number of trips relative to 2015 by 20%<sup>12</sup>;
  - ‘Transformational’ growth, reflecting likely transport demand if growth within the region significant exceeds that set out in the Cambridge and South Cambridgeshire Local Plans. This assumes the increased demand that would arise from the delivery of a further 33,500 homes within Cambridge and South Cambridgeshire (or 100,000 across the Combined Authority area, as per the aspirations of the Mayor), in addition to that committed under the Local Plans. This would be equivalent to an increase in travel demand into Cambridge of approximately 40% from current (2015) levels.
- **Increase in public transport mode share.** We have considered two scenarios:
  - **+ 35% increase in public transport demand** – this considers existing 2015 public transport demand, plus an additional 35% uplift, representing modal shift from car delivered by an improved transit system. This is informed by the experience of other mass transit schemes in the UK (where the mode shift is typically considerably less than 35%) and the post-opening evaluation of the Cambridge Guided Busway (where mode shift was estimated at 40%<sup>13</sup>).
  - **40% capture of in-scope highway demand** – this considers existing 2015 public transport trips, plus the ridership captured if 40% of all existing highway trips to the Cambridge urban area transfer to public transport. This reflects the attractiveness of the new mass transit system, together with the wider aspiration of the Greater Cambridge Partnership to reduce car trips into Cambridge city by 15%;

5.5 We have used the highest demand Scenario (Scenario 5) as the basis for the design capacity, as this represents the level of demand that the system would be future-proofed for.

5.6 The scenarios are summarised in Table 5.1 below:

**Table 5.1: Summary of Demand Scenarios**

	Base public transport demand (2015)	+ 35% mode shift	+40% capture of in-scope highway demand	+ Local Plan growth (c.20% growth in trips)	+ High growth (double Local Plan – c.40% growth in trips)
Base demand	✓				
Scenario 1	✓	✓			
Scenario 2	✓		✓		
Scenario 3	✓	✓		✓	
Scenario 4	✓	✓			✓
Scenario 5	✓		✓		✓

*Scenario 1: Base transit demand, 2015, with 35% mode shift*

5.7 This scenario is designed to estimate likely corridor public transport demand, based on existing 2015 public transport trips, plus an additional 35% uplift, representing modal shift from car.

<sup>12</sup> Informed by Atkins CSRM2 2031 ‘foundation year’ forecast

<sup>13</sup> Brett, A. and Menzies, B. 2013. Cambridgeshire Guided Busway – Usage Research, as presented to the European Transport Conference 2013.

This is informed by post-opening evaluation of the Cambridge Guided Busway, which indicates that at least 30% of Busway users<sup>14</sup> (and possibly as high as 50%<sup>15</sup>) previously travelled by car.

- 5.8 This is designed to represent likely public transport patronage, based on existing 2015 public transport demand (including Park-and-Ride), plus mode shift in line with that observed on the Cambridge Guided Busway (CGB) in the absence of any disincentives to travelling by car (e.g. workplace parking levies).

*Scenario 2: Transit demand, 2015, with 40% highway mode shift*

- 5.9 This scenario reflects potential public transport demand, based on existing 2015 public transport trips (including Park-and-Ride), plus the ridership captured if *40% of all existing highway trips to the Cambridge urban area transferred to public transport*. This represents a situation where either the attractiveness of the new mass transit system, or additional disincentives to driving into Cambridge, result in public transport displacing a significantly greater proportion of trips from car than Scenario 1.

- 5.10 Under this scenario, this would result in the number of public transport trips to Cambridge increasing by 95%, with car trips into Cambridge under this scenario would fall by 40%, compared on 2015 demand. It should be noted that this magnitude of modal shift towards public transport would be unprecedented, and in our view, represents the very upper end of what any scheme could realistically achieve.

*Scenario 3: Transit demand, 2031, with Local Plan assumptions + 35% mode shift*

- 5.11 This scenario is designed to reflect likely public transport demand, including additional trips generated by housing and employment growth in line with that set out in the Cambridge and South Cambridgeshire Local Plans (+ 33,500 additional dwellings 2011 – 2031), plus a 35% modal shift to public transport, as for Scenario 1. It assumes that these additional dwellings increase travel demand by 20% by 2031, across all modes.
- 5.12 The additional peak trips related to local plan growth has been informed by the CSRM2 2031 foundation case model.
- 5.13 This is designed to represent likely future public transport patronage, based on committed growth plus mode shift in line with the CGB, in the absence of any further disincentives to travelling by car. This would represent an increase in public transport trips into Cambridge of 62% from 2015 to 2031, with car trips remaining broadly stable, with a 2% increase 2015 to 2031.

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<sup>14</sup> Brett, A. and Menzies, B. 2013. Cambridgeshire Guided Busway – Usage Research, as presented to the European Transport Conference 2013.

<sup>15</sup> Ogilvie D, Panter J, Guell C, Jones A, Mackett R, Griffin S. Health impacts of the Cambridgeshire Guided Busway: a natural experimental study. Public Health Res 2016; 4(1).

*Scenario 4: Transit demand, future, with transformational growth + 35% mode shift*

- 5.14 This scenario is designed to reflect likely public transport demand, if growth within the region significant exceeds that set out in the Cambridge and South Cambridgeshire Local Plans. It assumes the increased demand that would arise from the delivery of a further 33,500 homes within Cambridge and South Cambridgeshire (or 100,000 across the Combined Authority area, as per the aspirations of the Mayor), in addition to that committed under the Local Plans. This would be equivalent to an increase in travel demand into Cambridge of 40% by 2031, informed by the CSRM2 model, assuming that the trip rates and propensity to travel for new dwellings is similar to that today. This scenario also assumes that a future mass transit also achieves a 35% mode shift to public transport, in line with scenarios 1 and 3.
- 5.15 Overall, this level of growth and the mode shift assumption would lead to an increase in public transport patronage into Cambridge of 89% relative to 2015, with highway trips increasing by 19% (despite the mode shift to rapid transit). This scenario anticipates a significantly greater level of growth than has recently been accommodated, and is unlikely to be achievable without a significant change in planning policy.

*Scenario 5: Transit demand, future, with transformational growth + 40% highway mode shift*

- 5.16 This scenario is designed to represent likely transit demand, were housing and employment growth to be significantly greater than that set out in the Local Plans (as per Scenario 4) and 40% of all existing and future highway trips transferring to public transport (as per Scenario 3). This would represent an increase in total travel demand of 40%, an increase of public transport usage into Cambridge of 172% relative to 2015 (more than two and half times) and a fall in highway trips relative to 2015 of 16%.
- 5.17 This is designed to represent the very upper end of public transport demand within the planning horizons of this study, representing the potential growth generated by both large-scale housing development significantly greater than that proposed in the Local Plans, and significant new disincentives to driving into Cambridge (such as reduced highway capacity and / or the implementation of some form of demand management regime<sup>16</sup>) for which there are no current proposals but there is an acceptance that such measures require further consideration.

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<sup>16</sup> For example, emissions / congestion charging or a workplace parking levy

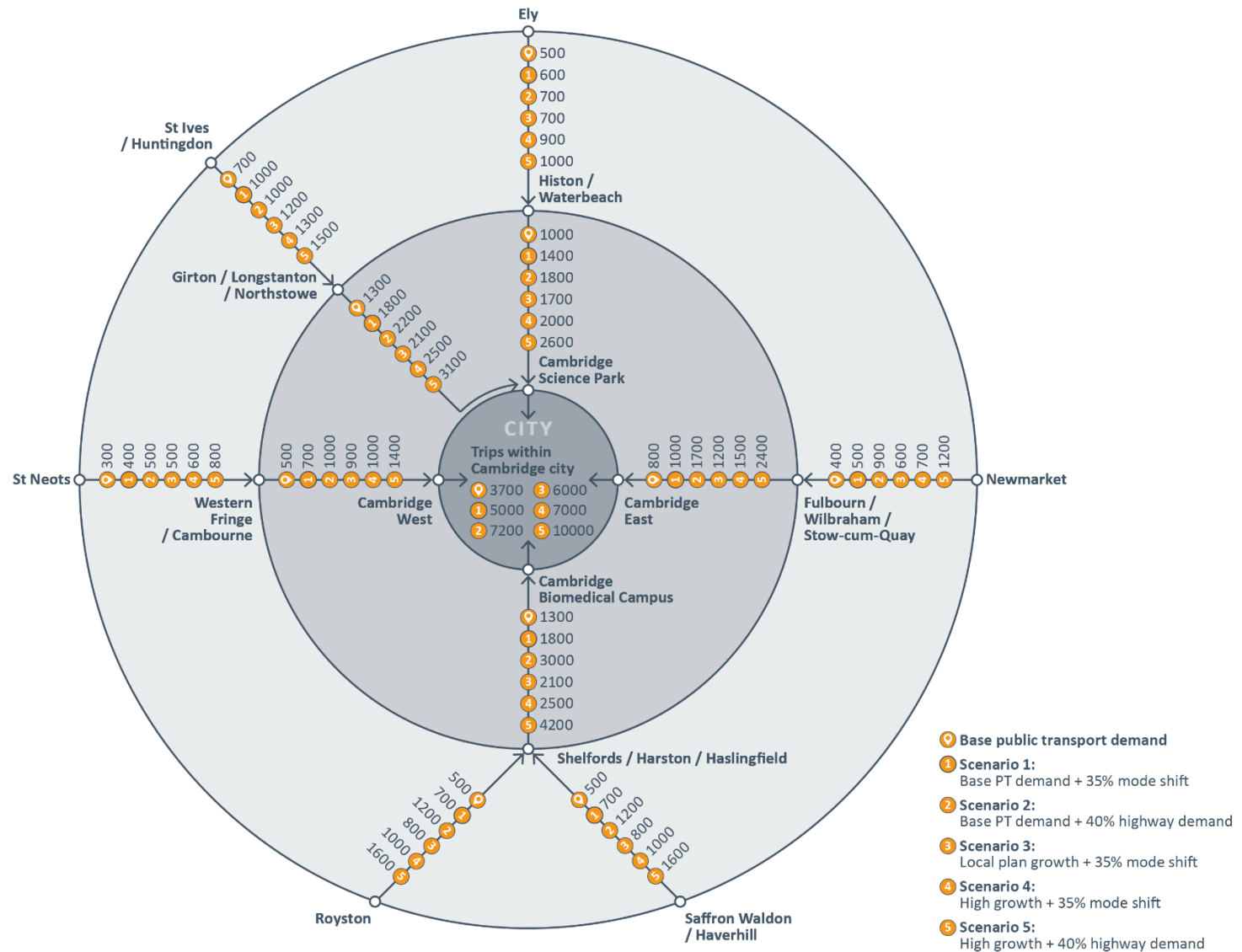
## Corridor Assessment of Potential Demand

- 5.18 Our approach considered the likely magnitude of overall public transport demand on the key corridors into the Cambridge urban area based on the scenarios outlined above.
- 5.19 Figure 5.1 overleaf illustrates total potential public transport demand along each corridor into Cambridge for the busiest AM peak hour under each scenario<sup>17</sup>, as shown in the key. For example, under Scenario 2, approximately 1,800 trips are estimated to be made into Cambridge in the high peak hour, of which approximately 700 originate from outside the 'city fringe' of Histon and Waterbeach (e.g. from Ely / Haddenham).
- 5.20 It should be noted that this illustrates the total size of the *entire* public transport market by corridor, rather than a forecast of demand for any given mass transit system, which would depend on the exact alignment and stop locations of the system in question. Several corridors (especially to the south) benefit from high-capacity, high-frequency rail links (e.g. to Shelford / A10 villages / Royston), which even following construction of any mass transit system would be expected to still carry large volumes of passengers along these corridors into Cambridge.

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<sup>17</sup> Flows were estimated from the current base year (2015) travel demand into the Cambridge urban area by CSRM2 sector, aggregated into seven corridors into the city, by mode, for a typical AM peak hour. We have used the morning peak hour (0800 to 0900) as it represents the busiest hour and is therefore the demand level that informs the planning capacity requirements for mass transit. We have undertaken checks which show, for example, that the modelled peak hour demand on the Guided Busway validated extremely well against observed (known) demand for the inbound peak hour.

Figure 5.1: Corridor Demand Schematic





### Potential corridor demand

- 5.21 Figure 5.1 outlines that, under the base scenario, AM demand per corridor is approximately 500 – 1300 people per hour closest to Cambridge. Only a small proportion of trips originate from outside the ‘city fringe’ area, marked as the middle ‘ring’ on the diagram, with no corridor having an indicative public transport demand in excess of 1,000 people per hour.
- 5.22 Public transport demand under alternative scenarios, which capture housing and employment growth and a high degree of modal shift, is significantly greater. Most corridors have a potential public transport demand of 1,000 – 3,000 people per hour closest to Cambridge, dependent on the scenario in question. Public transport demand is expected to be greatest on the corridors to the south of Cambridge, with a demand under Scenario 5 of 4,200 people per hour, where the A10 corridor is already well-served by rail links, including the imminent introduction of new 12-car Thameslink services from 2018.

## Planning Capacity Requirement for Mass Transit

### Planning Capacity Key Corridors

- 5.23 Therefore, a **planning capacity of 4,000 people per hour per corridor in each direction** into the Cambridge urban area would therefore accommodate:
- All existing public transport trips by bus and rail (except the A10 corridor where further growth could be partly accommodated by the existing rail network);
  - Headroom for future housing and employment growth, including significantly in excess of Local Plan forecasts, and;
  - Large-scale modal shift to public transport, significantly in excess of that experienced elsewhere.
- 5.24 This figure both provides sufficient headroom for future growth under every scenario, and caters for a more than doubling of existing public transport patronage on each corridor.

### Capacity through the Core

- 5.25 Analysis of movements in the City Centre suggests that central area demand could be comfortably catered for by any mass transit mode which meets the 4,000 people per hour corridor requirement.

# 6 Mass Transit Options

6.1 This chapter provides a review of potential technology options for a mass transit network within Cambridge. It considers both a ‘long list’ of transit technologies in use globally, before considering a ‘short list’ of three systems proposed for use in Cambridge, informed by the local geography, aspirations for growth and demand assessment presented in earlier chapters.

## ‘Long list’ of potential technologies

6.2 Several mass transit systems and technologies could be applicable to a future mass transit system in Cambridge. These range from generic systems widely used across the world, to proprietary system with much less coverage, as well as systems recently or currently proposed. This section considers the following transit technologies:

‘Traditional’	‘Emerging’
<ul style="list-style-type: none"><li>• Rail Based Metro</li><li>• VAL (Véhicule Automatique Léger)</li><li>• Light Rail Transit (LRT) / Tram</li><li>• Monorail</li><li>• Gondola / cable car</li><li>• Kerb guided bus</li><li>• Other guided bus</li></ul>	<ul style="list-style-type: none"><li>• Ultra Light Rail (ULR)</li><li>• Personal Rapid Transit (PRT)</li><li>• Autonomous and driverless technology</li><li>• Affordable Very Rapid Transit</li></ul>

6.3 This study is considering options for mass transit on identified corridors, and hence technologies considered are all based on the use of fixed alignments. It should be noted, however, that there are a number of emerging technologies being incorporated into these systems, as set out in the descriptions below.

## ‘Traditional’ technologies

6.4 **Rail Based Metro** refers to systems such as the London Underground, Tyne and Wear Metro or Docklands Light Railway, where the common feature is the use of electric traction, railway signalling, steel wheels and rails and a fully segregated right of way. Systems typically offer very high capacity, very high frequency services (up to 36 trains per hour, with a total capacity of 30,000 people per hour on the London Underground Victoria Line), and typically have two types of operation:

- Conventional operation – a driver in a front cab is responsible for the operation of the train, supported by the signalling system (such as the London Underground);
- Automatic operation – the system is operated centrally, with no driver or traditional cab, although may still have a member of staff on board (e.g. Docklands Light Railway).

- 6.5 **VAL (Véhicule Automatique Léger)** is an automated rubber-tyred metro, originally developed in France. VAL systems have similar attributes to rail based metros, but with vehicles instead operating on rubber tyres, with guideways providing guidance, rather than steel wheel-on-rail. VAL systems therefore provide a capacity and frequency commensurate with rail-based metros, and have been implemented both as urban mass transit systems in France, Italy, Taiwan and South Korea.
- 6.6 **Light Rail Transit (LRT) / Tram** systems feature vehicles operating on steel rails, operating on either segregated alignments or in shared running with traffic or in pedestrianised areas, and are hence more flexible than traditional rail-based metros. Systems are driver operated, and typically controlled on a line-of-sight basis using traffic signals at junctions, reducing the need for complex signalling compared to rail based metros, and operate from overhead electric lines (although in a few cases supplemented by batteries).

Figure 6.1: Shared Running LRT – Croydon, UK



Source: Steer Davies Gleave

- 6.7 LRT systems typically offer high frequency services, with circa 30m vehicles operating either singly or in multiple to deliver a capacity of up to 15,000 people per hour.
- 6.8 **Monorail** systems operate with vehicles running on a single rail or beam, typically elevated or in tunnel, with a more slender structure than other elevated transit systems. At grade sections need to be fully segregated from other users. Most monorail vehicles run on rubber tyres, and the majority of monorail systems in operation are located either in theme parks/leisure facilities or within airports, although several mass transit systems can be found in Japan and China.

- 6.9 **Gondola and cable car** systems feature cars suspended on moving cables, and are typically used to provide public transport across difficult terrain such as mountainous areas or ski resorts, ravines and bodies of water. They have also been used in several public transport applications, such as the Emirates Air Line (crossing the River Thames in East London) or the Metrocable in Medellín, Colombia. Systems are typically of relatively low speed and capacity, and are best suited to locations where the terrain makes other transit options difficult or costly to implement.
- 6.10 **Bus Rapid Transit (BRT)** is an umbrella term that encompasses a wide range of rubber-tyred, bus-based transit systems used globally. Most BRT systems aim to emulate LRT levels of capacity, speed, frequency and service quality, but at lower cost using bus technology. Improvements in the level of service and capacity over conventional bus services are achieved by adding a series of measures to improve the performance and quality of service, including:
- Segregated right-of-way, bus only streets and dedicated lanes;
  - Use of physical or optical guidance;
  - Priority at junctions;
  - Modern, low floor, high-capacity (often articulated) ‘tram like’ vehicles;
  - Multiple door boarding;
  - Off-bus ticketing;
  - Distinctive branding;
  - High quality stops/shelters
  - ITS/Real-time information
- 6.11 BRT systems are typically driver operated on a line-of-sight basis, and their flexibility can cater for a wide range of desired frequencies and capacities. Segregated busway infrastructure can facilitate very high frequency, high capacity services, with several systems in Australia (Brisbane), Brazil (Curitiba) and Colombia (Bogotá) globally operating at frequencies of more than 120 buses per hour, with a total capacity of 15,000 – 20,000 people per hour.

Figure 6.2 BRT, Nantes, France



Source: Steer Davies Gleave



- 6.12 **Kerb guided bus** involves operating conventional bus vehicles guided along a concrete busway ‘track’, but also capable of operating normally with general traffic with manual steering. This can achieve a better ride quality than simply operating along a tarmac road, together with a narrower right-of-way. Kerb guided systems are operated in Essen (Germany) and Adelaide (Australia), together with several UK cities including Leeds, Bradford, Crawley, Luton, Salford and Cambridge. Several of these systems also have further BRT-type attributes, such as junction priority, distinctive branding and off-bus ticketing.

Figure 6.3 Cambridge Guided Busway



Photo © David P Howard (CC-BY-SA/2.0)

- 6.13 **Other guided bus systems** have also been applied, based on the use of adapted conventional buses fitted with a guidance system. Optical guidance systems, in which the vehicle path is determined by markings painted on the road surface have been more successful, but are being supplanted by the more sophisticated guidance systems now being developed for autonomous vehicles (e.g. LIDAR).

#### **‘Emerging’ technologies**

- 6.14 Several ‘emerging’ transit technologies have also been developed in recent years, offering either new mass transit modes (such as Ultra Light Rail) or further development of established transit technologies (such as increased automation). These are discussed below.
- 6.15 **Ultra Light Rail (ULR)** is the application of smaller, lighter transit vehicles on steel rails, representing an evolution of LRT systems. ULR proponents often aim to combine lower-cost components from the road industry with lighter weight track solutions to achieve a significant reduction in the cost of implementing light rail, making it affordable in situation where a conventional solution would be too costly. No mass transit ULR systems have yet been implemented in the UK, although a system is currently being developed by Warwick University’s Warwick Manufacturing Group, with a demonstrator vehicle planned for 2019, and longer-term aspirations to use ULR to link Coventry to the Birmingham HS2 station.

- 6.16 **Personal Rapid Transit (PRT)** is a system in which small, lightweight, driverless electric vehicles provide on-demand, direct (non-stop) trips between origin and destination. In concept, such systems could operate on existing road networks as fully autonomous vehicles, but with the technology currently available vehicles are limited to a specific guideway. Vehicles are rubber tyred and battery powered. An Ultra PRT system operates at Heathrow Airport, operating over 3.8 km of unidirectional guideway, with a system capacity of 800 passengers per hour per direction.
- 6.17 **Autonomous and ‘driverless’ technology** will enable a number of features and benefits to be incorporated into a mass transit system. These include:
- Driverless technology - This has the potential to significantly reduce system operating costs and therefore increase the financial viability of mass transit.
  - Autonomous guidance – this enables the flexibility of operating on segregated and on-street on a ‘fixed’ route, without the associated costs of guidance infrastructure (e.g. rails or guideway).
  - Platooning of vehicles – vehicle to vehicle communications can enable multiple transit vehicles to be ‘platooned’, allowing capacity to be scaled to reflect demand
  - Network management – this allows for network optimisation across the fleet to ensure services are ‘flighted’ in the most operationally efficient way - improving both the passenger service and reducing operating costs
  - Electric vehicles – technology will allow for fully electric vehicles with zero emissions at the point of use
- 6.18 **Affordable Very Rapid Transit (AVRT)** is a conceptual system, intended to represent a creative approach to use new and future technologies to deliver an effective mass transit system within a capital and operating budget that is affordable for a small but growing city region. While the system has been designed to meet the transport requirements of Cambridge, the promoters argue that it could also serve the needs of many other small, vibrant, cities across the UK and abroad – such as Oxford and Milton Keynes. The current AVRT concept is intended to illustrate the nature of what might be, to contribute to a debate, rather than proposing a definitive solution.
- 6.19 The AVRT promoters have argued that cities the size of Cambridge do not have the volumes of movement necessary to justify a conventional underground metro system, and the AVRT project aims to address this by reducing the costs by a range of measures including:
- Use of fully autonomous vehicles, of smaller dimensions than typical rail-based transit vehicles, with a capacity of approximately 40 passengers, capable of operating singly or in platoons;
  - Rubber tyred, running on a flat paved surface to avoid the costs and spatial requirements of conventional steel rail track;
  - Battery powered operation to avoid the costs of overhead line infrastructure, with rapid recharging provided at each of the stations;
  - Smaller diameter tunnels to reduce tunnel construction costs;
  - Operation as a series of simple single-track end to end shuttles, to avoid the need for a complex railway-type signalling system;
  - High speed running (192 km/hr) and high acceleration and braking rates to achieve fast journey times (necessary to achieve high frequency service with the shuttle operation).



**Figure 6.4: Artists' impression of an AVRT vehicle**



Source: Smart Cambridge: Affordable Mass Transit for Cambridge and the Wider Region

- 6.20 Key differences between AVRT and other mass transit systems from a passenger perspective are that there are no through-services, and passengers need to transfer from one service to another at each of the stations for most journeys. While this helps facilitate the 'shuttle' services operating through single track tunnels, and hence cost savings through reduced tunnelling, the limited number of stations in the system could mean that the onward connection from the station to the final destination may be longer than with other systems, requiring separate 'last mile' solutions to be adopted for destinations further from the stations. While passengers are required to make transfers, the interchange times will be relatively short due to the high service frequency.
- 6.21 AVRT is also reliant on the use of a number of new and emerging technologies. The promoters view is that these are all either proven in use or under active development, and they also note the level of worldwide investment in these technologies from industry and UK Government support for the necessary changes to legislation, approvals processes and regulatory regimes to facilitate their widespread adoption.
- 6.22 Further details of the AVRT concept and network within Cambridge are discussed in Chapter 7.
- Refinement of Technologies - Cambridgeshire Autonomous Metro**
- 6.23 Several 'emerging' technologies are expected to mature in the development timescales of a Cambridge mass transit network, notably automation and driverless vehicles. Hence it has been considered how these can be combined with the modes outlined earlier to develop a more optimum scheme for Cambridge.
- 6.24 We have looked at the features and benefits that technological developments can deliver in the context of a mass transit solution for Cambridge, and sought to develop an option that utilises these. These features and benefits are summarised below.
- 6.25 Increased maturity of driverless systems is expected to result in any future Cambridge system being capable of driverless operation (at least on segregated infrastructure), which has the

potential to greatly improve operational efficiency and also create a transit solution suitable for a 'city of firsts'. Operational efficiencies can be achieved through the direct savings associated with driverless operation, through greater operational flexibility and through and network management (a fleet of 'connected' vehicles can be optimised in real-time).

- 6.26 Guidance systems, including through autonomous operation, have developed significantly through GPS and on-board sensors (e.g. LIDAR) to the extent that physical or optical guidance is no longer required – which other than the vehicle, is the key characteristic of LRT. This means that guidance can effectively be provided without the need for conventional physical infrastructure (i.e. guideways for guided bus, or rails for LRT), potentially reducing capital costs.
- 6.27 Any Cambridge system would utilise electric operation, most likely through battery technology, both for operation underground and to improve local air quality. Combined with further development in vehicle design, power sources and guidance technologies, any future mass transit system would be expected to be significantly different from a current BRT scheme
- 6.28 For the purposes of developing a concept that utilises the potential opportunities afforded by technology, a concept that we refer to as 'Cambridgeshire Autonomous Metro' (or CAM) has been identified and included in the shortlist of options take forward. The concept employs elements of both LRT and AVRT. Specifically, it seeks to achieve the network coverage and connectivity that is intrinsic to the Cambridge Connect LRT proposal, while utilising many of the technological features of AVRT. The CAM concept also includes tunnelling to overcome the key constraint within the city – in common with both LRT and AVRT options.

#### **Summary**

- 6.29 Table 6.1 summarises the characteristics, frequencies and capacities of the modes considered in this chapter.

**Table 6.1: Mapping of System Characteristics**

	Conventional Rail Based Metro	Automated Rail Based Metro	Light Rail Transit/Tram	PRT	VAL	Cambridge AVRT	Bus Rapid Transit / Guided Bus / CAM	Monorail	Cable Car
System Capacity (people per direction per hour)	9,000 – 31,000	3,000 - 24,000	2,000 – 15,000	120 – 1,800	6,600 – 26,400	1,000 – 4,000	500 – 18,000	3,000 - 24,000	Up to 4,500
Vehicle Capacity (people per vehicle)	600 – 850	200 – 600	200 – 500	4	440	40 – 80	50 – 150	200 – 600	c. 10 for 'gondola'
Frequency (vehicles per hour)	15 – 36	15 – 40	10 - 30	120 – 480	15 – 60	25 – 50	10 - 120	15 – 40	450 (c. every 8 secs)
Maximum Speed (km/hr)	100	100	80 or road speed limit	40	80	190	80 or road speed limit	100	Slower than other options
Vehicle Guidance	Steel wheel / rail	Steel wheel / rail	Steel wheel / rail	Optical / vertical kerb face	Rubber tyre / vertical guide rail	Automatic – System not stated	Unguided / kerb face / optical	Typically concrete track	Wire
Signalling and Control	Driver, Fixed block signalling	Automatic, Moving block signalling	Driver, Line of sight	Automatic – Central System Control + Autonomous Systems	Automatic Central control system	Autonomous Local control systems only	Driver, Line of sight	Typically driver, fixed block signalling	Automatic
Energy Source	Electric, Third rail	Electric, Third rail	Electric, Overhead Line / battery	Battery	Electric, Third rail	Battery	Various	Electric	Electric
Segregation	100% Segregated	100% Segregated	Segregated or Shared with priority	100% Segregated	100% Segregated	100% Segregated	Segregated or Shared with priority	100% Segregated	100% Segregated
System proven in service? Other risks?	Many examples worldwide	Several examples Generally proprietary technology	Many examples worldwide	Very limited experience	Established system. Single supplier	Proposed system reliant on several new technologies	Many examples worldwide	Several examples Generally proprietary technology	Many examples worldwide

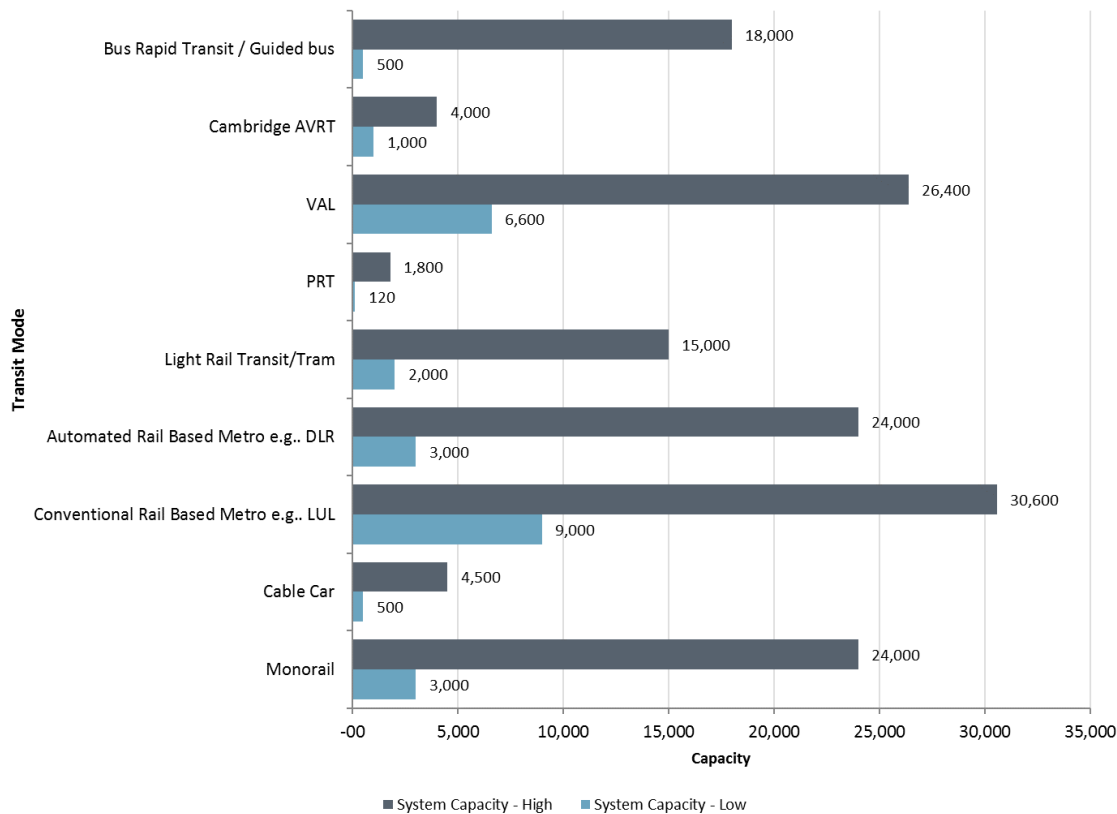
Developing a ‘Short List’

Passenger Capacity

6.30 Table 6.1 summarises the capacity delivered by each mass transit technology identified in the ‘long list’, and our approach for estimating likely demand for a mass transit system in Cambridge suggests a planning capacity per corridor of **4,000 people per hour**. Transit technologies have been sifted on their ability to meet the required corridor capacity, and their likely deliverability and acceptability within Cambridge.

6.31 Figure 6.5 summarises the capacity provided by the primary modes under consideration. Guided bus systems have been included with bus rapid transit in the graph, since they share the same parent technology. The upper range of the BRT capacity reflects the high frequencies at which some systems operate (a service every 15 to 30 seconds) along the highest capacity BRT routes.

Figure 6.5: Capacities of transit modes under consideration



6.32 Rail-based metro (both conventional and automated, including Monorail) and VAL offer a capacity significantly in excess of that required in Cambridge, and have substantially higher infrastructure costs than modes (LRT, BRT) offering intermediate levels of capacity, and have hence been discounted at this stage. Conversely, PRT-based systems (such as Heathrow Ultra), together with ULT, do not offer sufficient capacity for either current corridor demand or the scale of potential growth. Both systems have also never been deployed across a network as extensive as that proposed for Cambridge, although PRT-type systems could have a role in providing ‘last mile’ connectivity to future Cambridge mass transit stops.

6.33 LRT and BRT-type systems offer the required corridor capacity for Cambridge, and hence have been taken through to consideration in the ‘short list’. Whilst in its current form, with single

track tunnels, AVRT is unlikely to meet the corridor capacity requirement, it is recognised that the system is at an early stage of development and further development of the system (such as the provision of twin-bored tunnels) would be expected to both meet the required capacity, and provide a high-quality, high-frequency system required for Cambridge. It has therefore also been taken forward to the 'short list'.

### Other Considerations

- 6.34 While the capacity analysis was the primary consideration in the shortlisting of modes, other factors were considered in the decision not to take forward the following options:
- **Cable Car** – while Cable Car could provide capacity on individual corridors, it would not allow for these corridors to funnel into common sections within the Cambridge area (as can be achieved with other transit modes). The consequent limitation on central area capacity therefore makes this option unsuitable. In addition, the topography of Cambridge is not suited to cable car operation, and the visual impacts would be unacceptable within the city.
  - **Monorail** – in addition to the higher cost of this option, the potential visual intrusion impacts of this option were also deemed to make this unacceptable.
- 6.35 The recommendation not to proceed with 'rejected' modes on the long-list was tabled with the client team and stakeholders during the course of the study, to ensure 'buy-in' to the options taken forward.

### Option Shortlist

- 6.36 The shortlist of modal options taken forward to the more detailed strategic assessment stage are therefore:
- Light Rapid Transit (LRT)
  - Affordable Very Rapid Transit (AVRT)
  - Cambridgeshire Autonomous Metro (CAM)
- 6.37 The shortlist was presented to, and discussed with, the client team and stakeholders through the course of the study. The definition of shortlisted options is described in more detail in the next Chapter.

# 7 Description of Shortlisted Options

## Shortlisted options

- 7.1 Three technology options have therefore been shortlisted for potential use in a mass transit system within Cambridge:
- LRT;
  - AVRT; and
  - Cambridgeshire Autonomous Metro (CAM).
- 7.2 The aim was to develop options capable of serving the wider Greater Cambridge area. However, we were also mindful of the fact that mass transit systems typically operate in urban areas, where demand levels are higher and can support the cost of implementing and operating a mass transit system. Accordingly, for LRT and AVRT both a 'city' and 'regional' variant was considered, serving the city and the wider corridors respectively. For 'city' variants access to mass transit from radial corridors would be provided via P&R and feeder services. CAM was developed as an option to provide regional coverage, whereby new and existing segregated infrastructure would facilitate the operation of direct services to all key radial corridors, without the requirement to interchange.
- 7.3 The options considered are summarised in Table 7.1. The following sections consider, for each option:
- vehicles that would be used;
  - the infrastructure necessary;
  - the operational concept in the context of Cambridge;
  - the network; and
  - high-level capital and operational costings.



**Table 7.1: Overview of Shortlisted Options**

Option	Description	Capital Cost (indicative)
LRT City Network	<ul style="list-style-type: none"> <li>42km network</li> <li>Based on Cambridge Connect</li> <li>Assume 10tph</li> </ul>	£2.8bn
LRT Regional Network	<ul style="list-style-type: none"> <li>90km network</li> <li>Based on Cambridge Connect</li> </ul>	£4.5bn
AVRT City Network	<ul style="list-style-type: none"> <li>15km network</li> <li>Based on John Miles proposals</li> <li>Single or twin-bore options</li> </ul>	£1.1 - £1.7bn (Dependent on single or twin-bore)
AVRT Regional Network	<ul style="list-style-type: none"> <li>56km network</li> <li>Based on John Miles</li> <li>Twin-bore option to meet planning capacity</li> </ul>	£2.1bn
Cambridgeshire Autonomous Metro (CAM) – Regional Network	<ul style="list-style-type: none"> <li>49km new infrastructure, of which:               <ul style="list-style-type: none"> <li>24km new segregated infrastructure in Cambridge (including tunnel)</li> <li>25km of planned / proposed segregated links</li> <li>Use of existing infrastructure to provide a 75km regional network</li> </ul> </li> </ul>	£1.5 - £1.7bn (Dependent on level of tunnelling required)

## Light Rapid Transit

### Vehicles

- 7.4 Cambridge Connect would operate as a traditional ‘light rail’ system, using vehicles similar to those used on the Midland Metro, Manchester Metrolink, and Sheffield Supertram, together with numerous cities globally. It would operate at a maximum speed of 70 - 100km/h, powered by overhead traction, with the opportunity for battery operation if required. Each tram service would have a capacity of approximately 200 passengers, with the ability to operate in multiple to increase capacity as required.

### Infrastructure

- 7.5 Any LRT system such as Cambridge Connect would require the installation of twin steel tracks along the extent of its route. Stops would be equipped with shelters, real time information and step-free access. Within the City Centre, a 3.2km tunnel would be provided from the Mill Road area to the West Cambridge site, together with a shorter tunnel between Mill Road and Newmarket Road.

### Operations

- 7.6 Cambridge Connect would operate as a typical LRT system, and a frequency of 10 trams per hour (one every six minutes on each line) would provide a ‘turn-up and go’ service which would provide the required capacity, be commensurate with that implied by a mass transit system, and be sufficiently attractive to present a viable alternative to car.
- 7.7 Cambridge Connect would operate largely segregated from existing traffic, and at the outset would be driver operated on a line-of-sight basis, with minimum signalling and junctions controlled by traffic signals. In the future, there would likely be opportunities for driverless operation, dependent on the development of tram technology.

## Network

7.8 Two options have been proposed, differing only in scale:

- a **'city' network option**, comprising 36 stations and 42 kilometres of track, operating between Milton Road P&R, Trumpington, Granta Park, Newmarket Road P&R, Girton and the West Cambridge Site. Development could be phased, with an initial 'Isaac Newton' line running from Girton via the City Centre to Addenbrookes, Trumpington and Granta Park, with further extensions developed around this core to deliver a full city network; and
- a **'regional' network option**, comprising the city centre option above with additional links to Haverhill, Bar Hill, St Neots and Burwell. This option would total 90 km, with 51 stations. Interchange with existing Guided Busway services would be available at the Cambridge Science Park and Cambridge North.

7.9 These two options are displayed here as Figures 7.1 and 7.2 respectively. Average speeds comparable to London Tramlink would deliver journey times of 15 minutes to travel from Milton Road to Addenbrookes, and 33 minutes for the whole length of the Isaac Newton line.

Figure 7.1: Cambridge Connect 'City' network

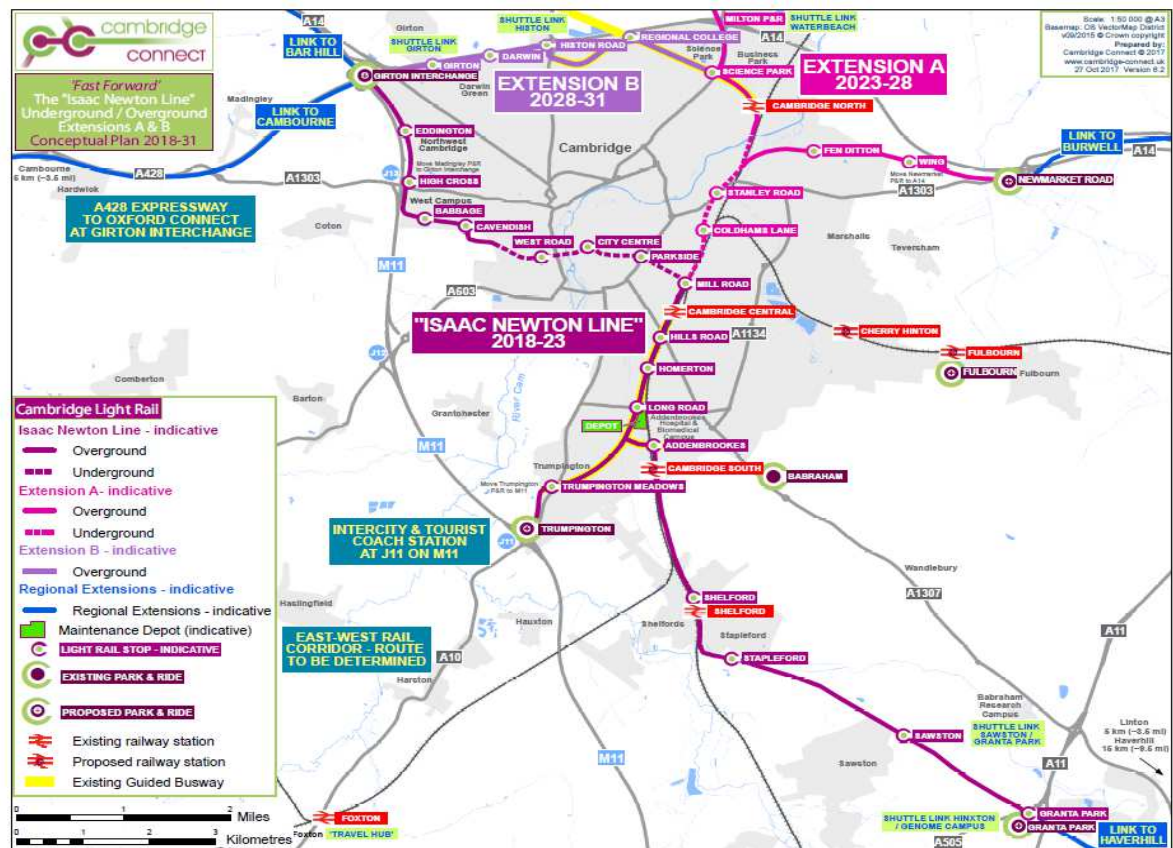
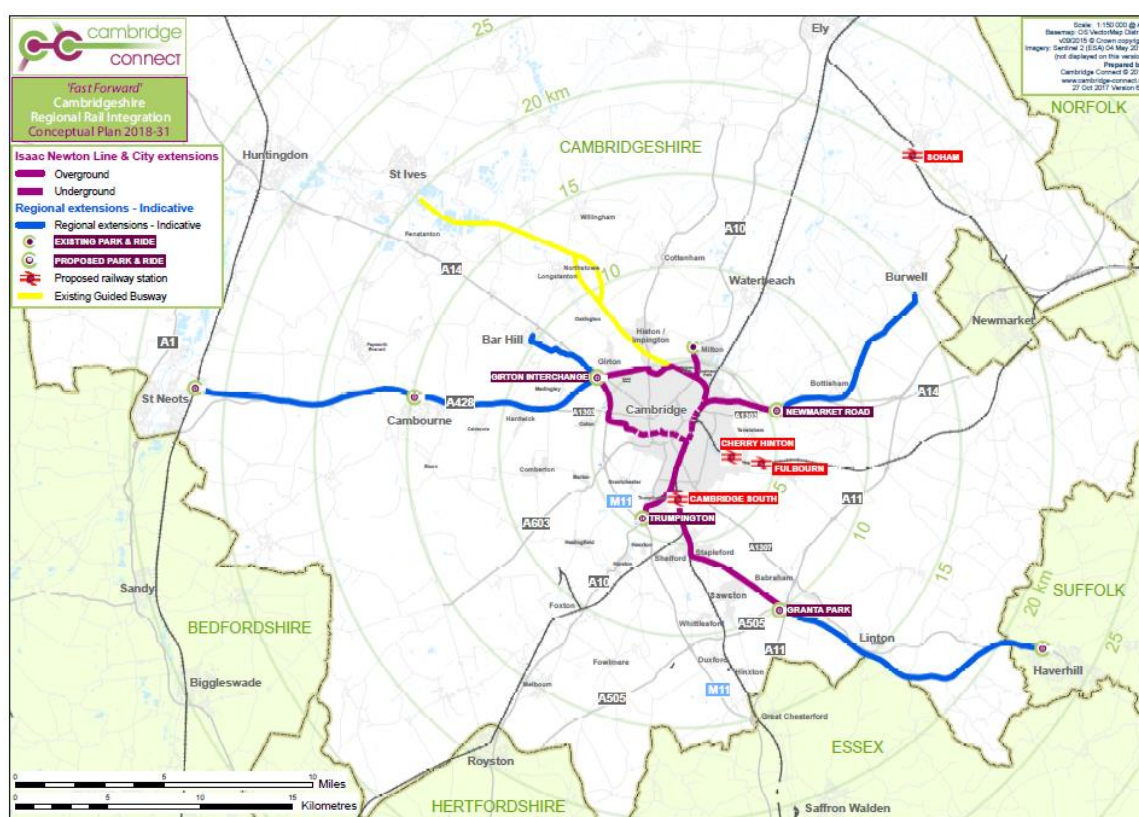


Figure 7.2: Cambridge Connect 'Regional' Network



## Affordable Very Rapid Transit

### Vehicles

- 7.11 Cambridge AVRT would operate using new, bespoke vehicles, using autonomous technology. Vehicles would be powered by batteries, recharged at interchange points, rubber-tyred, operating on a flat tarmac or concrete surface, and capable of 120 mph operation. Each vehicle would carry approximately 40 passengers.

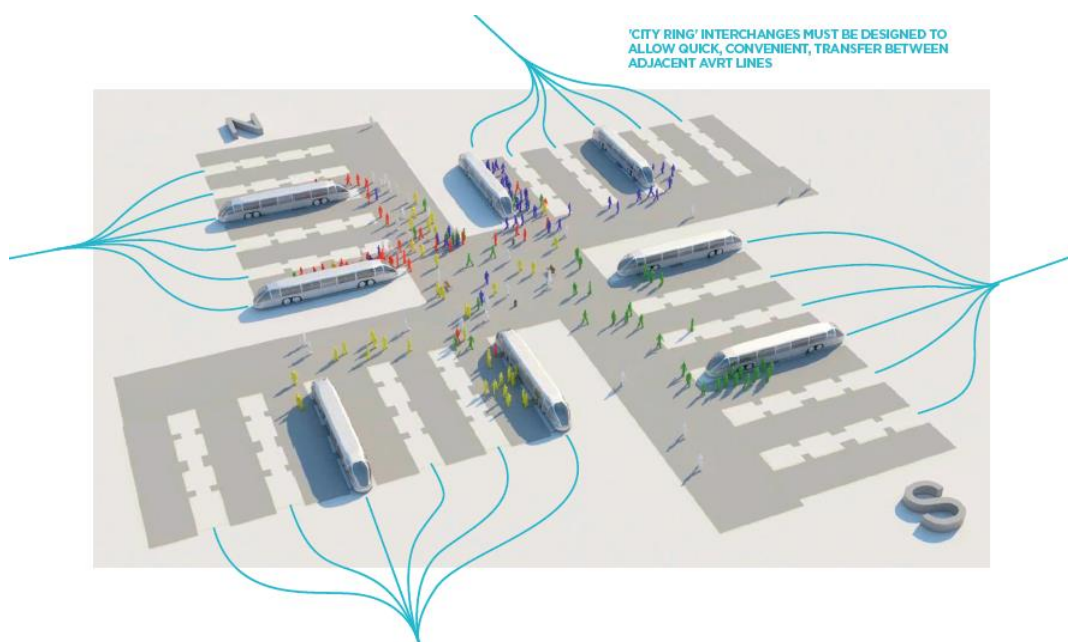
### Infrastructure

- 7.12 Cambridge AVRT would operate on a fully segregated alignment, with routes tunnelled within the city (shown as the purple lines on Figure 7.4), and the wider network operating largely at-grade. The 'city' network option has been costed for both single- and twin-bore tunnel options, whilst it is assumed that to provide the required capacity and operational resilience a 'regional' network would be required to be twin-track throughout. The twin-bore option would provide additional capacity and operating resilience, and allow services to operate at speeds that are likely to be more acceptable and comfortable from a passenger perspective.
- 7.13 Within the City Centre, a large underground interchange would be provided, as shown in Figure 7.3, with battery charging facilities to provide power to vehicles.

### Operational Concept

- 7.14 Vehicles would operate at high speeds in shuttles between two stops, achieving frequencies of three minutes on each leg. To save costs on tunnelling, each tunnel accommodates only one vehicle running in one direction at any one time, with service frequencies not compromised as a result of the speed of the vehicles. The shuttle system means passengers travelling from one fringe site to another would have to interchange in the central station; similarly, passengers from the regional network would have to change to access the city network. To aid speedy interchange, the proposers have developed 'city ring' interchanges rather than conventional station designs, as shown in Figure 7.3.

**Figure 7.3: Central Cambridge AVRT Interchange (located underground)**



## Network

- 7.15 Two potential networks have been considered at this stage:
- a ‘city-based’ network, comprising stations at Addenbrookes, West Cambridge, Cambridge Airport and the Science Park with a City Centre interchange between them, comprising approximately 15 km of track, and;
  - a ‘regional’ network, including both the above and four additional routes, linking the outer hubs to Park-and-Ride interchanges at Cambourne (to the west), Shelford (to the south), the A14 (to the east) and Stretham (to the north). This could be expanded incrementally, as required.
- 7.16 Both networks are shown in Figure 7.4, with the purple lines depicting the city network and the orange lines the wider regional network.

## Costs

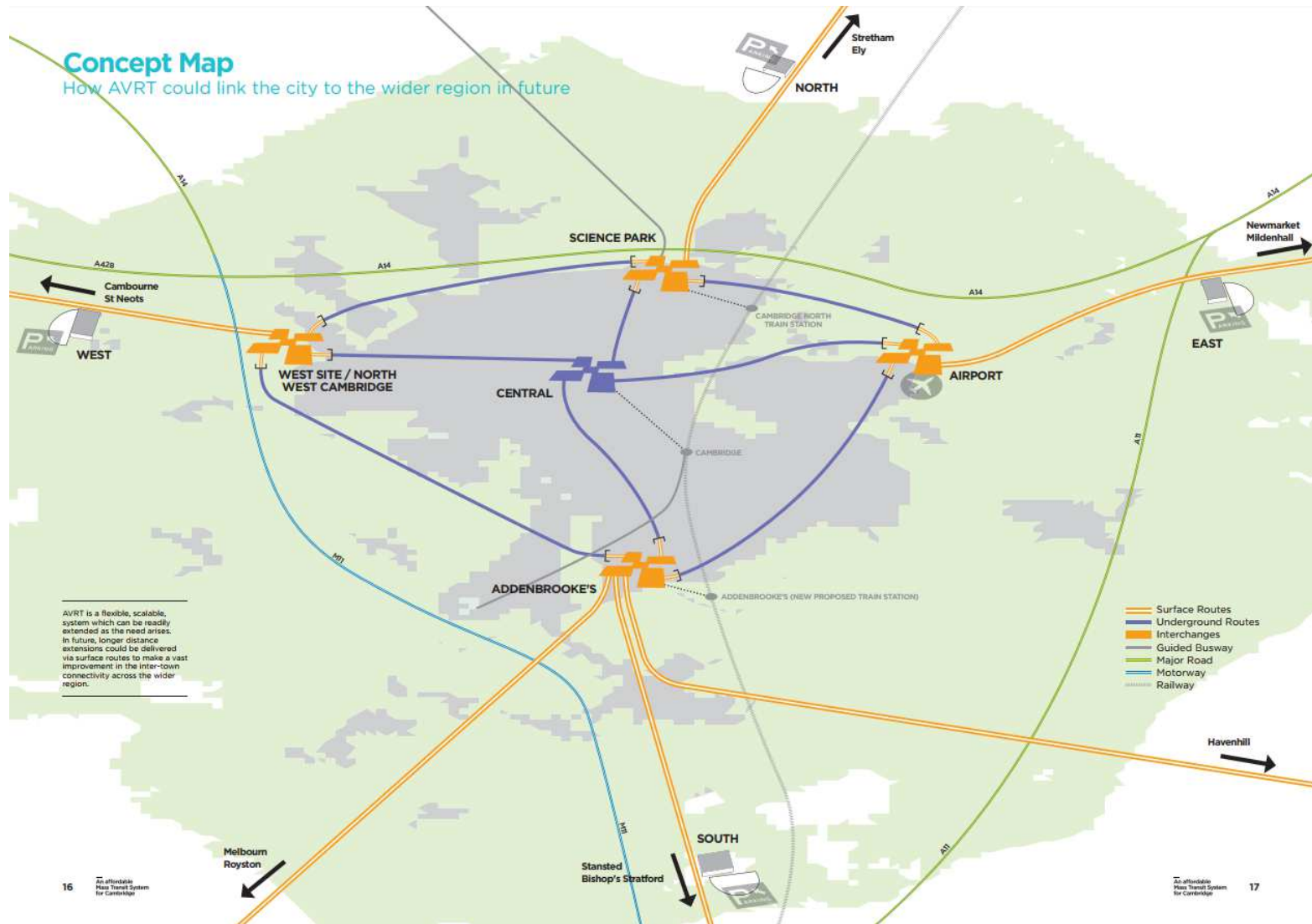
- 7.17 In calculating the costs for the two AVRT variants Steer Davies Gleave undertook an independent review and benchmarking of costs. Tunnelling and underground interchange costs are based on London Bridge Associates analysis (as part of the Steer Davies Gleave-led team) of tunnelling and station costs, which form the major cost components of AVRT. Other costs (e.g. vehicles) have been taken as presented in the AVRT literature.
- 7.18 The AVRT capital costs include a 15% design and project management cost and a 64% optimism bias. Both the ‘city’ and ‘regional’ network have been costed based on the networks described above.

**Table 7.3: Cambridge AVRT Capital Costs (millions)**

Component	AVRT City Costs (£m)	AVRT Regional Costs (£m)
Underground interchanges	189 - 377	377
Overground interchanges	5	14
Park and rides	140	140
Tunnelling	745 - 1,162	1,192
Road	N/A	95
Viaducts	N/A	222
Vehicles	28	42
Power and systems	20	20
<b>Total</b>	<b>1,130 - 1,740</b> (Dependent on single or twin-bore)	<b>2,090</b>



Figure 7.4:  
Cambridge AVRT  
Concept Map





## Cambridgeshire Autonomous Metro (CAM)

7.19 Cambridgeshire Autonomous Metro (CAM) is a concept that seeks to best deliver the transport outputs and benefits that a Cambridge mass transit scheme should achieve, while maximising value for money and affordability. The development of the option aimed to combine the key elements of LRT, in terms of quality and coverage, and some of the key technological features and benefits of AVRT. It includes:

- utilising the benefits afforded by autonomous and connected technology;
- making best use of existing and planned segregated infrastructure; and
- limited use of short sections of tunnelling where required to secure segregation.

7.20 CAM is a working title used for the purposes of this report. For any mass transit option taken forward (equally so for LRT and AVRT) further work would be required to develop the name and brand concept for the scheme.

### Vehicles

7.21 CAM vehicles would be high-quality, offering a level of ride quality and comfort comparable to that of LRT, and would be zero-emission, powered by electric batteries recharged overnight and at route termini throughout the day without a need for overhead wires. CAM could utilise bespoke rubber-tyred articulated vehicles, with a maximum speed of 80 – 90km/h and a capacity of 100 – 250 people, dependent on the chosen vehicle and demand requirement.

7.22 Vehicles would have the ability to be operated autonomously, without a driver, using guidance technologies such as LIDAR as they mature. Platooning technology, where a group of vehicles form a 'chain' and communicate wirelessly using 'V2V' communications, could also be adopted when technology allows, increasing capacity and fleet optimisation and reducing energy consumption.

### Indicative Vehicles

7.23 Figures 7.5 - 7.7 provide examples of the types of vehicles that could be adopted by CAM.

7.24 Figures 7.5 and 7.6 depict a VanHool ExquiCity, an articulated or bi-articulated vehicle with a capacity of 105 – 180 people<sup>19</sup> (dependent on length and configuration) and capable of hybrid (diesel or CNG) or electric battery operation. These are currently in operation in Metz (France), Malmo (Sweden), Linz (Austria), and are expected to enter operation on the Belfast Rapid Transit in September 2018. Figure 7.7 depicts a narrower, longer 'tram-like' rubber-tyred vehicle recently introduced in Zhuzhou, China, which is expected to become driverless in the near future.

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<sup>19</sup> Note that operation of vehicles longer than 18.75m, with a capacity of greater than 110 people, would under current legislation require dispensation from the Department for Transport,

Figure 7.5: VanHool ExquiCity Vehicle - Metz



Figure 7.6: VanHool ExquiCity Vehicle - Interior



Figure 7.7: Zhuzhou ART Vehicle – China

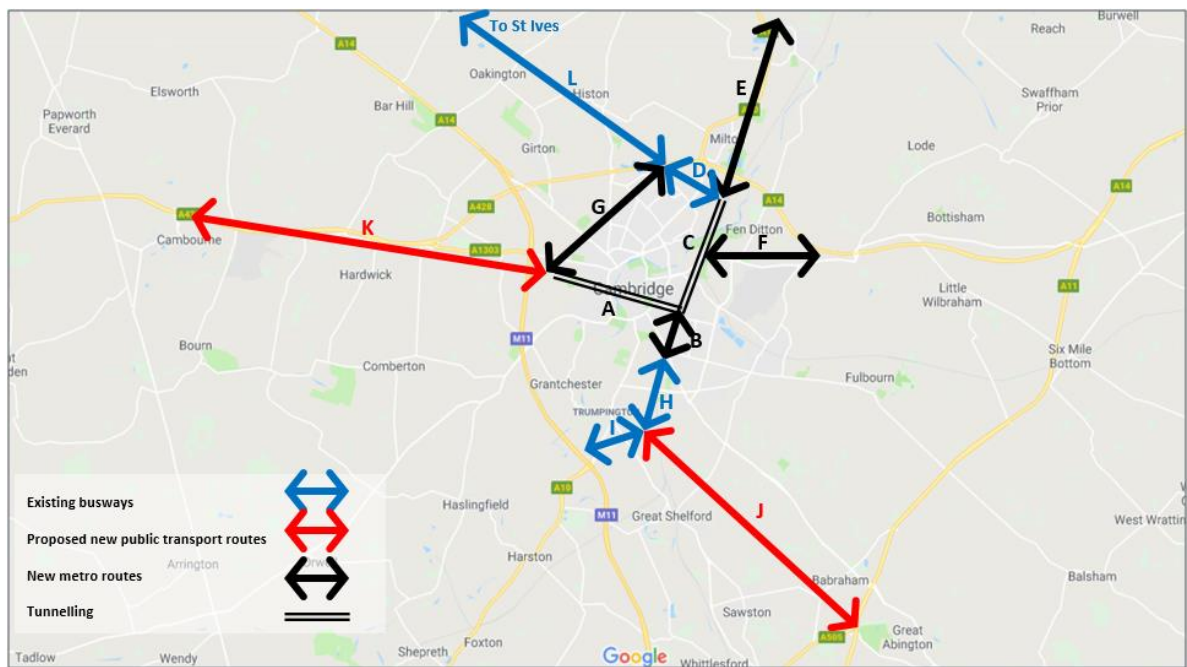


## Infrastructure

- 7.25 The infrastructure requirement reflects what would need to be implemented to deliver the segregated alignments (and hence journey time reliability and cross-city connectivity) for CAM. We have not undertaken detailed feasibility or design work, so there are some elements of the newly required segregated infrastructure which could either be implemented at-grade or, if required, in tunnel. The cost range estimates for CAM reflect this uncertainty at this stage.
- 7.26 Development of the route alignment is at an early stage, and hence should be considered **indicative** only. It consists of:
- Up to 6km of tunnel in the City Centre, where physical constraints are greatest, connecting the West Cambridge Site to Mill Road, from Mill Road to Cambridge North, and potentially towards Newmarket Road;
  - Direct services connecting to the routes currently served by the Cambridge Guided Busway, with future services operating to Trumpington, the Cambridge Biomedical Campus, the Cambridge Science Park, Orchard Park / Histon Rd, Northstowe and St Ives;
  - New services utilising the proposed segregated ‘public transport spine’ planned between Maddingley Road and Histon Road as part of the North-West Cambridge and Darwin Green developments;
  - New services extending to Cambourne and St Neots in the west, Waterbeach Barracks in the north, Newmarket and Cambridge Airport in the east and Haverhill in the south-east, using a mixture of segregated and shared running, including along the routes of the proposed busway infrastructure planned for the first two of these corridors<sup>20</sup>
    - Such infrastructure could be developed *incrementally*, in line with demand and future housing development;
  - Integration with the existing and proposed network of Park-and-Ride sites surrounding Cambridge, with services replacing existing P&R bus services to the City Centre; and
  - Expansion and / or relocation of the existing Park-and-Ride sites surrounding Cambridge, with transit services linking directly to P&R sites.
- 7.27 Overall, the system would involve 49km of new/ proposed infrastructure (shown in black and red in Figure 7.8) which would combine with existing segregate infrastructure (shown in blue) to provide an overall segregated network of 75km. Each stop would also be equipped with a shelter, real time information and step-free access, in a similar respect to LRT. No overhead line infrastructure would be required. The infrastructure elements are shown, schematically, in Figure 7.8.

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<sup>20</sup> Proposals of the Cambridge to Cambourne busway have recently been subject to public consultation. A report on the A10 Corridor, including a public transport link to Waterbeach, has recently been published (January 2018).

**Figure 7.8 CAM Segregated Infrastructure**

## Operations

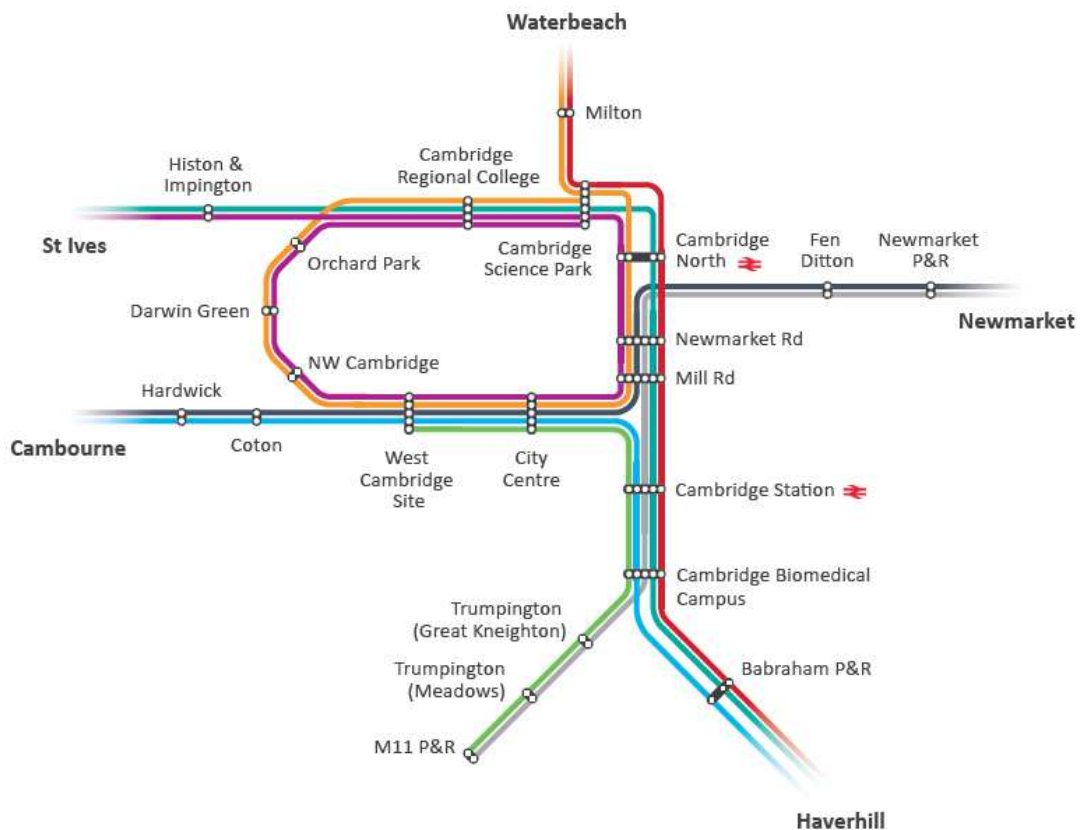
- 7.28 CAM would operate services at high frequencies across multiple routes, aiming to maximise direct connectivity to each of the key destinations identified in Chapter 3 without the requirement to interchange. Considering the smaller capacity of CAM vehicles relative to LRT, it is expected that it would provide more frequent services (especially in the peak) compared to LRT.
- 7.29 This system would operate with stops throughout the city. If predicated on one vehicle in each direction on each line every five minutes, one vehicle would enter a tunnel every minute on the busiest part of the network. This is feasible using existing technology; platooning and vehicle-to-vehicle technology would allow far greater capacities. Five minutes is also a headway allowing for ‘turn up and go’ services able to encourage mode shift away from the car.



## Network

- 7.30 The vehicles' ability to travel on road as well as on segregated infrastructure allows almost limitless opportunities for a network, without the requirement for additional infrastructure. This flexibility is particularly useful when determining routes on the outskirts of the core network, and in the ability to reconfigure services over time to respond to changing pattern of demand. However, to maintain reliability as much of the route as possible should be segregated, particularly in the city centre. Figure 7.9 illustrates a possible network, utilising the existing busway to St Ives and Addenbrookes, running alongside the railway from Cambridge North to Cambridge station and through a tunnel in the city centre.

Figure 7.9 Illustrative Network Concept for CAM



## Costs

- 7.31 The concept of CAM is to make the best use of existing segregated infrastructure and proposed public transport corridors in Greater Cambridge to create a network which serves broadly the same geography as the Cambridge Connect 'city' variant. With the assumption that CAM vehicles can operate on a surface akin to planned segregated public transport routes, the base network costs are extrapolated from an average cost per kilometre for the five Cambourne to Cambridge busway options.
- 7.32 It is difficult to estimate costs without fixed routes and service patterns, which are more flexible than solutions with fixed infrastructure such as the other shortlisted options. We have estimated costs based on providing the same service coverage as the LRT City network.
- 7.33 As with the other shortlisted concepts, the CAM capital costs include a 15% design and project management cost and a 64% optimism bias, shown in Table 7.4.

**Table 7.4: CAM Capital Costs**

Component	CAM Network (£m)
At-grade segregated public transport costs	297
Vehicle costs	189
Stations (in tunnel)	424
Tunnelling	537 - 797
<b>Total</b>	<b>1,460 - 1,720</b> (Dependent on level of tunnelling required)

## Summary

- 7.34 Table 7.5 summarises the three shortlisted modes.

**Table 7.5: Summary of Shortlisted Options**

	LRT City Network	LRT Regional Network	AVRT City Network	AVRT Regional Network	CAM Network
Infrastructure (km)	42	90	15	49km new (75km including existing segregated infrastructure)	49
Tunnelling (km)	6.4	6.4	15	15	Up to 6.4
Service coverage (km)	42	90	15	75	90
Indicative service frequency	6 minutes	6 minutes	3 minutes	3 minutes	5 minutes
Capacity per vehicle	100-300	100-300	40	40	100-300
Capital costs	£2,770m	£4,490m	£1,130m - £1,740m	£2,090m	£1,460m - £1,720m

Notes: AVRT range estimate reflects costs of single-bore tunnels, or twin-bore. LRT and CAM costed based on twin-bore tunnels. CAM cost range reflects potential length of tunnelling infrastructure required.



## 8 Strategic Options Assessment

### Introduction

- 8.1 This chapter assesses each shortlisted option against a set of criteria within an overall Strategic Options Assessment Framework (OAF) framework, as summarised in Table 8.1 overleaf. The strategic options assessment sought to address two key questions. First, to what extent does the option deliver against the key requirements identified for a mass transit system in Greater Cambridge. Second, is the option viable in terms of value for money and affordability, and deliverable.
- 8.2 Our approach to assessment reflects Department for Transport WebTAG guidance, in line with that recommended for an early stage study, and our experience developing numerous comparable transport projects elsewhere in the United Kingdom. It assumes that scheme funding would be delivered largely through established funding mechanisms, including a significant contribution from Central Government, together with local contributions. Alternative funding solutions are discussed later in the report.
- 8.3 Population and employment growth has been assumed to reflect that set out within the Cambridge and South Cambridgeshire Local Plans for the purposes of assessing and comparing scheme options. However, all options have been developed to provide the planning capacity to support large-scale growth such as that proposed by the NIC in the longer term.

**Table 8.1: Option Assessment Framework**

Criteria	Sub-criteria / Description	Basis for assessment
<b>Costs</b>	<p>Capital costs:</p> <ul style="list-style-type: none"> <li>Capital costs represent the total cost to implement the scheme, and include infrastructure, vehicles, land, and scheme development / promoter costs.</li> </ul> <p>Operating costs:</p> <ul style="list-style-type: none"> <li>Operating costs represent the ongoing costs to operate the system, including infrastructure renewal, staff costs and operational overheads.</li> </ul>	<ul style="list-style-type: none"> <li>Cost estimates prepared based on a review of Promoter costs and a high-level cost estimate, prepared by SDG based on 'unit rate' approach.</li> </ul>
<b>Transport outputs and benefits</b>	<p>How well does the option deliver key transport outputs and benefits that, in turn, support the wider growth ambitions of the region. Benefits assessed in terms of:</p> <ul style="list-style-type: none"> <li>Network coverage</li> <li>Coverage (spatial coverage of services)</li> <li>Route flexibility</li> <li>Frequency</li> <li>Quality</li> <li>Journey times</li> <li>Reliability</li> <li>Interchange (minimised)</li> <li>Accessibility (no. stops served)</li> </ul>	<ul style="list-style-type: none"> <li>Qualitative assessment of individual criteria</li> <li>Qualitative assessment of overall benefits</li> </ul>
<b>Demand Potential / Scenarios</b>	<p>What is the demand potential of the options, informed by?</p> <ul style="list-style-type: none"> <li>Demand benchmarking</li> <li>Demand scenarios</li> </ul>	<ul style="list-style-type: none"> <li>Qualitative description of demand potential</li> </ul>
<b>Affordability / Value for Money</b>	<p>Which option is likely to perform best in value for money terms?</p> <p>What is the value for money potential of each option?</p> <ul style="list-style-type: none"> <li>Is the option likely to financially sustainable – i.e. are revenues likely to cover operating cost, or might the option require an ongoing subsidy?</li> </ul>	<ul style="list-style-type: none"> <li>Qualitative assessment informed by costs and benefits</li> </ul>
<b>Deliverability</b>	<p>Risk based approach to identifying potential risks that could represent a 'showstopper' risk for options. Deliverability risks considered are:</p> <ul style="list-style-type: none"> <li>Technical Feasibility</li> <li>Technology</li> <li>Value for Money</li> <li>Affordability</li> <li>Powers / consents / legislation</li> <li>Stakeholder / public acceptability</li> </ul>	<ul style="list-style-type: none"> <li>Qualitative assessment based on delivery risk</li> </ul>

## Environmental and Heritage Considerations

- 8.4 The shortlisted options are all at the concept stage of development, with an insufficient level of alignment development to make a meaningful assessment of specific impacts on environmental criteria such as air quality, noise, townscape, heritage and ecology.
- 8.5 For whichever mass transit option was taken forward, there would need to be significant further work to identify, scope and assess impacts, and then to either avoid or mitigate impacts that are assessed to be potentially significant. This process would involve engagement and consultation with local stakeholders (for example Cambridge Past, Present and Future) and statutory consultees (e.g. Natural England, Environment Agency).
- 8.6 Though specific impacts cannot be assessed at this stage, it is possible to identify some high-level impacts that are common to all options. These include:
- That **tunnelling is a common element to all proposals**. The rationale for tunnelling reflects the constraints in the city centre that are largely related to Cambridge's historic core. Also, from a heritage perspective there are not viable or acceptable solutions that would permit, additional capacity to be provided through the city centre at-grade. The imperative of protecting Cambridge's heritage is therefore an underlying rationale for the consideration of a tunnelled solution.
  - There will be **significant potential local environmental impacts associated with the construction of the tunnel and underground stations**. At a general level, the scale of impacts from tunnelling will reflect the length of new tunnelled infrastructure required to support a mass transit system. Site-specific impacts would need to be identified and mitigated through planning and design. Environmental considerations will be a key consideration in informing specific decisions on the location of tunnel portals and underground stations. Heritage impacts (impacts on historic buildings and their setting) will also be a key consideration.
  - **All options would be zero-emission at the point of use**, and therefore have no impact on local air quality. Tyre-based metro options (AVRT and CAM) would have greater particulate impacts (from the interface between tyres and the tarmac surface) than rail-based options (LRT).
  - **All options would deliver reductions in car-borne emissions** (local emissions and greenhouse gases) through modal shift. More localised impacts (air quality and noise at specific locations) would need to be assessed in more detail as part of the scheme development stage.
- 8.7 In summary, therefore, environmental considerations have not been assessed for the purposes of comparative assessment, due the concept level of scheme definition at this stage. However, environmental and heritage considerations will be a key consideration in the further design and development of whichever option is taken forward.

## General Assumptions

- 8.8 Any mass transit solution will inevitably be focused on higher demand corridors, and/or those that can support significant new housing development. However, to ensure the benefits of any mass transit system are maximised, it will be necessary to develop a range of complementary initiatives that extends the effective reach and catchment of mass transit, including:
- Strategic Park-and-Ride sites to capture car trips;
  - Local access improvements (e.g. walking and cycling improvements, fixed-route or ‘on-demand’ connecting bus services);
  - Integrated, multi-modal and multi-operator ticketing; and
  - Consistent real-time information systems, covering all modes.
- 8.9 Reflecting the early stage of this study, we have not defined *specific* measures associated with each scheme option. Rather, it is assumed that these supporting measures would be planned and implemented alongside *any* mass transit solution. The ‘in-scope’ demand and demand potential for each option are hence considered in this broader context.
- 8.10 We identify potential complementary measures in Chapter 9 – Recommendations.

## Option Costs

- 8.11 The overall capital costs for each shortlisted scheme options are presented in Table 8.1.
- 8.12 The table identifies the cost of the infrastructure elements associated with each option, and the area of service coverage that the infrastructure would support.
- 8.13 The cost driver of LRT and AVRT is related to the provision of bespoke new infrastructure over the entire length of the new infrastructure over which services would operate. By contrast, CAM would make use of existing (and planned) infrastructure which provides for segregated routing.
- 8.14 For CAM, the costs used in this assessment include the costs of both planned / proposed infrastructure (such as the Cambourne to Cambridge link, and link to Waterbeach), as well as the additional ‘new’ infrastructure we have identified that would be required to complete the development of a segregated CAM network within and beyond the city. This ensures that all options are assessed on a ‘like for like’ basis, in that they include the full costs of providing the required segregation and connectivity for a mass transit solution.

**Table 8.2: Shortlisted Mass Transit Options - Capital Cost**

Option	Description	Capital Cost (indicative)
LRT City Network	<ul style="list-style-type: none"> <li>42km network, with fixed track infrastructure</li> <li>Based on Cambridge Connect</li> <li>Corridors served via P&amp;R and bus feeders</li> </ul>	£2.8bn
LRT Regional Network	<ul style="list-style-type: none"> <li>90km network, with fixed track infrastructure</li> <li>Based on Cambridge Connect proposal</li> <li>Direct services to hinterland locations</li> </ul>	£4.5bn
AVRT City Network	<ul style="list-style-type: none"> <li>15km network, entirely new infrastructure</li> <li>Based on John Miles proposal</li> <li>Single or twin-bore tunnel options</li> <li>Corridors served via P&amp;R and bus feeders</li> </ul>	£1.1 - £1.7bn (Dependent on single or twin-bore)
AVRT Regional Network	<ul style="list-style-type: none"> <li>56km network, entirely new infrastructure</li> <li>Based on John Miles proposal</li> <li>Twin-bore option to provide required capacity</li> <li>Direct services to hinterland locations</li> </ul>	£2.1bn
Cambridgeshire Autonomous Metro (CAM) – Regional Network	<ul style="list-style-type: none"> <li>49km new infrastructure, including 24km of new segregated infrastructure in Cambridge (including up to 6km tunnel), and 25km of planned / proposed segregated links</li> <li>Provides a 75km segregated network through the use of existing segregated infrastructure (such as Cambridge North &lt;-&gt; St Ives)</li> <li>Direct services to hinterland locations</li> <li>Greater flexibility to serve regional destinations through shared running (e.g. to Haverhill or St Neots) if required, extending network to 90km +</li> </ul>	£1.5 - £1.7bn (Dependent on level of tunnelling required)

## Transport Outputs & Benefits

- 8.15 Transport outputs relate to the properties that each option delivers ‘on the ground’, such as capacity (to accommodate demand), connectivity (linkages and journey times between key locations) and accessibility (access to the transport network). These characteristics determine the overall ‘attractiveness’ of the system (and hence the level of demand), and are in turn based on the overall coverage, frequency, quality of service, degree of interchange, reliability and journey times offered by the mass transit system in question.
- 8.16 These individual facets, or attributes, of a journey are what is measured and valued within transport modelling and the economic appraisal of transport schemes. The greater the transport improvements delivered by an option, the greater the level of benefits (each ‘existing’ transport user benefits by more time) and demand (the greater the benefits, the more additional users are attracted to an option).
- 8.17 The assessment of transport outputs and benefits therefore helps inform:
- How well an option delivers the core requirements of a Mass Transit solution for Cambridge, by enhancing public transport capacity, connectivity and accessibility; and
  - The level of benefits that an option is likely to deliver which, in turn, informs the overall value for money performance of the option.

## Transport Benefits

- 8.18 We have assessed each option against the criteria set out in Table 8.2. The assessment of each option against these criteria is presented in Table 8.3. The assessment is comparative in nature, intended to show which options perform better in relative terms.

**Table 8.3: Benefit Assessment Framework**

Output / benefit / journey attribute	Description
Network coverage	What is the spatial coverage of direct services provided by each option?
Route flexibility	Does the option offer route flexibility? e.g. <ul style="list-style-type: none"> <li>to directly serve more locations (e.g. smaller centres)</li> <li>to serve areas of future growth</li> </ul>
Frequency	How frequently is a service likely to operate?
Quality	What is the quality provided by the mode? This is less tangible, but typically modes that are rail-based (e.g. LRT) are deemed to provide a better 'quality' of service than, for example, buses. A portion of this 'quality' attribute reflects the improved ride quality and modern 'image' of trams. Other elements may reflect measurable 'attributes' above (e.g. LRT often offers better journey time reliability, though this is a function of its segregation rather than an intrinsic modal 'quality'.
Journey time (in-vehicle) and journey time reliability	How fast are services likely to be? How reliable are services likely to be under each option?
Interchange (minimised)	What is the level of interchange that is likely to be required under each option? i.e.: <ul style="list-style-type: none"> <li>Where direct services cannot be provided there will be a requirement to interchange for key movements.</li> </ul>
Accessibility (no. stops served)	How well does the option serve locations on its route? <ul style="list-style-type: none"> <li>This assesses whether the stop-spacing provides good accessibility to people/destinations on the route.</li> </ul>



Table 8.4: Assessment of Transport Benefits

	LRT - City	LRT - Regional	AVRT - City	AVRT - Regional	CAM	Comment
Network coverage	✓✓	✓✓✓	✓	✓✓	✓✓✓✓	<ul style="list-style-type: none"> <li>CAM offers widest potential service coverage, across all radial corridors.</li> <li>LRT city network provides good coverage, but only within the city area.</li> <li>LRT regional network would serve radial corridors, but not those to the north (e.g. Huntingdon / Waterbeach), where interchange would be required with existing / proposed bus services.</li> <li>AVRT would serve four radial corridors &amp; AVRT city network coverage is more limited than other options.</li> </ul>
Route flexibility	✓✓	✓✓	✓	✓	✓✓✓	<ul style="list-style-type: none"> <li>CAM provides for greater route flexibility through its ability to operate on existing segregated and on-street infrastructure.</li> <li>LRT and AVRT networks could be developed incrementally, but network expansion would incur significant capital costs and higher deliverability risk than the more limited infrastructure required for CAM. In absence of bespoke fixed infrastructure bus feeder services could link to LRT and AVRT hubs.</li> </ul>
Frequency	✓✓	✓✓	✓✓✓	✓✓✓	✓✓	<ul style="list-style-type: none"> <li>All options would operate at an attractive service level: <ul style="list-style-type: none"> <li>AVRT would operate at highest frequency of options to serve expected demand, as the vehicle capacity is lower.</li> <li>Higher capacity of LRT means that fewer vehicles per hour likely to operate compared to CAM.</li> </ul> </li> </ul>
Journey time / reliability (in-vehicle)	✓✓	✓✓	✓✓✓✓	✓✓✓✓	✓✓	<p>All options would provide attractive journey times, due to segregation of key sections of route from general traffic.</p> <ul style="list-style-type: none"> <li>AVRT is fully segregated and would have a faster in-vehicle time.</li> <li>Through segregation LRT and CAM would both offer faster journey times, and significantly greater journey time reliability, over current provision.</li> </ul>
Interchange (minimised)	✓✓	✓✓✓	✓	✓	✓✓✓✓	<p>Interchange is unattractive from a user perspective.</p> <ul style="list-style-type: none"> <li>CAM would provide the greatest opportunity for direct services, to and across the city, both due to a more expansive network and smaller vehicle sizes.</li> <li>LRT would provide direct access to the city centre and for some cross-city movements. The LRT city network would require interchange from 'feeder' corridors.</li> <li>AVRT involved potentially multiple interchanges for some movements (any that are directly between the two stations at either end of each tunnel)</li> </ul>
Accessibility (no. stops served)	✓✓	✓✓	✓	✓	✓✓	<ul style="list-style-type: none"> <li>AVRT offers comparatively poor overall direct accessibility, and the network within the urban area comprises only one city centre station and four on the city periphery.</li> <li>Other options provide better levels of accessibility.</li> </ul>
Quality	✓✓✓✓	✓✓✓✓	✓✓	✓✓	✓✓✓	<ul style="list-style-type: none"> <li>LRT would, likely, offer a more attractive ride quality than the other modes.</li> <li>CAM would provide a higher quality offer than existing bus provision, through a higher quality vehicle, stops and information provision.</li> <li>AVRT quality is uncertain – it would operate at very high speed and this may compromise passenger comfort.</li> </ul>

## Interpretation

- 8.28 The scores that underpin the comparative assessment cannot be ‘summed’ to show the best option, as each attribute cannot be considered to be equivalent in importance. However, the analysis does show where there are key trade-offs between options, and can be used to infer the overall scale of benefits likely to be delivered by each option:
- LRT options would deliver significant transport benefits, and would, as a rail based mode, probably provide the best ride quality of the modal options considered. While the frequency (especially off-peak) is likely to be lower than for other modes due to the requirement to balance capacity while operating larger vehicles, LRT would still operate at an attractive service frequency (at least every 10 mins). The requirement for interchange (for the ‘city’ network) and inability to provide route flexibility can each be mitigated through the provision of complementary services and infrastructure, such as bus feeders and P&R sites. However, interchange is perceived as unattractive from a user perspective.
  - AVRT provides the fastest in-vehicle journey times, though this is counterbalanced by the requirement for interchange for the majority of movements, and multiple interchange for cross-city movements. Given the relatively short distances over which AVRT would have a journey time advantage, any actual time benefit over LRT and CAM would be modest. The findings from the stakeholder engagement suggested that journey time reliability was the key issue for mass transit to address, rather than speed per se. AVRT would also not provide route flexibility, though this could again be mitigated as for LRT. The quality of AVRT is uncertain, given the speeds at which AVRT would seek to operate at.
  - CAM would provide a strong performance against the range of key transport benefit areas. It would provide a segregated and high frequency service, combined with wide route coverage, flexibility and accessibility (maximising overall connectivity). It performs as well, or better than, LRT across the range of attributes considered. The key issue for CAM would be its ability to deliver sufficiently high-quality that, from a user perspective, would make the mode attractive as an alternative to car. While this quality is intrinsic to LRT (as a generic mode), the specification of CAM in terms of vehicle quality, stop quality and segregated running would need to ensure that a level of quality equivalent to LRT was provided. The CAM option has been specified to deliver this quality, as described in Chapter 7.

## Demand Potential

- 8.29 The demand potential for Mass Transit is linked to the overall attractiveness of the mode, based on the range of transport characteristics described above. The overall attractiveness informs both the demand potential, and the valuation of benefits<sup>21</sup> that are used to demonstrate the value for money for major transport investments.

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<sup>21</sup> Transport benefits are based on ‘monetised’ improvements in generalised journey time as a result of an improvement. Generalised journey time is a concept that captures all facets of a journey (walking to a stop, waiting, in-vehicle time, fare, interchange time) and also ascribes ‘weightings’ (or penalties) to journey elements that passengers typically find unattractive – such as interchange, or time spent waiting for services.

- 8.30 As part of this study, we have not undertaken detailed demand modelling, and have not therefore produced *forecasts* (predictions based on transport models) of the demand for each mode and mode variant, which would need to be undertaken as a subsequent stage. However, based on an assessment of the transport outputs above, we consider that LRT and CAM have the potential to deliver greater benefits, and therefore attract more demand, than AVRT. We would expect that both LRT and CAM would attract a similar proportion of current and future demand along any given corridor, assuming they serve the same key destinations, although the level of overall demand would inevitably be influenced by the overall coverage of the transit network.
- 8.31 Instead, we have undertaken separate high-level analyses by benchmarking of a potential Cambridge Mass Transit system against international and UK comparators. The focus of this is on LRT and tram systems<sup>22</sup>, to assess whether Cambridge and the wider area is likely to provide (now or in the future) the critical mass of demand to support such a network (and justify its costs). The extent to which each scheme option is likely to capture sufficient demand to represent value for money is discussed in the following section.

## Value for Money

### Context

- 8.32 Promoters of all major transport projects are required to demonstrate that the proposed scheme represents ‘value for money’, as estimated using Department for Transport WebTAG guidance.
- 8.33 Key to the value for money assessment is the ‘benefit cost ratio’, the ratio of the net welfare benefits of the scheme versus the cost to the public sector, and based on a standard approach to economic appraisal and valuing the benefits of transport investment. The Department for Transport provide a categorisation of a scheme’s Value for Money (VfM), based on the benefit cost ratio (BCR), as follows:
- Very High, if BCR is greater or equal to 4;
  - High, if BCR is between 2 and 4;
  - Medium, if BCR is between 1.5 and 2;
  - Low, if BCR is between 1 and 1.5;
  - Poor, if BCR is between 0 and 1; and
  - Very Poor, if BCR is less or equal to 0.
- 8.34 Traditionally, the expectation is that a project would typically need to achieve a benefit cost ratio of 2 or above to meet the DfT’s funding criteria.
- 8.35 The value for money and cost-benefit analysis essentially informs two key elements of the DfT’s approach to sifting and prioritising transport schemes:
- **Option selection** - when identifying a preferred option, the cost-benefit analysis and value for money assessment would be used to assess the relative performance of options that meet the core objectives of the scheme (in this case to improve accessibility and support planned growth within Cambridge). The preferred scheme would need to meet the core objectives for the scheme. Where more than one options meet these objectives, a VfM

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<sup>22</sup> There are no systems that are directly comparable with AVRT or CAM.

(measured by the BCR) assessment shows which option delivers these objectives in the most cost-effective way.

- **Preferred Scheme Appraisal** – demonstrating the value for money of the preferred option, with the preferred option (from the option selection process) undergoing further development towards the preparation of an Outline and Full Business Case to demonstrate it represents an affordable intervention which meets the scheme objectives. The economic analysis within the business case would support the overall VfM assessment, and determine whether the scheme would be likely to receive DfT funding. To be eligible for funding, a project would be expected to deliver a BCR of 2 or more.

### Comparative VfM Assessment

- 8.36 There are essentially two fundamental drivers of the overall economic performance of major transport schemes such as Cambridge Mass Transit – firstly *the capital cost of the scheme*, and secondly *the overall magnitude of ‘user benefits’* in the form of time savings to existing and future public transport and highway users (through reduced highway congestion).
- 8.37 In terms of demand and benefits our assessment is that CAM and LRT would broadly deliver a similar order of demand and benefits, and at a higher level than AVRT.
- 8.38 However, the capital costs of the CAM are estimated (at up to £1.7 billion) to be 62% of the LRT ‘city’ network cost and only 38% of the LRT ‘regional’ network cost. This therefore suggests that CAM can deliver equivalent benefits to LRT at substantially lower costs, and therefore represents better value for money in comparative terms.
- 8.39 Our assessment is that CAM would deliver higher demand and benefits than AVRT, and would better meet the core requirements and objectives of a mass transit system in Greater Cambridge. In value for money terms, CAM would deliver these greater benefits at a similar cost to the AVRT ‘city’ network (comprising 5 stops), and around 80% of the cost of the AVRT ‘regional’ network. The comparative assessment is therefore that CAM would deliver greater benefits at lower cost than AVRT, and hence deliver a better comparative VfM performance.
- 8.40 In comparative assessment implies that the benefits for either LRT or AVRT would need to be orders of magnitude greater to deliver a better cost-benefit ratio than CAM. The assessment of the transport outputs and benefits presented earlier in this section suggests that, overall, CAM could deliver overall transport benefits of a similar order to those of LRT and greater than that of AVRT. While there clearly some uncertainty about the relative scale of benefits that could be delivered by CAM versus LRT our judgement is that LRT would not, under any plausible scenario, deliver a scale of benefits that would counterbalance the significantly higher costs of LRT.
- 8.41 Whilst it is not possible at this early stage to state definitively that the CAM option would deliver value for money (based on meeting thresholds based on current DfT guidance) we conclude that of the options assessed, CAM is the only one with a realistic prospect of achieving value for money. Therefore, on a comparative basis, our assessment is that CAM would deliver significantly better value for money than LRT or AVRT.

### Absolute VfM Assessment – by option

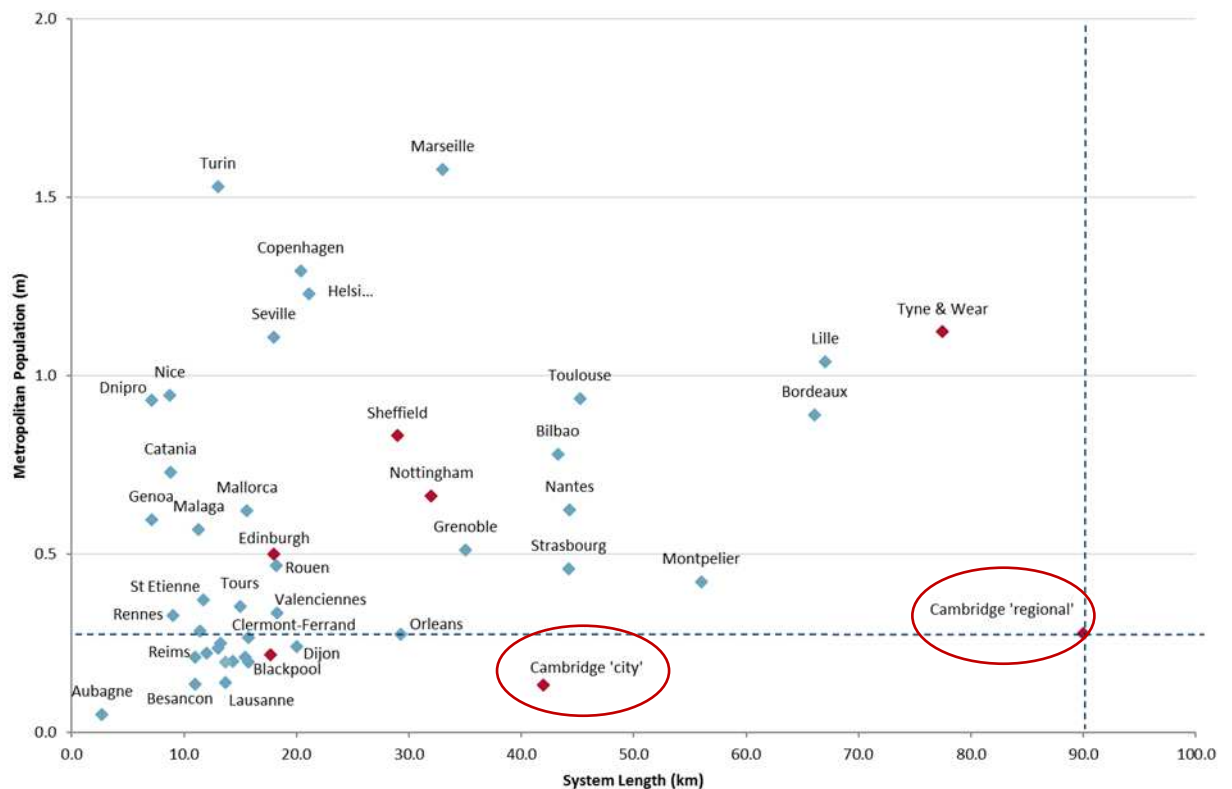
- 8.42 While CAM appears to represent better value for money than LRT or AVRT, a further consideration is whether any option is likely, in *absolute terms*, to deliver value for money. Clearly, there could be an argument for progressing a more expensive option (e.g. LRT) if it were deemed to deliver better against wider objectives, even if it performed less well in

economic or VfM terms. Any option would still need to deliver a positive benefit-cost ratio (probably of greater than 2) to be deliverable under current DfT funding criteria.

#### VfM Assessment - LRT

- 8.43 Whereas LRT clearly does have the potential to deliver significant transport improvements, several considerations present significant doubts over whether any LRT scheme within Cambridge could deliver a positive BCR, and hence be deliverable. Fundamentally, the smaller geography of Cambridge – with a lower transit catchment and population density than other UK cities with LRT or metro systems – raises a question of whether the scale of benefits would be commensurate with that required to deliver a positive benefit-cost ratio.
- 8.44 Successful LRT networks are typically located within larger cities and conurbations, where routes link orbital corridors to large city centres. Figure 8.2 illustrates the population of various metropolitan areas<sup>23</sup> against the length of their respective LRT systems, with UK cities marked in red. Cambridge is shown assuming a ‘city’ LRT network (against the population of Cambridge city *only*) and a 90km ‘regional’ LRT network (against the population of Cambridge and South Cambridgeshire combined).

Figure 8.1: LRT System Size vs. City Population



<sup>23</sup> British metropolitan areas are based on the Centre for Cities 'Built Up Area' definition, French cities 'l'aire urbaine' (effectively continuous built-up area) and others the United Nations 'world urban areas' definition.

#### 8.45 This analysis raises several insights:

- Generally, the smaller the city's population the smaller their LRT network. Larger LRT systems, greater than 35km in length, are exclusively found in metropolitan areas with at least 400,000 people, significantly greater than the population of both Cambridge and South Cambridgeshire, which extends over significantly larger geography than the Cambridge metropolitan area.
- Any 'city' LRT system with a geographic extent comparable to the Cambridge Connect 'city' scheme would therefore be amongst the largest for a metropolitan area of comparable size in Europe.
  - Only three European cities - Aubagne, Lausanne and Besancon – that are similar or smaller in population than Cambridge have LRT networks; each of these is less than 15km in length, with the former a 2.7 km line which operates free-of-charge to all users (together with the rest of the local public transport system)
- Any 'regional' LRT network, at approximately 90km in length, would be amongst the longest LRT networks in the world, despite only serving a population (at most) of 288,000 people within Cambridge and South Cambridgeshire, significantly less than most metropolitan areas served by LRT systems.
  - Even if the population of Greater Cambridge increased significantly, such as an increase of 150,000 people or more than 50%, a 'regional' LRT network would still benchmark very poorly against other large LRT systems elsewhere;
  - Nowhere globally has a LRT system of equivalent length serving a medium-sized city and its wider hinterland, and it is difficult to envisage a plausible development scenario that would justify the development of such a network.
- Additionally, our assessment of the in-scope population catchment of the 42km Cambridge 'city' LRT network suggests that approximately 60,000 people would be within 500m of a stop, 45% lower than the average of all UK LRT systems, despite a total network length 21% longer.
  - A 'regional' LRT network would significantly increase the length of the system while further lowering the population per station, especially considering that many settlements served within the corridors are predominately low-density (such as Cambourne) in nature. This would further worsen the likely viability and value for money of the network.

#### 8.46 Based on the above, it is unlikely in our view that patronage on a Cambridge LRT network (either 'city' or 'regional') will be sufficient to generate the magnitude of benefits required to represent value for money. Moreover, the inclusion of tunnelling infrastructure within any Cambridge LRT network would, other things being equal, make the costs of implementing LRT in Cambridge significantly greater (in proportional terms) than other UK systems, which are predominantly on-street. At an intuitive level, this therefore suggests that it may be difficult to achieve a sufficiently strong BCR to justify a Cambridge LRT network.

#### 8.47 Additionally, when considering the development of potential phases of the network, additional value for money challenges arise:

- On a route from Cambridge Station to Trumpington and Addenbrookes (a key aspect of any Cambridge LRT network) the time savings that could be achieved would be modest, given that the Guided Busway currently operates on a segregated route along the same corridor. The economic analysis would need to compare LRT journey times with those under a 'Do Minimum' (i.e. guided bus) and, if the journey time improvements were



modest, the corresponding benefits would be correspondingly low. The benefits along this section would therefore be unlikely to justify the costs of providing LRT on this section on a 'stand-alone' basis. This would also weaken the case for a route extending this route to Granta Park / Haverhill;

- Similarly, on the section from the City Centre to Cambridge North / Science Park, the benefits of faster journey times on this tunnelled section would be offset by the requirement for users travelling from the St Ives / Huntingdon or Waterbeach / Ely corridors to interchange between other public transport modes (guided bus or rail) and LRT. Again, this would erode the potential scale of benefits that would need to offset the costs of tunnelling on this section.

- 8.48 Overall, there is therefore a significant risk over whether any LRT solution has the potential to meet the value for money criteria that would be a pre-requisite for public sector funding. It is highly unlikely in our view that any Cambridge LRT scheme would achieve VfM based on current guidance and funding criteria.

*VfM Assessment – AVRT*

- 8.49 Similarly to LRT, several aspects of the Cambridge AVRT are likely to make it very challenging to achieve VfM. Considering the capital costs of AVRT, combined with the smaller geography and lower population density of Cambridge and the more limited coverage of the AVRT network, it is unlikely that the magnitude of benefits would be greater than the costs of AVRT required to achieve a positive benefit-cost ratio.
- 8.50 While the journey time savings for passengers travelling between points well-served by the AVRT network would be greater than that for LRT or CAM (due to the limited-stop, high speed services), overall (as discussed in Table 7.3) the transport benefits of the scheme would be less than LRT or CAM, due to the limited number of stops and the reliance on interchange for many journeys. For example, the DfT's WebTAG guidance suggests that the poor passenger perception of interchange is equivalent to a time penalty of 5 to 10 minutes, and would be valued as such within any appraisal of the scheme. These considerations mean that it would be extremely challenging to achieve a benefit-cost ratio required to justify the scheme.
- 8.51 Again, our view is that given the costs of AVRT it is highly unlikely that the benefits would deliver a VfM based on current guidance and funding criteria. In any event, we view the potential demand and benefits of AVRT to be materially lower than that of CAM (substantially so for the AVRT 'city' network, with only 5 stops), but at a similar (for the AVRT 'city' network) or much greater (for the AVRT 'regional' network) cost.

*VfM Assessment – CAM*

- 8.52 It is not possible at this early stage to state definitively that the CAM 'regional' network concept would deliver value for money, due to the uncertainty in the volume of CAM demand and the journey time savings it would deliver. However, several criteria point towards this option being the most likely to both meet the objectives for a mass transit network in Cambridge, and achieve value for money.
- 8.53 Notably, the lower capital costs of the CAM network, largely delivered through utilising existing segregated infrastructure, and seeking to minimise the length of tunnelled infrastructure, mean that it can attract significant demand and deliver an integrated network offering direct connectivity to, and across, the city centre, at a significantly lower cost than other options. Key to the level of value for money is whether the benefits, in the form of time

savings and mode shift (decongestion), are sufficient to justify the high expenditure on tunnelled infrastructure in the city centre which is critical to the CAM concept.

- 8.54 Several factors point towards a city centre tunnel potentially being able to achieve value for money as part of a wider CAM network:
- Any tunnel would deliver significant journey savings for trips both *to* the City Centre (e.g. Cambourne to Market Square), but especially for trips *across* the City Centre (e.g. Camborne to Cambridge Biomedical Campus). These are currently poorly served by public transport, often requiring interchange, and likely to become increasing common with employment growth at ‘fringe’ sites. These trips could achieve time savings of more than 20 minutes, and attract significant modal shift;
  - Since the tunnel the key ‘link’ within the CAM network, it is likely to be used by a high volume of trips serving an extensive range of origins and destinations, and each experiencing a significant time saving; and
  - It provides a fully segregated alignment through the most congested part of Cambridge, delivering significant reliability benefits, that no other alignment could realistically achieve.
- 8.55 Illustratively, if five million trips per annum used the tunnel, with each saving an average of 10 minutes per person, this could yield journey time benefits worth £300 to £400 million across a 60-year appraisal period. Moreover, factors such as avoided interchange, improved journey time reliability and enhanced journey quality can also be valued within the core economic appraisal, and are likely to represent significant additional benefits which would apply to all users (tunnel and non-tunnel). Wider economic impacts, such as increased agglomeration, could also be considered, which considering the high-skill, high-value nature of Cambridge employment, would be highly significant. Therefore, the illustrative benefits do suggest that there is the potential for benefits to outweigh the costs of tunnelling.
- 8.56 Careful consideration would also need to be given to the ‘Do Minimum’ scenario of the future without a rapid transit network – and how Cambridge’s transport network would operate, given the scale of planned growth in the absence of a tunnelled solution. Given the critical role of the capacity and connectivity delivered by the tunnel in supporting future growth, a relevant question is whether – in the absence of any other new strategic infrastructure – future growth could take place at the same level, and if not what the economic cost to the Cambridge and national economy would be.
- 8.57 Illustratively, if only 1% of the 44,000 planned jobs to 2031 did not come forward, the equivalent ‘loss’ in Gross Value Added would be around £26 million per annum (Cambridge’s average GVA per worker is currently approximately £60,000 per year), or over £500 million in present value terms over a 60-year appraisal period. While the national GVA impact captured within the appraisal would likely be less, since a proportion of these jobs would be displaced from elsewhere in the region or the UK, this benefit would be over and above that captured through time savings, reliability and connectivity outlined above.
- 8.58 Further substantive work would be required to assess the tunnel length, alignment, costs and whether segregation could be provided ‘at-grade’ for some sections where physically possible, to maximise the value for money of the overall scheme. The capital cost of underground stations would be significant, and the number and location of stations would require detailed consideration. These elements would be tested, refined and optimised through further

scheme development at Strategic Outline Business Case stage, and through further discussions with local stakeholders.

### **Ongoing affordability and financial sustainability**

- 8.59 Promoters of major transport projects are also required to demonstrate that their proposed scheme is *financially sustainable* in that they either operate without ongoing subsidy, or that any operating subsidy is fully locally funded (e.g. through a workplace parking levy). Schemes which would result in an ongoing cost to the *national* exchequer are rarely supported by Government, so any revenue shortfall would need to be met locally.

#### **LRT**

- 8.60 Considering the typical operating costs of UK LRT systems, and the level of demand that a Cambridge ‘city’ LRT network would generate compared to other UK LRT systems (as discussed under ‘demand potential’ earlier in this Chapter), it is unlikely that a Cambridge ‘city’ LRT network could operate without an ongoing subsidy. The 42km ‘Cambridge Connect’ ‘city’ network, for example, has a population catchment of 60,000 people within 500m of each stop – 45% lower than the average for a UK LRT network, despite a network 21% longer.
- 8.61 Since the majority of UK LRT systems operate with a subsidy (from either local or national government), it is highly unlikely that the levels of demand on a Cambridge LRT would be sufficient to avoid requiring an operating subsidy.
- 8.62 The Tyne-and-Wear Metro, for example, receives revenue support from the Government of £25 million annually for a 78km network, despite serving a conurbation of 1.1 million people. It supports 40 million journeys annually – considerably more than could realistically be expected for a Cambridge LRT – in an area by contrast with an established public transport market and comparatively low levels of active travel and car ownership. Any Cambridge ‘regional’ LRT network would be longer in length, yet serve a region with less than a quarter of the population of Tyne-and-Wear, and would hence be highly unlikely to operate without a significant ongoing subsidy.
- 8.63 LRT is significantly more expensive to operate, on a vehicle kilometre basis, than bus or BRT. While LRT can be more efficient operationally where it serves high-density, high-demand corridors, the demand potential in Cambridge, and the settlement pattern beyond the city, means that the cost of operation is not commensurate with the likely demand required to generate a revenue surplus.
- 8.64 Were a LRT system to be in operation in Cambridge, in our view it would require an ongoing subsidy which, under current Government transport policy, would need to be funded from local contributions and/or the scheme promoter.
- 8.65 We also assessed the potential value for money and affordability of LRT under a Transit-Oriented Development scenario – where new housing development would be focused on transit corridors. The key conclusion is that a transit-oriented development approach would not alter the fundamental conclusions about the ability of an LRT network serving Greater Cambridge to provide a value for money and affordable solution.

## AVRT

- 8.66 We have not considered the operating costs of a Cambridge AVRT system, reflecting the lack of certainty in the proposed technology. Whilst the AVRT concept has the potential to deliver lower operating costs than an LRT system – such as through driverless operation from the outset – there is significant uncertainty in the vehicle requirement, energy usage and required level of staffing, which together with the uncertainty in identifying the level of likely transit demand, means it is not possible to state whether the system would require an operating subsidy.

## CAM

- 8.67 Our view is that CAM is likely to operate at a surplus, due to the combined effects of:
- CAM has a lower unit rate operating cost. Whereas the operating cost per vehicle km for LRT is over £4 per km<sup>24</sup>, the equivalent for a high-quality high capacity BRT (akin to CAM) would be closer to £3 per km, which would reduce to closer to £2 per vehicle kilometre if it were to operate driverless.
    - It should be noted, however, that a similar cost reduction would be observed on other options which transitioned to autonomous operation;
  - At the likely levels of demand for a Cambridge metro system CAM would provide a more cost-effective way of meeting this demand;
  - The presence of segregation means that CAM can deliver faster and more reliable journey times, which makes it more attractive to users (generating revenues) and lowers operating costs;
  - CAM offers significantly greater flexibility to be able to scale the level of operations to meet anticipated demand, and align service levels (the key driver of operating cost) to transit demand (driver of revenue), due to the use of smaller vehicles than LRT. Hence:
    - In the shorter-term (and on lower-demand corridors in the longer term) CAM will provide a significantly more cost-effective service than LRT by better scaling transit demand with service provision;
    - CAM services retain greater flexibility to be scaled up to accommodate planned growth / growth in demand over time; and
    - Driverless operation better enables a more efficient service operation between peak and inter-peak operations, as driver costs and shift lengths limit the efficiency gains of operating lower frequencies outside the peaks. A possible option for CAM, under driverless operation, is that a common frequency could be provided across the day, but that vehicles could be platooned in the peaks to deliver greater capacity.
- 8.68 Whereas LRT can be a more efficient means of carrying large-demand volumes, the levels of demand in Cambridge (in particular on several corridors, and outside peaks) would result in LRT providing significant over-capacity, where demand / revenues would not cover operating costs. CAM offers more appropriate and flexible service options, which can also cater for demand in the high-peaks.

## Deliverability

- 8.69 We have also undertaken an assessment of the deliverability of each option, to establish if technological, political or financial constraints are likely to present significant risks to the

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<sup>24</sup> Based on our understanding of typical costs across several UK LRT systems.

delivery of the project. It follows a 'risk-based' approach, identifying the extent to which individual risk categories would threaten the successful deliver of the project.

8.70 The risks considered are:

- **Technical Feasibility** – is the option technically feasible?
- **Technology** – how proven is the technology now / in the near future?
- **Value for Money** – is the option likely to demonstrate value for money, and hence be fundable?
- **Affordability** – is the option likely to make an ongoing surplus, or require on-going subsidy?
- **Powers / consents / legislation** – what are the risks that the project will not secure powers?

8.71 The development of any mass transit scheme will involve a lengthy and complex period of scheme development, involving a number of processes, statutory requirements and extensive consultation. There are therefore few areas that can be deemed 'low risk' at this stage of strategic assessment. The purpose of this assessment is primarily to identify potential 'show-stopper' risks that could render an option undeliverable.

8.72 Our assessment of the risks is presented in Table 8.4.

8.73 Both LRT and CAM are assumed to operate with drivers in the near term (hence the ambition for automated operation is not a constraint on deliverability), although depending on the maturity and speed of development of autonomous technology both options have the potential to be operated without a driver in the future.

8.74 As part of the commission Transport Research Laboratory has undertaken a review of the technical solution proposed by AVRT, which has informed our deliverability assessment.

**Table 8.5: Assessment of Scheme Risks**

	LRT - City	LRT – Regional	AVRT - City	AVRT - Regional	CAM	Comment
Technical Feasibility						<ul style="list-style-type: none"> <li>There are technical issues for all options, but there are no feasibility ‘showstoppers’ at this stage.</li> <li>The key issue is not feasibility, but the acceptability of solutions in relation to tunnelling and underground stations.</li> </ul>
Technology						<ul style="list-style-type: none"> <li>Both LRT and CAM use existing technologies, and do not present significant feasibility risks, although technical challenges remain regarding tunnelling under historic Cambridge.</li> <li>LRT is a proven technology, in use in the UK and abroad.</li> <li>CAM could use, as a starting point, technology already available in the market (e.g. VanHool ExquiCity), and does not rely on bespoke solutions.</li> <li>AVRT is a bespoke proposition, using new technology in untested settings, and hence technological risks (and technology interface risks) are correspondingly higher.</li> </ul>
Value for Money						<ul style="list-style-type: none"> <li>There are significant risks over whether LRT or AVRT (both ‘city’ and ‘regional’) have the potential to deliver a VfM solution based on current WebTAG guidance and funding sources.</li> <li>CAM represents the most likely option to achieve VfM, although due to the high cost of tunnelling a VfM case is still subject to further analysis.</li> </ul>
Affordability						<ul style="list-style-type: none"> <li>Both LRT &amp; AVRT ‘regional’ networks are expected to require a significant ongoing subsidy, due to the low levels of transit demand relative to other regions with LRT networks.</li> <li>Flexibility in service planning and vehicle capacity of CAM means that services can better match transport demand to capacity, and are likely to achieve an operating surplus.</li> <li>While the AVRT and LRT ‘city’ networks may require operating subsidies, this is uncertain and therefore medium risk.</li> </ul>
Powers / consents / legislation						<ul style="list-style-type: none"> <li>All options would require powers, and are likely to receive objections.</li> <li>New consents would be required for all options, both for the new technology required for AVRT and the underground running for LRT/CAM.</li> <li>It is not possible to make a detailed, comparative assessment at this stage,</li> </ul>
Stakeholder / public acceptability						<ul style="list-style-type: none"> <li>Stakeholder and public consultation would be required for all options, including both strategic (is this the right solution?) and detailed (e.g. alignment and stop locations) issues.</li> <li>It is not possible to make a detailed, comparative assessment at this stage of which option is most likely to be acceptable to the public and policymakers.</li> </ul>



## Overall Assessment Summary

8.109 The overall assessment summary, based on the performance of each modal option against the key criteria for mass transit is summarised in Table 8.6. This demonstrates that CAM has the potential to:

- deliver the key transport and wider objectives of a mass transit system;
- provide a value for money solution; and
- be deliverable and affordable.

**Table 8.6: Overall Assessment Summary**

Feature	LRT	AVRT	CAM	Benefits of CAM
Connectivity	✓✓	✓	✓✓✓	<ul style="list-style-type: none"> <li>• Delivers maximum connectivity within Cambridge, to major 'city fringe' employment centres, satellite centres and market towns</li> </ul>
Capacity	✓✓✓	✓✓	✓✓✓	<ul style="list-style-type: none"> <li>• Provides capacity for growth, and network coverage to support growth across the region</li> </ul>
Quality	✓✓✓	✓✓	✓✓✓	<ul style="list-style-type: none"> <li>• Segregated routes and high-quality vehicles will benefit passengers and encourage significant modal-shift from car</li> </ul>
Flexible and scalable	✓	✓	✓✓✓	<ul style="list-style-type: none"> <li>• Can be planned on basis of automated vehicles, and systems allowing for platooning (capacity) and network management (system optimisation and efficiency)</li> <li>• Concept allows flexible operation to support growth over time</li> <li>• Operation efficiency through optimising service levels and demand / capacity by corridor, time-period etc.</li> </ul>
Value for Money	X	X	✓	<ul style="list-style-type: none"> <li>• Most cost-effective means of delivering connectivity, quality and capacity outputs, by making best use of existing and planned infrastructure and taking advantage of opportunities from rapidly advancing technology</li> <li>• Most likely meet criteria for, and secure, Government funding contribution</li> </ul>
Affordable	X	?	✓	<ul style="list-style-type: none"> <li>• Likely to deliver an operational surplus i.e. not require ongoing subsidy</li> </ul>
Deliverable	✓	X	✓	<ul style="list-style-type: none"> <li>• Elements of proposition can be implemented within next 5 years</li> <li>• Delivery of full concept would be quicker than for other options considered</li> </ul>

## 9 Recommendations

### Development of the Cambridgeshire Autonomous Metro (CAM) Proposition

- 9.1 This options assessment has identified Cambridgeshire Autonomous Metro (CAM) as the best option to take forward for further development and appraisal. The central finding is that CAM has the potential to deliver the capacity, connectivity and accessibility required to support sustainable long-term growth, and deliver wider outcomes such as the delivery of housing, supporting jobs and increasing productivity.
- 9.2 The next stage will be to develop the CAM concept to a greater level of detail, in terms of outline design, feasibility, costing, modelling and forecasting, and the assessment of potential environmental, property and heritage impacts.
- 9.3 This work would inform the development of a Strategic Outline Business Case (SOBC). The SOBC needs to be prepared in line with Treasury and DfT guidance and set out the case for the scheme using the '5-Case' model. The five cases are:
  - setting out a robust case for change that fits with wider public policy objectives - the **'strategic case'**
  - demonstrate value for money – **the 'economic case'**;
  - are commercially viable – **the 'commercial case'**;
  - are financially affordable – the **'financial case'**; and
  - are achievable – the **'management case'**.
- 9.4 The work undertaken for this study provides much of the evidence that would underpin the strategic case, and the requirement to consider and assess how a range of options could meet stated policy objectives. More detailed work will be required to develop a preferred scheme, and to assess the economic, financial, commercial and management cases.
- 9.5 The development of CAM needs to be considered both from the perspective of how an 'end state' network would look, and from the imperative of delivering elements of the scheme in the short-term to address current transport constraints.
- 9.6 A key benefit of CAM is that it has the potential to deliver benefits in the shorter-term (compared to other Mass Transit options considered). However, any measures must be designed and implemented in a way that ensures the network is future-proofed, and is a phased element towards delivering the 'end state' vision.

## Scheme Development – Infrastructure and Vehicles

9.7 The key areas of option development are summarised in Table 9.1.

**Table 9.1: Development of CAM Proposition**

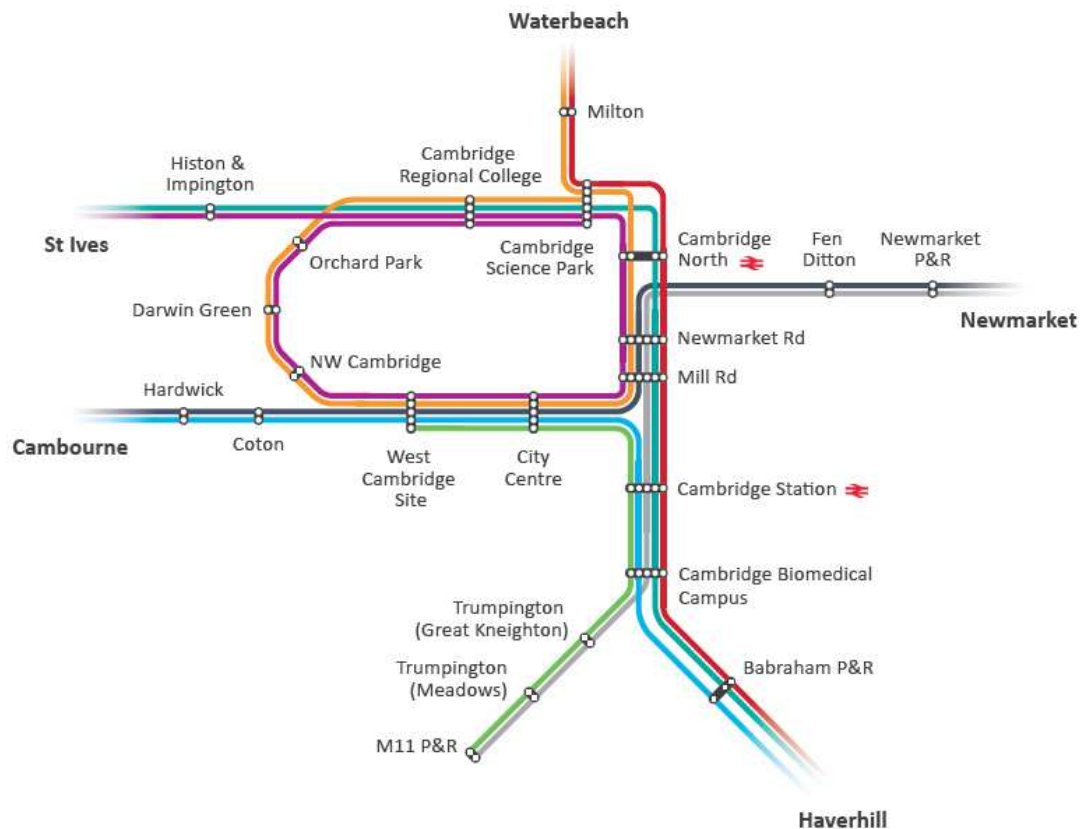
Area	Details
Alignment and route infrastructure	<ul style="list-style-type: none"> <li>• Tunnelled / segregated sections within Cambridge area</li> <li>• Link with proposed / planned segregated infrastructure (under GCP)</li> <li>• Identification of new segregated infrastructure linking to satellite centres / market towns</li> </ul>
Stops	<ul style="list-style-type: none"> <li>• Identification and assessment of potential city centre stops, with the identification of a location for an underground central area stop likely to be a key issue</li> <li>• Identification of other stops, including at existing / new/ relocated P&amp;R sites, and at transit 'hubs' and interchanges</li> </ul>
Vehicles	<ul style="list-style-type: none"> <li>• Review of vehicle technology and emerging mass transit vehicles</li> <li>• Output specification for CAM, and identification of the key attributes vehicles should have</li> <li>• Vehicle strategy – whether to have a single standard CAM vehicle, or to have a mix of medium and higher capacity vehicles to reflect different demand levels and provide greater flexibility</li> </ul>
Enabling infrastructure	<ul style="list-style-type: none"> <li>• Vehicle charging infrastructure</li> <li>• Making existing segregated infrastructure 'autonomous-ready'</li> </ul>

### A Service Proposition

9.8 A feature of CAM is that it allows for the flexible and responsive development of services to meet future demand, and to provide the right balance of services between different corridors and time periods.

9.9 However, it will be necessary to set out a service proposition which reflects a best view of how routes and services would be configured. As part of this study we have identified a potential operational concept, as shown in Figure 9.1. The concept aims to combine high service frequencies with direct connectivity to the city centre and key other destinations.

Figure 9.1: Indicative CAM Operational Map



9.10 This will need to be developed into a more detailed service specification, for the purposes of testing, refining and optimising through the SOBC work. The service options will need to take account of:

- The phasing of infrastructure elements, and the service options these offer;
- Demand growth over time, and how services should respond to growth; and
- The requirement that, for Mass Transit to be attractive and viable, a minimum service threshold will be required on each corridor.

9.11 Service options will need to be developed for at least two future year scenarios, for the purpose of demand forecasting, operating cost analysis and to estimate the vehicle requirement.

#### Phased development of network

9.12 The CAM concept can be delivered in phases, and a key benefit of CAM over other options considered is that it has the potential to deliver benefits earlier.

9.13 The centrepiece of the concept will be the delivery of the new segregated infrastructure, including a tunnelled section, within the city. This will provide the step-change in connectivity, accessibility that will allow for fast and reliable movements to and across the city centre.

9.14 However, the delivery of the tunnel will require significant scheme development work, consultation, and require powers to construct through a Transport and Works Act (TWA)

Inquiry process. The delivery of the tunnelled element is therefore unlikely to be implemented before the mid to late 2020s.

9.15 There are, nevertheless, significant elements of the CAM concept that can be delivered in the shorter-term. The elements that can be delivered in advance include:

- The development of CAM vehicles and existing infrastructure to make them autonomous-ready;
- The delivery of planned and proposed segregated infrastructure being progressed by the GCP; and
- The identification of potential future segregation and priority measures that could be implemented across a wider area (aligned with growth and congestion) to ensure quality and reliability of services across the entire network. There is the opportunity to align the development of future segregated infrastructure with future housing and employment development, and with the funding of infrastructure through capturing the value of development.

9.16 Indeed, the CAM concept will allow for transit-oriented development, whereby development can be targeted in areas with higher public transport accessibility. In this way, CAM can be developed to both respond to and shape current and future spatial strategies. Again, this allows for an alignment between spatial planning, transport planning and infrastructure funding.

#### **Roll Out of Autonomous, Connected, Driverless Operation**

9.17 The vision for CAM is that it will be at the leading-edge of, and deliver the benefits associated with, emerging Mass Transit technology.

9.18 The key technology elements within the CAM concept, including automated / driverless operation, connected vehicles, network management and vehicle charging are either proven or sufficiently advanced such that the scheme development should be planned with these in mind.

9.19 However, the roll out of different elements will be informed by the rate at which the associated infrastructure can be made autonomous-ready and by the regulatory environment. While there are some uncertainties around these, we believe that a reasonable expectation of the phasing of technology elements could be:

- The operation of fully autonomous vehicles on segregated sections of the network within five years. This could be, for example, a service between the Cambridge Biomedical Campus and Cambridge Station;
- The roll out of autonomous operations on the wider network could take place as and when regulatory policy permits driverless operations on general road network; and
- Existing infrastructure supporting high-quality vehicles and services in the interim.

9.20 The development of the CAM concept provides the opportunity for Greater Cambridge to position itself at the centre of the development and application of innovative technology applied to Mass Transit. This builds on the area's established reputation as an internationally recognised centre of innovation and technology, and the CAM concept can be developed as part of the city's Smart Cambridge initiative – where driverless technology and intelligent mobility are central themes.

## CAM - Integration with other Proposals

- 9.21 The development of CAM must be integrated with the range of other transport and wider policies and interventions, to ensure that it delivers its full potential in maximising transport benefits and supporting the delivery of wider economic, social and environmental outcomes.
- 9.22 CAM would be transformational, and as such would need to be reflected in policy and integrated with planned interventions. Examples where such integration would be required are set out in Table 9.2.

**Table 9.2: CAM – An Integrated Network**

Area / theme	Examples
Linkage to strategic infrastructure	<ul style="list-style-type: none"> <li>• Oxford Cambridge Expressway</li> <li>• East West Rail</li> </ul>
Linkage to local infrastructure	<ul style="list-style-type: none"> <li>• Integrate development and phasing of concept with planned / proposed segregated public transport links</li> </ul>
First and last mile connectivity	<ul style="list-style-type: none"> <li>• Mobility as a service (cross-modal information and ticketing)</li> <li>• Cycle access and dispersion</li> <li>• Local public transport links (fixed link or demand responsive)</li> <li>• Local car access e.g. from villages to nearest stop</li> </ul>
Park & Ride	<ul style="list-style-type: none"> <li>• Complementary P&amp;R strategy considering expanded / new/ relocated sites</li> </ul>
Complementary public transport routes and services	<ul style="list-style-type: none"> <li>• Integration with rail network</li> <li>• Integration with bus network, and potential opportunities to optimise bus services.</li> </ul>
Branding and Ticketing	<ul style="list-style-type: none"> <li>• Development of CAM brand within wider e.g. Transport for Greater Cambridge coordination of transport planning and service delivery.</li> <li>• Integrated smart ticketing across transport modes</li> </ul>
City Access Strategy	<ul style="list-style-type: none"> <li>• Complementary role with City Access Strategy</li> <li>• Enabling role of potential demand management or parking levy</li> <li>• Towards zero-emissions from transport in city centre</li> </ul>
Smart Cambridge	<ul style="list-style-type: none"> <li>• Driverless technology</li> <li>• Intelligent mobility</li> </ul>
Spatial planning policy	<ul style="list-style-type: none"> <li>• Supporting current spatial strategic and accelerating housing delivery</li> <li>• Informing and potentially shaping future spatial strategy</li> <li>• Ensuring CAM reflected in local planning policy documents</li> </ul>
Transport policy	<ul style="list-style-type: none"> <li>• Integrate CAM within development of Local Transport Plans and supporting modal strategies.</li> </ul>

## CAM Operations

- 9.23 A fundamental requirement of CAM is that it must be high-quality, both in terms of vehicles and services.
- 9.24 As segregated infrastructure, CAM could be developed as 'private' infrastructure, which would be owned and managed by the Combined Authority. This would give the CPCA control and the ability to specify quality and service aspects of CAM. The operation of services could be provided by third parties (e.g. a transport operator) subject to them meeting these requirements. Alternatively, the CPCA could seek to specify service levels and let a franchise for operations to a single operator, either for the network or for specific routes.



- 9.25 The traffic and network management capability that technology would afford would enable services to be optimised in real-time to respond to demand, ‘flight’ services through central sections, and hence deliver services in the most operationally efficient way possible.
- 9.26 CAM would be fully integrated with other public transport modes and first/last mile solutions - creating one transport ‘brand’ for Cambridgeshire, and a familiarity and ease of use for passengers similar to TfL and TfGM.

### **Funding of CAM**

- 9.27 An important question in developing and implementing a large-scale transport infrastructure scheme is identifying how it can be funded. This is particularly important given the wider economic and political environment of a tighter public purse leading to the end of an era where UK central government grant funding would be made available provided the proposed scheme had a strong case and was technically feasible.

#### *Policy Context*

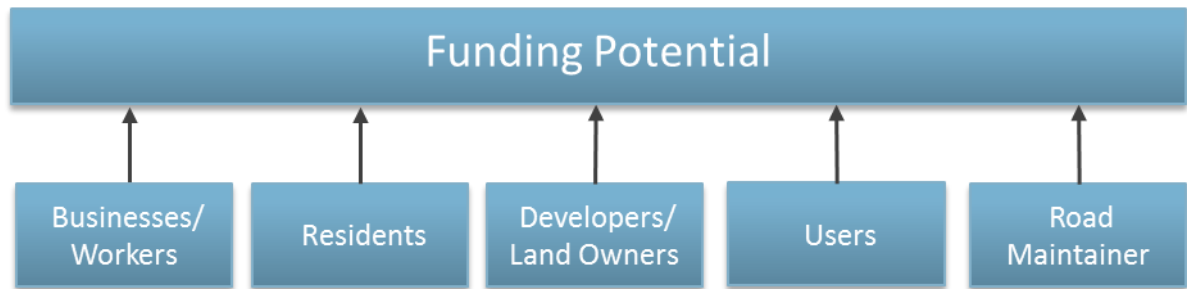
- 9.28 Public investment in the UK is more dependent than ever on finding sufficient funding and increasingly the ability to generate revenues locally is determining whether any scheme is taken forward or not. As central government funding has become increasingly constrained, the days when a public investment would be delivered largely on the economic, social or environmental benefits it generates have gone. In addition, devolution has focused decision making on seeking to find local beneficiaries for any investment.
- 9.29 Crossrail is setting the benchmark for establishing the case for public investment in transport infrastructure and identifying and securing an appropriate funding package. These include the following broad principles:
- At least 50% of funding required to deliver a transport infrastructure project is from local sources;
  - That the project should be able to cover its operating, maintenance and ideally renewal costs;
  - That a mix of local funding can be secured including support from local businesses, development and users; and
  - That the wider economic benefits of the project are significant and that increased taxes can help recover any central government outlay (particularly increased productivity, generating additional and higher paying jobs)

#### **CAM Funding Potential**

- 9.30 An assessment of the funding potential to support a mass transit system has been undertaken. The funding assessment is summarised below.
- 9.31 This assessment focuses on funding that can be generated locally from third parties (i.e. not central or local government grant funding). It is important to note that the assessment presents a range of different potential funding sources and does not consider at this stage the economic, environmental and, most importantly, political challenges in developing and agreeing a robust funding package.

*Beneficiary Pays*

- 9.32 A key concept in our assessment of new funding and financing options is the concept of ‘benefactor pays’. This concept is based on the principle that those who benefit from the improvement in transport should contribute to its cost. An overview of the potential beneficiaries of the Cambridge Mobility Options is provided below, including how they could benefit from the project.

**Figure 9.2: Transport Funding Potential**

- **Businesses/Workers** benefit from the improved mobility through agglomeration as greater productivity and lower costs arise from the concentration of economic activity. The increased concentration has a productivity ‘bonus’ that is shared between businesses and workers that can lead to increased revenues and/or reduced costs. In addition, businesses can benefit from being able to draw from a wider pool of prospective employees who can more easily access their business.
- **Residents** benefit from the improved mobility through improved connectivity and increased mobility and (if they own their property) through the uplift in land values.
- **Developers/land owners** benefit from the improved mobility through an increase in land value as more businesses and/or residents look to relocate to the area. This benefit translates into a financial benefit as higher land values can result in higher density developments and/or an increase to rental values and/or sale incomes.
- **Users** of transport services benefit from the improved mobility through reduced journey times, improved reliability and/or improved frequency. These benefits allow users to access a wider pool of jobs and can lead to productivity gains where both may result in financial benefits to the user.
- **The Road Maintainer** benefits from the improved mobility through reduced road usage as people increasingly travel by public transport, walking or cycling as opposed to by private car. In this instance, it may reduce the need to expand the road network around Cambridge to meet growing demand.

## Funding Mechanisms

- 9.33 We identified a long list of 20 funding options for mass transit in Greater Cambridge and assessed this long list based on: potential contribution, legal deliverability, political deliverability and alignment with beneficiaries. From this assessment, we identified a short list of seven possible funding options. The short-listed funding options are shown below in Table 9.3.

**Table 9.3: Short Listed Funding Options**

Funding Mechanism	Beneficiary
Business Rate Supplement	Businesses
Workplace Parking Levy	Businesses/Workers
Road Pricing Scheme (intelligent charging)	Road Users
Highway England Contribution (Shadow Toll)	Road Maintainer
Council Tax Precept	Residents
Community Infrastructure Levy	Developers
Local Tax Retention	Businesses/Residents

- 9.34 We have focussed on funding mechanisms that the local authorities or CPCA has the power to implement<sup>25</sup> (i.e. they do not require primary legislation).
- 9.35 Our funding assessment indicates that local funding, based on the mechanisms above, has the potential to over half of the total funding towards the scheme. These are based on the funding mechanisms being applied in Cambridge and South Cambridgeshire.
- 9.36 Additional local funding could be secured through:
- Land value capture (a model currently under consideration by the Mayor across a range of transport and infrastructure projects); and
  - Extending the geography over which local funding is sought, for example to East Cambridgeshire. In practice, other local authorities may locally fund incremental improvements to CAM (e.g. segregation within their local area, development of CAM interchange ‘hubs’) to support the development of CAM across a wider area.

<sup>25</sup> Note, this may be subject to approval with other parties e.g. a Business Rate Supplement and the Local Enterprise Partnership.

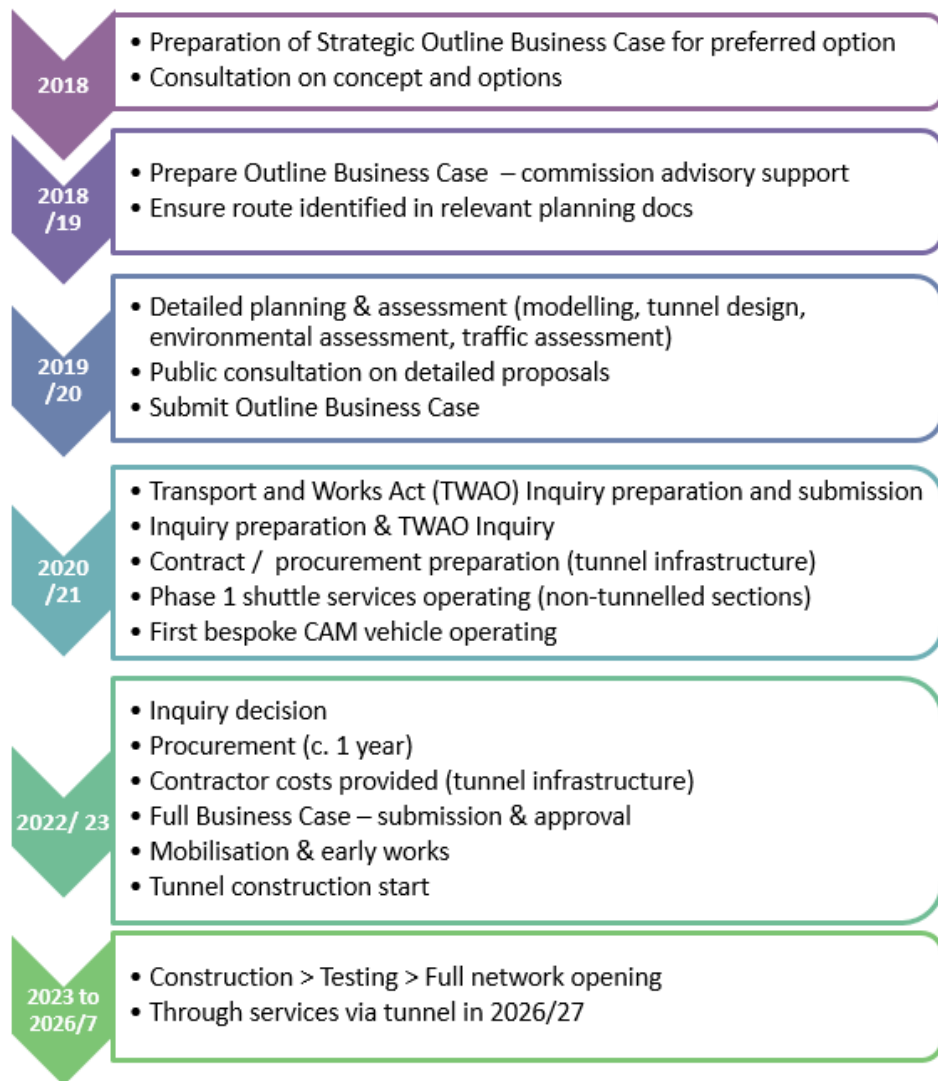
### **Funding Conclusion**

- 9.37 The funding review suggests there is the potential for a significant proportion of the funding to be secured locally, aligned to leveraging funding from the potential beneficiaries of the project.
- 9.38 In addition, subject the further work on the SOBC, the project could be eligible for central Government funding through a combination of:
- Large Local Majors funding, administered by the DfT, for large-scale transport projects;
  - Housing Infrastructure Funding (HIF), administered by the Ministry for Housing, Communities and Local Government. This is available for major infrastructure that support the delivery of housing. The current HIF round has a total allocation of £3bn, which up to £250m available for projects that support strategic housing delivery; and
  - Technology funding, administered by Innovate UK, which could support technology development and piloting of CAM elements.
- 9.39 The current funding available from each of the above covers a relatively short-term (for spend up to 2020/21) but it is likely that further allocations and / or successor funds will be available, for which the Promoter can seek funding from Government.

### **Outline Implementation Plan**

- 9.40 An indicative timetable for the implementation of CAM is set out in Figure 9.3. The programme assumes that the detailed design, planning and powers would be focused on the new bespoke segregated infrastructure (including the tunnel) while the securing of segregated alignments on planned / proposed routes (e.g. to Cambourne, Waterbeach) would be progressed as separate projects. This reduces planning risk / dependency, and enables planned infrastructure to come forward in advance of the tunnel.
- 9.41 While the planning and delivery of parts of overall segregated CAM network can be progressed separately, it will be imperative that the overall strategic case for CAM is made at the network level, and takes account of wider complementary planned transport initiatives (e.g. demand management).

Figure 9.3: Indicative Timescale for Delivery



## 10 Conclusions and Next Steps

### Conclusions

- 10.1 As part of this study we have identified and assessed a range of mass transit technologies to determine which option is most appropriate for delivering the long-term sustainable growth of the Greater Cambridge area.
- 10.2 The study concludes that Cambridgeshire Autonomous Metro (CAM), which would pioneer the use of emerging technology and make best use of current, planned and proposed infrastructure, is the mass transit option that should be taken forward to further development.

### Next Steps

- 10.3 The immediate next step is to undertake further development work on the CAM option to identify a preferred network, routes, vehicles and technology, and the service proposition.
- 10.4 This would support the development of a Strategic Outline Business Case.





## CONTROL INFORMATION

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**Prepared by**

Steer Davies Gleave  
28-32 Upper Ground  
London SE1 9PD  
+44 20 7910 5000  
www.steerdaviesgleave.com

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**Prepared for**

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**Author/originator**

Tom Leach

---

**Reviewer/approver**

Tom Higbee

---

**Other contributors**

Ed Robinson  
David Mack  
Mark Hobden  
Michael May  
Tom Higbee

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