Commercialising Connected and Automated Mobility

East Birmingham to North Solihull Automated Shuttle

Feasibility Study

InnovateUK Project № 10042602

November 2023

Contents

Glossary of terms

- **AB** Autonomous Bus
- **ABoD** Autonomous Bus on Demand
- **AC** Autonomous Car
- **AD** Autonomous Driving
- **AEVA** The Automated & Electric Vehicles Act (2018)
- **AGT** Automated Gateway Transit
- **AJT** Actual Journey Time
- **ALARP** As Low As Reasonably Practicable
- **ALKS** Automated Lane Keeping System
- **API** Application Programming Interface
- **APM** Automated People Mover
- **APTV** Autonomous Public Transport Vehicle
- **AQ** Air Quality
- **AQMA** Air Quality Management Area
- **ART** Autonomous Rail Transit (aka "Trackless Trams")
- **ARTS** Automated Road Transport System
- **ASDE** Authorised Self-Driving Entity
- **ATN** Automated Transit Network
- **ATS** Autonomous Transport System
- **AV** Automated/Autonomous Vehicle
- **AVRT** Advanced Very Rapid Transport
- **BCC** Birmingham City Council
- **BCR** Benefit/Cost Ratio
- **BRT** Bus Rapid Transport
- **BSIP** Bus Service Improvement Plan
- **BSI** British Standards Institution. (The national standards body of the United Kingdom).
- **CAM** Connected and Automated Mobility
- **CAPEX** Capital Expenditure
- **CAV** Connected and Automated Vehicle
- **CAVPASS** Connected & Automated Vehicles: Process for Assuring Safety & Security
- **CAZ** Clean Air Zone
- **CCAV** Centre for Connected & Autonomous Vehicles
- **CCTV** Closed Circuit Television
- **CIA** Confidentiality, Integrity & Availability
- **CPO** Compulsory Purchase Order
- **CRSTS** City Region Sustainable Transport Settlement
- **CWZ** Core Walking Zone
- **DARPA** Defence Advanced Research Projects Agency
- **DD Bus** Double Decker Bus
- **DfT** Department for Transport
- **DLR** Docklands Light Railway
- **DPMT** Dynamic Personal Micro Transport
- **DRT** Demand Responsive Transit
- **EBNS** East Birmingham to North Solihull
- **EBS** East Birmingham - Solihull
- **EV** Electric Vehicle
- **EZ** Enterprise Zone
- **EZIP** Enterprise Zone Investment Plan
- **FFJT** Free Flow Journey Time
- **FQ** Feasibility Question
- **FVD** Floating Vehicle Data
- **GBSLEP** Greater Birmingham & Solihull Local Enterprise Partnership
- **GJT** Generalised Journey Times
- **GPS** Global Positioning System
- **GRT** Group Rapid Transit
- **GVA** Gross Value Added
- **HA** Hazard Analysis
- **Headway** - The time between each vehicle in service on a public transport route and used to denote the frequency of the service.
- **HGIP** Hub Growth & Infrastructure Plan
- **HMI** Human Machine Interface
- **IB** InBound
- **IOBC** Interim Outline Business Case

Glossary of terms

- **InnovateUK** The national innovation agency that supports business-led innovation in all sectors, technologies and UK regions.
- **IVT** "In-Vehicle" Travel Time
- **ISO** International Standards Organisation. An international standard development organization composed of representatives from the national standards organizations of member countries.
- **KPI** Key Performance Indicator
- **KRN** Key Route Network
- **LCWIP** Local Cycling & Walking Infrastructure Plan
- **LIDAR** Light Detection and Ranging
- **LRT** Light Rail Transit
- **LTP** Local Transport Plan
- **MB** Manual Bus (does not refer to transmission type)
- **MC** Manual Car (does not refer to transmission type)
- **MEC** Marginal External Costs
- **MFM** Midlands Future Mobility
- **MRM** Minimum Risk Manoeuvre
- **MSOA** Middle-Layer Super Output Area
- **NCAP** New Car Assessment Programme
- **NEC** National Exhibition Centre
- **NOMIS** National Online Manpower Information System
- **NPPF** National Planning Policy Framework
- **NPPG** National Planning Practice Guidance
- **NPV** Net Present Value
- **NSG** Next Shuttle Generation (ZF Shuttle)
- **NVH** Noise, Vibration and Harshness
- **OD** Origin-Destination
- **ODD** Operational Design Domain
- **OB** Outbound
- **OEM** Original Equipment Manufacturer
- **ONS** Office of National Statistics
- **PPHPD** Persons Per Hour Per Direction
- **PRISM** Planning & Reporting Information System for Management
- **PRT** Personal Rapid Transit
- **PT** Public Transport
- **PVR** Peak Vehicle Requirement
- **RAG** Red, Amber, Green (Status indicator)
- **RSU** Roadside Units
- **RTC** Road Traffic Collision
- **SAE** Society of Automotive Engineers (now deprecated). A professional association and standards developing organization for engineering professionals in various industries.
- **SAV** Shared Autonomous Vehicles
- **SDV** Self-Driving Vehicle
- **SMBC** Solihull Metropolitan Borough Council
- **SRN** Strategic Route Network
- **STP** Strategic Transport Plan
- **TA** Transport Assessment
- **TAG** Department for Transport's Transport Appraisal Guidance
- **TfWM** Transport for West Midlands
- **TOD** Transit Orientated Development
- **TS** Transport Statement
- **TWAO** Traffic & Works Act Orders
- **UNECE** United Nations Economic Committee for Europe. A United Nations economic regional commission with the aim to promote pan-European economic integration.
- **V2X** Vehicle to Anything
- **V/C** Volume over Capacity
- **VfM** Value for Money
- **VRU** Vulnerable Road User
- **WMCA** West Midlands Combined Authority

Study Consortium Members

- **Arup -** A British multinational professional services firm headquartered in London that provides design, engineering, architecture, planning, and advisory services across every aspect of the built environment.

  Contact:
  Daniel McCool - daniel.mccool@arup.com
  Lara Tabet - lara.tabet@arup.com

- **Syselek** – A developer of innovative technology and toolchain solutions using automation for high integrity systems.

  Contact:
  Alan Walker - alan.walker@syselek.com

- **ZF** - A global technology company that supplies systems for passenger cars, commercial vehicles and industrial technology.

  Contact:
  Neil Martin - neil.martin2@zf.com
  David Morgan - david.morgan@zf.com

- **Solihull Metropolitan Borough Council** - The local council of the Metropolitan Borough of Solihull in the West Midlands, England.

  Contact:
  Colin Maltby - colin.maltby@solihull.gov.uk

- **West Midlands Combined Authority** - A combined authority for the West Midlands metropolitan county in England. Incorporates Transport for West Midlands, the public body responsible for co-ordinating transport services in the West Midlands metropolitan county in England.

  Contact:
  Lewis Kelly - lewis.kelly@tfwm.org.uk
  Matthew Shelton - matthew.shelton@tfwm.org.uk

Executive Summary

Executive Summary

A high-level overview of the project

Introduction

This report is the output of the East Birmingham – North Solihull CAM Corridor Feasibility Study, funded by the Centre for Connected Autonomous Vehicle (CCAV) by a consortium comprising:

- Arup
- Solihull Metropolitan Borough Council
- Syselek
- West Midlands Combined Authority
- ZF

Study Objectives

1. Assess whether an automated transport system could feasibly operate on the route identified.
2. Where feasibility criteria are not met to the satisfaction of all consortium partners, specify further work required to provide answers to residual questions / identified issues.

Background

Over the past decade significant funding has been invested in developing the case for linking East Birmingham and North Solihull in the West Midlands via an extension to the West Midlands Light Rail Metro network. The need for a high-volume arterial link is well understood but the cost has always been prohibitive with the sum now, in 2023, expected to be in excess of £1Bn.

Since 2016 when the metro extension Interim Outline Business Case (IOBC) and associated scheme designs were released, there have been numerous advances in Connected and Automated Mobility (CAM) systems, supported by developments in regulations, legislature and human factors study relating to CAM services. This report seeks to understand if a CAM system could feasibly deliver the same benefits at lower cost.

Study Methodology

This study has sought to answer 21 Feasibility Questions (FQ), framed by seven under-lying Solution Requirements, found at 1.3. Each FQ, dependent upon research findings, is then attributed a traffic light rating, where Green indicates *From the work undertaken the answer to the FQ is positive, and no / limited concerns have been identified*; Amber indicates *The FQ appears feasible however further investigation is recommended. In such instances recommendations for further investigation are provided.* And where Red indicates *From work undertaken the answer to the FQ is negative and therefore the automated transport route has been deemed not feasible at this point.*

Key Findings & Recommendations

The following table over the next four pages provides a high-level summary of the key findings within this report, along with related recommendations where appropriate. 11 of the study's FQ's were assessed to be Green, and 10 Amber. No FQ's were deemed to reach the threshold where a Red rating was appropriate.

Executive Summary

A high-level overview of the project findings & recommendations

Qu	Feasibility Question	Chapter	Traffic Light	Summary Findings & Recommendations
FQ1	Do previous studies support the potential for CAM for public or mass transit?	Previous Studies		**Findings:** Through the desktop review of existing publications carried out there are valuable lessons to be learned and factored into our study. There is nothing to suggest that the route identified for the deployment of a Connected Automated Mobility mass transport system is not feasible. **Recommendations:** Best practise / lessons-learned visits to CAM deployments Engagement with leading academic institutions to model corridor
FQ2	Is this route supported by local, regional and national strategy and policy?	EBNS Strategic Context		**Findings:** The policies and aspirations from the UK government, regional authority and Local government presented here supports both the delivery of a public transport link on this route, and the deployment of innovative systems, such as a CAM solution. **Recommendations:** Incorporate learning from parallel WMCA EBNS corridor study currently underway – expected to conclude Q1 2024.
FQ3	Do future plans on this route support its viability?	EBNS Strategic Context		**Findings:** The future plans for the region support the deployment of a CAM solution along this route by allowing for greater connections to and throughout the region. **Recommendations:** Incorporate learning from parallel WMCA EBNS corridor study currently underway – expected to conclude Q1 2024.
FQ4	Is a new service along this route needed?	Constraints and Opportunities		**Findings:** The corridor currently acts as a main artery through the region and is prone to congestion through the daytime. Additionally, there are many rail and bus links in the area, but the full route is not frequently catered for residents. The proposed solution would enhance public and active travel options. **Recommendations:** Incorporate learning from parallel WMCA EBNS corridor study currently underway – expected to conclude Q1 2024.
FQ5	Is an automated solution (SAE Level 4) the optimal technology for this route?	Route Feasibility		**Findings:** Following a high-level assessment of emerging / non-standard mass transit modes no red flags have been identified. With the levels of global investment and development in the CAM sector, CAM is considered a mode that presents value to assess alongside traditional modes in the medium term. A deeper level assessment of alternative modes is recommended at the next stage to confirm initial findings. **Recommendations:** Incorporate learning from parallel WMCA EBNS corridor study currently underway – expected to conclude Q1 2024. Undertake a detailed assessment of emerging technologies applicability to the route
FQ6	Based on the agreed Solution Requirements, can a CAM solution deliver target outcomes within this urban context?	Route Feasibility		**Findings:** A leading multinational CAM supplier have analysed the identified route, and subject to the agreed levels of segregation detailed within the report stated that they are confident their technology will be able to deliver within the timeframes identified within this study. Case studies support this finding. **Recommendations:** Review best practice output from Project Fuse and connectivity plan from parallel EBNS study Research the potential congestion effects of different headway scenarios to meet demand Develop optimised traffic signal timing for junctions along the route Research the potential to optimise service reliability with V2X implementation

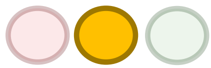
Executive Summary

A high-level overview of the project findings & recommendations

Qu	Feasibility Question	Chapter	Traffic Light	Summary Findings & Recommendations
FQ7	Can appropriate levels of segregation be provided along the route?	Route Feasibility		**Findings:** CAM technology is projected to be capable of running in 'mixed' traffic, not requiring segregated lanes. This would not however deliver a core requirement of mass transport interventions - Journey Time Reliability. The introduction of a segregated 'at-grade' CAM corridor is deemed to offer the optimum balance, based on expected future capability of CAM systems and associated communication technologies. Specific measures for full physical segregation 'at-grade' including fencing / upstands, platform edge doors and barriers at intersections have been considered but are not all recommended due to their impact on cost, severance and frequency, ergo demand. Further detailed designs of the full route will provide further assurance of the deliverability. **Recommendations:** Detailed design of full route to identify optimal level of segregation at each stage
FQ8	Could a CAM solution be delivered at a lower CAPEX when compared to LRT?	Capital Costs		**Findings:** Analysis indicates a cost per km of £20.0m for a CAM installation, based upon the level of segregation as detailed in Section 5.5. This is roughly half the cost of Light Rail (£37.9m) along an almost identical route. This therefore indicates a significant saving in relation to capital outlay. CAM is considered to be on par with Bus Rapid Transit in relation to CAPEX investment. **Recommendations:** Further design work to better define infrastructure works required along the route, stops design and depot / control centre / roadside infrastructure
FQ9	Could a CAM solution be delivered at a lower OPEX when compared to LRT?	Operations		**Findings:** This study used ZF's 15-seater vehicle platform as the primary CAM option, resulting in 78 shuttles being required to service the route. On this basis, when compared against LRT, calculations indicate that at this stage in technology development any reductions in costs associated with drivers are replaced by the greater cost and quantity of vehicles, the need for remote monitoring, and supporting technological infrastructure, demonstrating marginally higher OPEX. When comparing fewer, higher capacity CAM vehicles against LRT the CAM OPEX reduces significantly. Against BRT, equivalent capacity CAM OPEX is marginally lower. CAM technology costs could however be expected to drop over time, thus further improving operational savings against BRT. **Recommendations:** Calculate the impact of different vehicle sizes (passenger capacity) on operational costs and better understand maintenance requirements. Consider the impact a 24/7 service would have on benefits and operational costs. Carry out sensitivity analysis in relation to headway and its impact on ridership demand. Understand the extent to which technology development / maturity is likely to reduce future system costs.
FQ10	Can the required level of system reliability be delivered?	Operations		**Findings:** Current operating parameters of 'best in class' technology developers indicate that systems should be able to continue operating within the majority of environmental scenarios. This is demonstrated by the service delivery reliability at the Rivium automated system in Rotterdam. Capability in this area is projected to continue to improve as the sector continues to develop. **Recommendations:** Fully develop the ODD for the route
FQ11	Can the route be delivered with acceptable safety?	Operations		**Findings:** Significant time has been spent understanding the nature of the route, cataloguing potential hazards and identifying high-level mitigations. Alongside manufacturer assessment, an independent hazards analysis has been carried out to provide a deeper level of assurance of deliverability. There is a high level of confidence that, within the agreed Solution Requirements, this route can be delivered with acceptable safety. **Recommendations:** Full safety case. Support the CAM sector to develop commonly agreed and used goal orientation as a foundation for standardising safety cases.

Executive Summary

A high-level overview of the project findings & recommendations

Qu	Feasibility Question	Chapter	Traffic Light	Summary Findings
FQ12	Can fares be protected, on-board riders be safe, and accessible transport all be provided pragmatically?	Operations		**Findings:** The Rivium case study illustrates how automated services can be successfully integrated into public transport networks, delivering a safe rider experience where fares are protected. That said, this case study is not on the same scale as the EBNS route, and as such further work to identify solutions at scale is recommended. **Recommendations:** Conduct human factors research into behaviours relating to fare evasion; late night behaviours; perceptions of minority groups
FQ13	Will an automated solution be legislated for and insurable?	Operations		**Findings:** Evidence indicates that the UK is highly supportive of developing the required legislation to see automated systems made legal, however the precise legislation is still in formation and as such caution must still be exercised. Development of legislation will be a critical part of commercialisation of the technology. **Recommendations:** Continue to engage with the relevant public bodies to develop appropriate primary and secondary legislation to allow for future deployment of CAM systems
FQ14	Would a CAM solution be expected to provide value for money?	Cost Benefit Appraisal		**Findings:** The results of the early-stage economic appraisal indicate that a CAM public transport corridor would result in a benefit-to-cost ratio of more than 1. Whilst further work is required to update the demand modelling (to account for changes to the HS2 route, account for development along the corridor, and the impacts of the COVID-19 pandemic etc) it is noted that the potential for a higher frequency CAM solution (and minimal waiting time) could result in significantly higher demand for the corridor, and potentially a higher willingness to pay, versus a traditional, higher capacity and lower frequency service. A key constraint of the economic appraisal undertaken is that it does not account for potential negative impacts on general traffic, which should be a key consideration in any future transport modelling. **Recommendations:** Appraise larger vehicle capacities running at increased headways, When vehicle confirmed - investigate ride quality and the impact on benefits.
FQ15	Is automated transport a secure technology? (Physical & Digital)	Risk Appraisal		**Findings:** There are multiple risks to CAM solutions as demonstrated by the public's reaction to early deployments in locations such as San Francisco. The physical safety of vehicles therefore requires further exploration. There is currently high resilience to cyber security threats as this area has been extensively researched and this is not seen as an unacceptable risk. **Recommendations:** There is significant lack of understanding of Physical Security. Research is needed to raise the understanding of Physical Security to a par with understanding of Digital Security.
FQ16	Will an automated solution that can technically serve this route be ready within stated target timeframes?	Risk Appraisal		**Findings:** CAM solutions have been proven to be highly effective in controlled and semi-controlled environments. For complex urban deployments a CAM solution requires infrastructure to maintain a safe level of segregation, as identified within this study. Further study into the capability readiness is required. **Recommendations:** Detailed design of route and assessment against projected CAM capability

Executive Summary

A high-level overview of the project findings & recommendations

Qu	Feasibility Question	Chapter	Traffic Light	Summary Findings
FQ17	Are transport operators open to exploring delivering CAM services?	Risk Appraisal	Green	**Findings:** UK based operators have not yet declared intentions to deliver passenger transit services using automated vehicles. However, some operators are engaged in research activities, which suggests a keenness to familiarise themselves with automated vehicle technology. There are strong motivating factors to encourage operators to deliver passenger transit services with automated vehicles. **Recommendations:** Market engagement with traditional operators to explore co-ordinated development of CAM-based solution
FQ18	Will there be system / vehicle manufacturers ready to deliver the scale of system, with sufficient demonstrable evidence of delivery and funding to secure public / commercial contracts?	Risk Appraisal	Amber	**Findings:** OEMs are in the process of developing CAM solutions and while progress is being made there will be a steep learning curve during the initial deployments. Regulatory bodies will need to issue assurance frameworks in the very near future to allow the supply chain to develop systems that comply. There is currently no developed specification for public authorities to tender for such systems, and demonstration of delivery at scale is not readily available for any suppliers in the sector. **Recommendations:** Manufacturers must meet the product and service specifications used in public procurement. However, since vehicle product development can take up to 5 years. A universally agreed specification for UK public transport CAM is needed to guide manufacturers' development activities.
FQ19	Can we CPO for driverless solutions; is it politically palatable?	Risk Appraisal	Green	**Findings:** CPO is considered a last resort but is possible. The land acquisition outlined in the previous IOBC suggested the impact would be minimal along the corridor. Following a desktop review, it is evident that these locations identified in the IOBC will still need a detailed review for a CPO to allow for a segregated corridor. **Recommendations:** Complete a detailed CPO review at OBC stage
FQ20	Do we want to be first? Is there any advantage to being first? What are the disadvantages of being first?	Risk Appraisal	Amber	**Findings:** While this would not be the very first deployment, being first (/ amongst the first) could be expected to benefit from government involvement due to the high initial cost, long payback period and nature of innovation. This type of deployment would allow for innovation to grow in the region with reduced risk to commercial entities, however, lessons learned could be significant. **Recommendations:** Engage regional and national bodies to understand support on offer for delivery of route
FQ21	Will a CAM solution be socially accepted? Will it be abused / a target for abuse that makes it unreliable / unusable?	Risk Appraisal	Amber	**Findings:** While potential customers are keen on the concept of CAM, security and safety solutions must be put in place and significant engagement with the public will be needed. Further studies into the acceptance from other road users and residents will also be needed. Any deployment will need a detailed plan on how to protect passengers and the vehicles while in operation. **Recommendations:** Research and develop mitigations to protect passengers from anti-social behaviour Research and develop mitigation to protect the vehicle from anti-social behaviour Research the acceptance of CAM by non-CAM customers (residents, other road users, etc.) Develop public communications framework to support deployment of CAM service

1. Introduction

1. Introduction

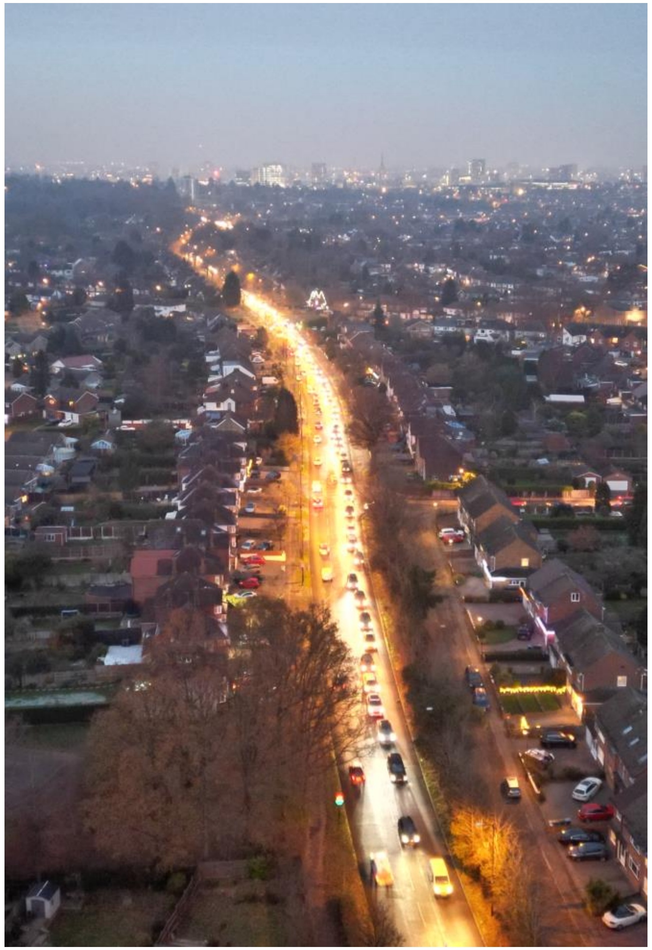
Can we connect East Birmingham and North Solihull with Automated Transport?

1.1 Purpose of Study

Over the past decade significant effort has been expended in developing the case for linking East Birmingham and North Solihull via an extension to the West Midlands Light Rail Metro network. The need for a high-volume arterial link is well understood but the cost has always been prohibitive with the sum now, in 2023, expected to be in excess of £1Bn.

Automated transport promises many benefits, but none more so than its ability to offer lower cost, higher frequency shared public transport. At a time when the delivery of public transport projects and services is coming under ever increasing pressure, could an automated transport system deliver the same, or similar, levels of benefits as Light Rail at a fraction of the time, cost and disturbance?

Over eleven chapters this feasibility study answers 21 questions relating to automated transport and its ability to play a role in linking East Birmingham and North Solihull and delivering wider mass transport solutions of the future. In doing so the study aims to provide a neutral, unbiased assessment, acknowledging the myriad of considerations when analysing the introduction of innovative cutting edge technological solutions.



Study Objectives:

1. Assess whether an automated transport system could feasibly operate on the route identified
2. Where feasibility criteria are not fully met, specify further work required to provide answers to residual questions / identified issues

1. Introduction

The study is based on the delivery of the route illustrated below – from Digbeth to Birmingham Int. Rail Station

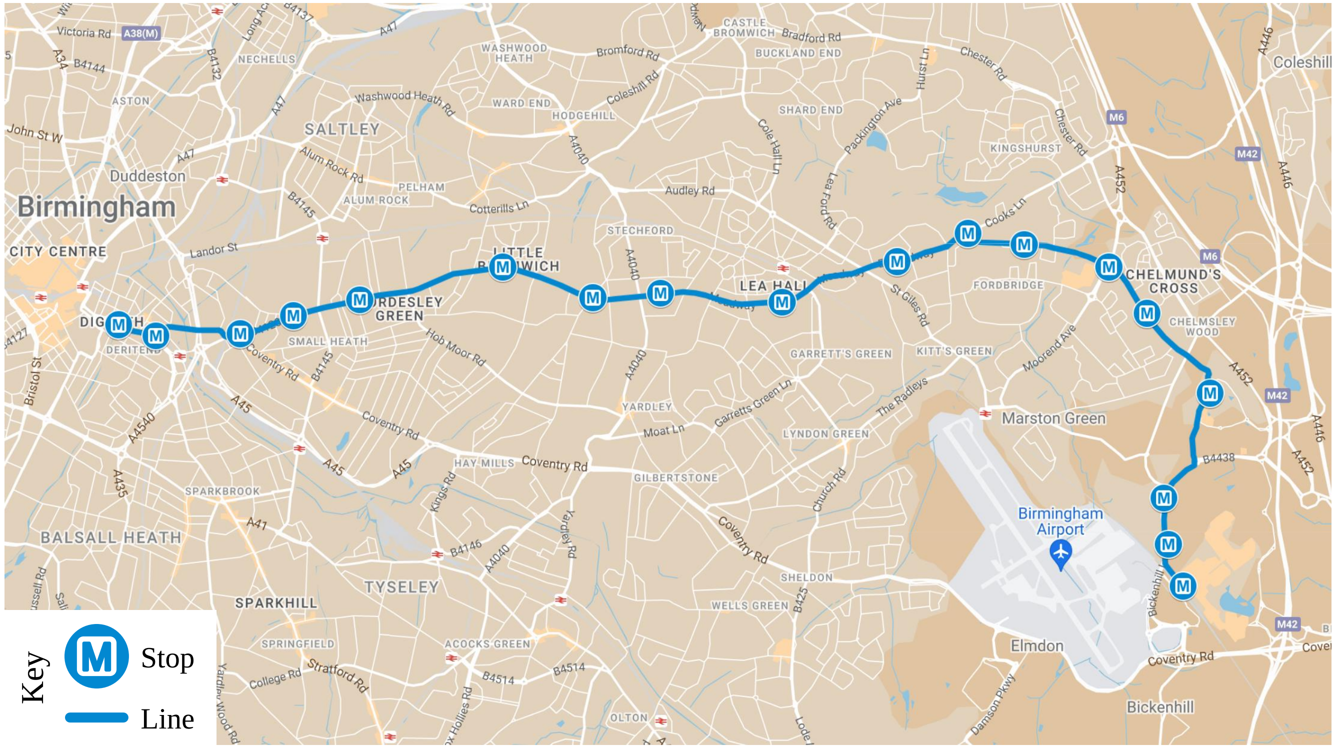
1.2 Study Route

The route that will be reviewed as part of this study has been inherited and modified from a previous IOBC developed in 2016.

A larger version of this image can be found in Appendix Chapter 1

Station List

1. High Street Deritend
2. Adderley Street
3. St Andrews
4. Bordesley Green
5. South & City College
6. Heartlands Hospital
7. Richmond Road
8. Station Road
9. Meadway
10. Lea Hall
11. Cooks Lane
12. Kingshurst
13. Chelmsley Wood
14. Carisbrooke Avenue
15. Birmingham Business Park
16. Starley Way
17. Elmdon Trading Estate
18. Birmingham International Rail Station



1. Introduction

The study will utilise seven core solution requirements

1.3 Study Methodology

To assess the feasibility of automated transport to deliver a mass transport service linking East Birmingham to North Solihull seven fundamental requirements were adopted. These requirements serve as a benchmark against which solution feasibility can be made, and are requirements readily used in the planning of any traditional public transport solution.

Solution Requirements

1. The system must convey the maximum passengers to serve the whole expected / modelled demand on the route, at appropriate frequencies, **therefore** the proposed system can't be a partial solution that requires additional solutions to serve the same route
2. The service should be capable of running 5am - 12 midnight 7 days a week, **therefore** this can't stop / start to account for busy periods / areas (i.e., football grounds), or adverse weather (i.e., snow, fog, etc) due to being outside of a systems expected capability
3. Levels of segregation should be provided to ensure journey time reliability, safety and deliverability; **therefore,** the system must adopt an appropriate level of segregation to enhance the feasibility of the service to meet its intended outcomes and critical success factors.
4. The system must be un-manned, **therefore** solutions for safety, fare protection and incident resolution must be factored into costs and feasibility
5. The size and capability of vehicle / system should be decided by the projected service requirements, **therefore** do not model exclusively with ZF’s Next Generation Shuttle in mind
6. The solution implementation window is for go-live in 2029, **therefore** do not project too near-term, or too far-term with regards to technology and legislation readiness
7. The study should allow for automated transport to be compared alongside other traditional forms of mass transport, **therefore** the use of industry standard assessment criteria and frameworks will be adopted

1. Introduction

The study will seek to answer 21 Feasibility Questions

1.3 Study Methodology

Feasibility Questions

With these assumptions adopted, the study then answers 21 Feasibility Questions (FQ). These questions are seen a critical measures of feasibility, and failing on any single one of these would indicate that the further exploration of delivery of this route utilising automated transport be paused.

FQ1 Do previous studies support the potential for CAM for public or mass transit?

FQ2 Is this route supported by local, regional and national strategy and policy?

FQ3 Do future plans on this route support its viability?

FQ4 Is a new service along this route needed?

FQ5 Is an automated solution (SAE Level 4) the optimal technology for this route?

FQ6 Based on the agreed 'Solution Requirements', can a self-driving solution be delivered within this urban context?

FQ7 Can appropriate levels of segregation be provided along the route?

FQ8 Could a CAM solution be delivered at a lower CAPEX when compared to LRT?

FQ9 Could a CAM solution be delivered at a lower OPEX when compared to LRT?

FQ10 Can the required level of system reliability be delivered?

FQ11 Can the route be delivered with acceptable safety?

FQ12 Can fares be protected, on-board riders be safe, and accessible transport all be provided pragmatically?

FQ13 Will an automated solution be legislated for and insurable?

FQ14 Would a CAM solution be expected to provide value for money?

FQ15 Is automated transport a secure technology? (Physical & Digital)

FQ16 Will an automated solution that can technically serve this route be ready within stated target timeframes?

FQ17 Are transport operators open to exploring delivering CAM services?

FQ18 Will there be system / vehicle manufacturers ready to deliver the scale of system, with sufficient demonstrable evidence of delivery and funding to secure public / commercial contracts?

FQ19 Can we Compulsory Purchase Order (CPO) for CAM solutions; is it politically palatable?

FQ20 Do we want to be first? Is there any advantage to being first? What are the disadvantages of being first?

FQ21 Will a CAM solution be socially accepted? Will it be abused / a target for abuse that makes it unreliable / unusable?

1. Introduction

The study will use a traffic light system to summarise Feasibility Question findings

1.3 Study Methodology

Rating

The extent to which the Feasibility Questions are answered, and the level of certainty of the answer, is indicated in the final summary slide of each chapter. For this, a Red Amber Green (RAG) methodology is used. Each assessment is qualified with summary narrative, and where necessary references are provided.

Optimism Bias

Although an automated vehicle manufacturer (ZF) are a consortium member, this report seeks to remain neutral and unbiased in its assessment of the potential for the technology. Engagement of a leading sector expert to act as an independent technology Subject Matter Expert within the consortium (Syselek) is seen as a core mitigation to the identified risk.

Red = **Unfeasible - Stop**. From work undertaken the answer to the FQ is negative and therefore the automated transport route has been deemed not feasible at this point

Amber = **Feasible – Further Work Advised**. The FQ appears feasible however further investigation is recommended. In such instances recommendations for further investigation are provided

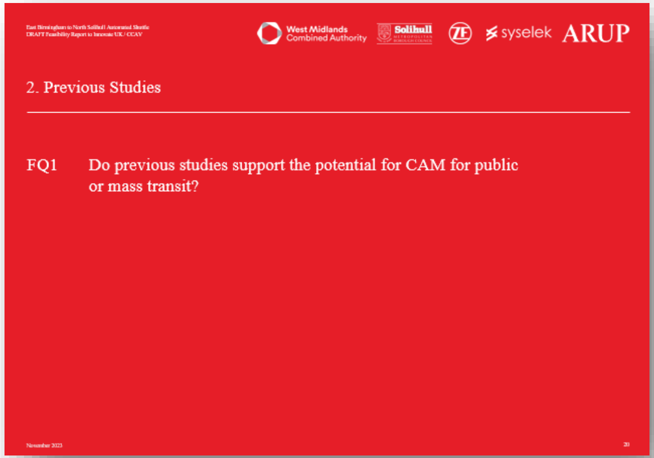
Green = **Feasible - Proceed**. From the work undertaken the answer to the FQ is positive, and no / limited concerns have been identified

1. Introduction

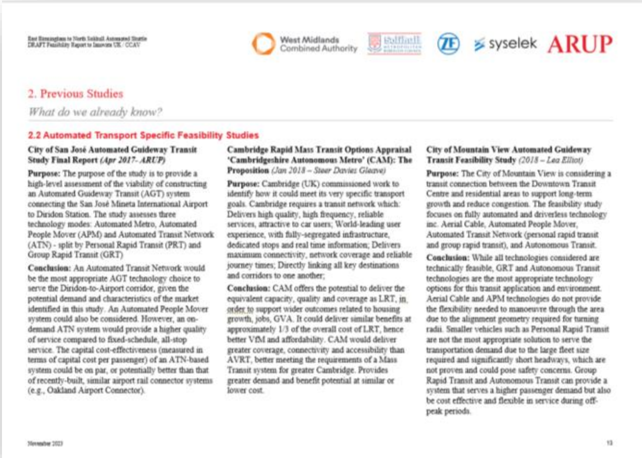
Can we connect East Birmingham and North Solihull with Automated Transport?

1.4 Report Structure

The 21 Feasibility Questions are answered across the 11 chapters of the report. Each chapter title page identifies the specific questions to be answered within the chapter, followed by the contents of the chapter, and finally a RAG status at the chapter summary.


2. Previous Studies

FQ1 Do previous studies support the potential for CAM for public or mass transit?


2. Previous Studies

What do we already know?

2.2 Automated Transport Specific Feasibility Studies

City of San José Automated Guideway Transit Study Final Report *(Apr 2017- ARUP)*

Purpose: The purpose of the study is to provide a high-level assessment of the viability of constructing an Automated Guideway Transit (AGT) system connecting the San José Mineta International Airport to Diridon Station. The study assesses three technology modes: Automated Metro, Automated People Mover (APM) and Automated Transit Network (ATN) - split by Personal Rapid Transit (PRT) and Group Rapid Transit (GRT)

Conclusion: An Automated Transit Network would be the most appropriate AGT technology choice to serve the Diridon-to-Airport corridor, given the potential demand and characteristics of the market identified in this study. An Automated People Mover system could also be considered. However, an on-demand ATN system would provide a higher quality of service compared to fixed-schedule, all-stop service. The capital cost-effectiveness (measured in terms of capital cost per passenger) of an ATN-based system could be on par, or potentially better than that of recently-built, similar airport rail connector systems (e.g., Oakland Airport Connector).

Cambridge Rapid Mass Transit Options Appraisal 'Cambridgeshire Autonomous Metro' (CAM): The Proposition *(Jan 2018 – Steer Davies Gleave)*

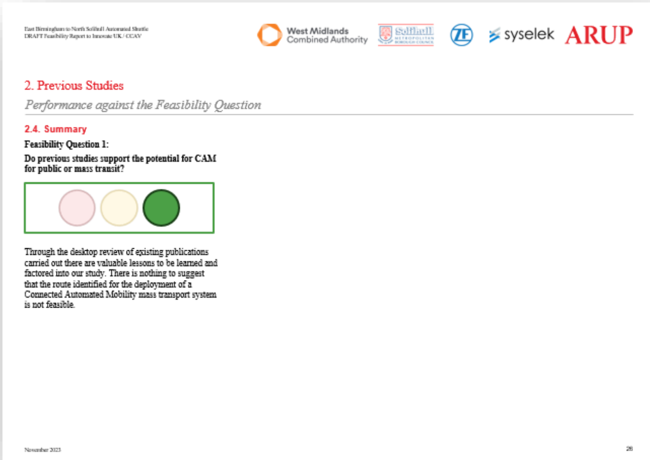
Purpose: Cambridge (UK) commissioned work to identify how it could meet its very specific transport goals. Cambridge requires a transit network which: Delivers high quality, high frequency, reliable services, attractive to car users; World-leading user experience, with fully-segregated infrastructure, 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;

Conclusion: CAM offers the potential to deliver the equivalent capacity, quality and coverage as LRT, in order to support wider outcomes related to housing growth, jobs, GVA. It could deliver similar benefits at approximately 1/3 of the overall cost of LRT, hence better VfM and affordability. CAM would deliver greater coverage, connectivity and accessibility than AVRT, better meeting the requirements of a Mass Transit system for greater Cambridge. Provides greater demand and benefit potential at similar or lower cost.

City of Mountain View Automated Guideway Transit Feasibility Study *(2018 – Lea Elliot)*

Purpose: The City of Mountain View is considering a transit connection between the Downtown Transit Centre and residential areas to support long-term growth and reduce congestion. The feasibility study focuses on fully automated and driverless technology inc. Aerial Cable, Automated People Mover, Automated Transit Network (personal rapid transit and group rapid transit), and Autonomous Transit.

Conclusion: While all technologies considered are technically feasible, GRT and Autonomous Transit technologies are the most appropriate technology options for this transit application and environment. Aerial Cable and APM technologies do not provide the flexibility needed to manoeuvre through the area due to the alignment geometry required for turning radii. Smaller vehicles such as Personal Rapid Transit are not the most appropriate solution to serve the transportation demand due to the large fleet size required and significantly short headways, which are not proven and could pose safety concerns. Group Rapid Transit and Autonomous Transit can provide a system that serves a higher passenger demand but also be cost effective and flexible in service during off-peak periods.


2. Previous Studies

Performance against the Feasibility Question

2.4. Summary

Feasibility Question 1:

Do previous studies support the potential for CAM for public or mass transit?

Through the desktop review of existing publications carried out there are valuable lessons to be learned and factored into our study. There is nothing to suggest that the route identified for the deployment of a Connected Automated Mobility mass transport system is not feasible.

2. Previous Studies

FQ1 Do previous studies support the potential for CAM for public or mass transit?

2. Previous Studies

We will provide a summary of study work on this corridor; international feasibility studies and academic research

2.0 Introduction

2

This chapter is split into three sections and serves as a 'lessons-learned' scan. The first section will consider previous work undertaken along this route, followed by a summary of similar automated transport feasibility studies, and finishing with a review of applicable academic studies that relate in some way to the aims of this paper.

2. Previous Studies

Significant foundational work has already been done to develop the case for mass transit on this route

2.1 Route Specific Studies

Strategic Case

The business case for a tramway connecting East Birmingham to Solihull has previously been investigated in-depth. An Interim Outline Business Case (IOBC) exploring the strategic, economic and commercial case, as well as an assessment of associated wider benefits, was published in August 2016. While several assumptions laid out in this IOBC do not reflect the current post-COVID and climate emergency landscape, the strategic case for the scheme remains largely unchanged.

Scheme objectives:

- Support regeneration in areas of high deprivation through improved connectivity with areas of opportunity
- Support economic development by improving the accessibility of (major) employment sites
- Encourage modal shift from private car by delivering a high quality and reliable public transport service
- Support an integrated transport network through providing seamless interchange
- Deliver a high-quality public transport service that supports local environmental and safety benefits.

The corridor is reliant on connections into the wider Midland Metro network. Provision of a seamless journey, together with the improved ride quality of tram vehicles, high quality passenger information and tram stop infrastructure were identified as key benefits for a tramway rather than enhanced bus or Bus Rapid Transport (BRT) service. Note that any non-Light Rail Transit (LRT) mode would require an interchange to take passengers onwards from the existing Midland Metro system. This would require considerations around integrated ticketing and provision of a user-centric interchange hub.

Three corridors were considered for this scheme, with the route via Bordesley Green ultimately taken forward for future business case development as it was found to serve more intermediate trip attractors, including Heartlands Hospital and Chelmsley Wood Shopping centre and St Andrew's football stadium.

The selected corridor suffers from chronic road congestion and a narrow highway corridor without width to enable segregated running. A tramway through the route would require the demolition of several commercial and residential premises, as well as historic buildings including a Snooker Hall and Fire Station. The narrower corridor width associated with an automated transport solution may lessen the need for demolition and road widening along the route.

A frequency of 5 trams per hour was proposed along the route. The journey time from High Street Deritend to Birmingham Interchange was approximated at 44 minutes, or 54 minutes to Victoria Square/ Birmingham Town Hall.

Economic Case

An environmental assessment of the route presented no ‘red flag’ environmental matters. Three sensitivity tests on the economic case found that value for money for the proposed tramway could be maintained even with a material increase or decrease in benefits and costs. Several beneficial social impacts were identified as a result of the proposed scheme, including on accessibility, reliability, access to services and on journey quality.

Wider Benefits Assessment

The wider impacts of the development of the corridor were found to contribute to a number of wider policy aims and the scheme objectives, including supporting regeneration, improving labour market accessibility and supporting the viability of new developments.

Other Studies

The East Birmingham to Solihull Medium-Term Options study also reviewed existing issues along this corridor and suggested options that may precede a tram/metro rapid transit option. A CAM Mass transit package was one identified solution.

2. Previous Studies

Similar feasibility studies have produced positive initial findings

2.2 Automated Transport Feasibility Studies – Desktop Study Summary

By way of identifying any lessons learned from previous automated transport mass transit studies a scan of equivalent publicly accessible studies was carried out.

City of San José Automated Guideway Transit Study Final Report (Apr 2017- ARUP)

This study provides a high-level assessment of the viability of constructing an Automated Guideway Transit (AGT) system connecting the San José Mineta International Airport to Diridon Station. The study assesses three technology modes: Automated Metro, Automated People Mover (APM) and Automated Transit Network (ATN) - split by Personal Rapid Transit (PRT) and Group Rapid Transit (GRT)

The study concluded an Automated Transit Network would be the most appropriate given the potential demand and characteristics of the market identified in this study. The capital cost-effectiveness (measured in terms of capital cost per passenger) of an ATN-based system could be on par, or potentially better than that of recently-built, similar airport rail connector systems.

Cambridge Rapid Mass Transit Options Appraisal 'Cambridgeshire Autonomous Metro': The Proposition (Jan 2018 – Steer Davies Gleave)

Cambridge (UK) commissioned work to identify how it could meet its very specific transport goals. The study concluded that CAM offers the potential to deliver the equivalent capacity, quality and coverage as LRT, to support wider outcomes related to housing growth, jobs, GVA. It could deliver similar benefits at approximately 1/3 of the overall cost of LRT, hence better VfM and affordability.

City of Mountain View Automated Guideway Transit Feasibility Study (2018 – Lea Elliot)

This study considers a connection between the Downtown Transit Centre and residential areas to support long-term growth and reduce congestion. The feasibility study focuses on fully automated and driverless technology inc. Aerial Cable, Automated People Mover, Automated Transit Network (personal rapid transit and group rapid transit), and Autonomous Transit.

The study concludes that while all technologies considered are technically feasible, GRT and Autonomous Transit technologies are the most appropriate technology options for this transit application and environment. Group Rapid Transit and Autonomous Transit can provide a system that serves a higher passenger demand but also be cost effective and flexible in service during off-peak periods.

East Contra Costa County Dynamic Personal Micro Transit Feasibility Study Report (2021 Advanced Mobility Group)

The purpose of this Feasibility Study was to analyse whether constructing and operating a DPMT system in the East County region is feasible and beneficial. The Study investigates how it operates, the potential benefits, potential ridership demand, implementation costs, and identification of risk mitigation strategies, potential business models, and funding strategies.

The assessment of various criteria in this feasibility study determines that the DPMT is feasible. A phased, Automated Transit Network (ATN)-based DPMT solution will bring micro transit connectivity to provide a faster, smoother, and higher quality mobility experience for its residents.

Summary

1. Automated systems are being considered across the globe and have been found to be feasible in differing forms
2. Assessed against other 'driverless' technologies Autonomous Transit Network (ATN) systems compare favourably in installation and operational cost terms

2. Previous Studies

Significant academic research has been undertaken in this space, providing valuable learning

2.3 Academic Literature Review – Desktop Study Summary

Globally, research into how automated transport will impact traditional transportation systems has been extensive. Relevant high-level findings from a literature review of academic studies are presented here.

- Automation is, on average, not necessarily perceived as valuable, if the travel time and fare of the systems are the same as those of a conventional bus. *Users' preferences towards automated road public transport: results from European surveys (2014)*
- If driver wage is no longer part of the cost structure, it might be worthwhile to operate buses with smaller capacities and higher frequencies. Not only is demand bundling, when possible, more economic than point-to-point service, there is also a user preference for high-frequency, line-based service over dynamic services. *Cost-based analysis of autonomous mobility services (2017)*
- It is expected that vehicle automation in more fixed modes of public road transport could primarily benefit the transport industry and government, with such effects as improved labour productivity and reduced subsidies. *Introducing autonomous buses and taxis: Quantifying the potential benefits in Japanese transportation systems (2019)*
- Should private ridesharing operators enter the market as competitors of public transport, decreasing passenger numbers could make conventional bus lines less profitable, creating a vicious circle of reducing costs by reducing services and falling passenger volumes. *Should autonomous shared taxis replace buses? A simulation study (2019)*
- Analytical and numerical results show that fully autonomous buses exhibit great potential through reduced operating and waiting costs even if the additional capital cost is high. A commercial speed comparable to conventional vehicles is crucial. The reduction in crew cost, the main component of the current bus cost structure, compensates for the loss in capital cost and allows the operator to work with smaller buses and larger fleets. This reduces the service headway, which is an improvement of the level of service by shorter waiting times. *Efficiency of Semi-Autonomous and Fully Autonomous Bus Services in Trunk-and-Branches Networks (2019)*
- Results show that intention to use autonomous buses was mostly positive both before and after using them. Most users felt safe while traveling by autonomous bus. Two suggestions for improvement made by the users were to: increase the speed and reduce the abrupt breaking of the autonomous buses. Overall, outcomes from this paper suggest that residents would be willing to use autonomous buses if these offer more frequent bus departures than the existing ones. *Autonomous buses: Intentions to use, passenger experiences, and suggestions for improvement (2020)*
- It is essential to propose secure, useful and comfortable autonomous systems if we wish to encourage more wide-spread adoption. Preventive equipment, such as seat belts, child safety seats, video surveillance or a means of dealing with emergencies (for example, a button for emergency stops or to open the doors and a means of communication) could also be made available. Potential users also require a means of compensating for the absence of a driver - for example, information screens and easy, obstacle-free access to the vehicle. *Factors of acceptability, acceptance and usage for non-rail autonomous public transport vehicles: a systematic literature review (2020)*

2. Previous Studies

Significant academic research has been undertaken in this space, providing valuable learning

2.3 Academic Literature Review – Desktop Study Summary

- Introduction of autonomous bus is a critical factor in increasing the effectiveness of road capacity as not only will the flow rate of traffic increase, but also more passengers can be accommodated. *Simulation Study of Autonomous Vehicles' Effect on Traffic Flow Characteristics including Autonomous Buses (2020)*

- For the user, the biggest impact of autonomous bus (AB) is the increased service frequencies which in turn can lead to a reduction in waiting time. However, due to the more attractive service, it can be expected that the passenger load on these lines is increased. For the operators of AB fleets, the main consequence is the shift in service frequency and the potentially longer operation times. The consequences of this study for manufacturers of AB are twofold. First, the study is in line with existing research which proposes a trend towards smaller bus capacities, which in turn requires smaller bus vehicles and leads to changed manufacturing needs. Second, in areas with high PT demand and especially between high demand OD pairs bigger buses will still be required to facilitate all passenger journeys efficiently. A complete shift towards small buses is therefore not likely. *Transition Towards Fixed-Line Autonomous Bus Transportation Systems (2020)*

- Initially, people are attracted to use a service if they perceived the information of the service to be sufficient, but they are demotivated to continue using the service if the comfort was worse, frequency was lower, or travel time was longer than expected. To promote individuals continued use of ABs, the public transport authorities and operators should work closely to increase the frequency of the services. It is also necessary to enhance the comfort of the ABs. *The dynamic and long-term changes of automated bus service adoption (2021)*

- The deployment of autonomous buses on fixed-line public transport networks leads to a reduction of operator costs and an increased infrastructure cost this is mainly due to the reduction in operating costs and an increase in total network length. As a direct consequence of the longer network the number of passengers boarding a bus is 2-3 times higher in the case of AB deployment compared to conventional systems. *Network design for line-based autonomous bus services (2021)*

- Non-technical challenges such as consumer trust, governance, and human behaviour towards autonomous driving play a major role in bringing AVs and related technologies to widespread use. *A Review on Autonomous Vehicles: Progress, Methods and Challenges (2022)*

- Over 70% of residents in the study reported having intentions to use the AB and public acceptance indicators suggest that it is feasible to implement this integrated AB-LRT system. *Autonomous Bus Pilot Project Testing and Demonstration using Light Rail Transit Track (2022)*

Summary:

Several valuable conclusions are reached that are relevant to this study.

1. Any system must be frequent, fast, comfortable & cost-effective to the end user
2. Lower capacity, more frequent services are desirable
3. Line-based services are valued
4. There is risk posed by automated taxis entering the space
5. Reduction in labour costs may be offset by increases in infrastructure costs
6. Indications suggest users would readily use automated services
7. Compensating for the absence of a driver will be crucial to providing a sense of safety & adoption

2. Previous Studies

Performance against the Feasibility Question

2.4. Summary

Feasibility Question 1:

Do previous studies support the potential for CAM for public or mass transit?

Through the desktop review of existing publications carried out there are valuable lessons to be learned and factored into our study. There is nothing to suggest that the route identified for the deployment of a Connected Automated Mobility mass transport system is not feasible.

3. EBNS Strategic Context

FQ2 Is this route supported by local, regional and / or national strategy and policy?

FQ3 Do future plans on this route support its viability?

3. EBNS Strategic Context

We will provide a review of national, regional, and local policy to support of the delivery of change.

3.0 Introduction

3

To understand the extent to which a) a public transport link along this route, and b) delivered by automated technology would be strategically supported, a deep dive of local, regional and national strategy will be undertaken.

3. EBNS Strategic Context

A review of national, regional, and local policy to support of the delivery of change.

3.1 National Policy

Decarbonising transport: a better, greener Britain

The 'Decarbonising transport: a better, greener Britain' white paper was published by the UK government in 2021. The white paper states that the transport sector is responsible for around a third of the UK's greenhouse gas emissions, and reducing those emissions is key to meeting the national net-zero emissions target by 2050.

Measures outlined in the white paper include the promotion of the use of zero-emission vehicles, improving public transport networks, alongside supporting the development of new electricity technologies for vehicles.

The government committed in the white paper to embed transport decarbonisation in spatial planning and across transport policymaking, alongside highlighting the need for collaboration between government, industry and consumers to achieve the goal of transport decarbonisation.

Deployment of CAM solutions will support decarbonisation by potentially improving the availability, reliability and frequency of public transport. This will make public transport a more viable option verses private vehicle usage

Future of Mobility: Urban Strategy

The 'Future of mobility: urban strategy' was published in March 2019 and outlines the government's approach to maximising the benefits from transport innovation in cities and towns. It sets out the principles that will guide government's response to emerging transport technologies and business models.

The strategy also contains details of the next steps for the government's Future of mobility grand challenge.

Alongside the strategy, the Department for Transport (DfT) has published the summary of responses to its Future of mobility call for evidence.

This proposal supports this policy by investigating the potential to deploy a CAM service along a known corridor and compare it to alternative transport plans. This give a realistic comparison and highlights area where further research is needed

National Planning Practice Guidance (NPPG)

The NPPG, or National Planning Practice Guidance, outlines the purpose of Transport Statements and sets out what should be included in them, for developments that generate a high quantity of traffic movement. According to the National Planning Practice Guidance, a Transport Statement should also consider:

- Information about the proposal and its layout;
- Information about neighbouring uses, character and amenity, alongside functional classification of the nearby road network;
- Existing public transport provision;
- A description of travel characteristics of the proposed development, including movements across all modes of transport which would result from the proposal going ahead; and
- Data relating to the current traffic flows on links/at junctions within the study area, and identification of critical links and junctions on the road network.

3. EBNS Strategic Context

A review of national, regional, and local policy to support the delivery of change.

3.1 National Policy

National Planning Policy Framework (NPPF)

The National Planning Policy Framework (NPPF) sets out the government planning policies for England and how they should be applied. It provides a framework which locally prepared plans for all developments can be produced.

All developments which generate significant amounts of movement should be supported by a Transport Statement (TS) or Transport Assessment (TA). These documents set out potential transport impacts and implications on the network of developments.

In line with the NPPF guidance, all developments should:

- Promote sustainable transport modes where possible;
- Provide a safe and suitable access to the site for all users;
- Present a design of streets, parking areas and other transport elements to the associated standards to reflect current national guidance; and
- Assess any significant impacts from the development on the transport network so that they can be cost effectively mitigated to an acceptable degree.

Developments should only be refused on ‘highway grounds’ if there would be an unacceptable impact on highway safety, or the residual impacts on the road network would be severe.

The work in this report has followed the recommendations in both the NPPG and NPPF.

3. EBNS Strategic Context

A review of national, regional, and local policy to support the delivery of change.

3.1 National Policy

Connected and Automated Vehicle Policy

The UK government has developed opportunities for the development of Connected and Automated Mobility vehicles (CAM) primarily through the Centre for Connected and Autonomous Vehicles (CCAV), but also through projects that predate CCAV. These projects were documented in UK Connected & Autonomous Vehicle Research & Development Projects 2018, published in September 2018. In the same year, the Automated and Electric Vehicles Act 2018 was passed into UK law and set out the initial legal framework for the use of CAM services in the UK. The following is an illustrative selection of examples where research has developed into policy/legislation.

Connected and automated vehicles: process for assuring safety and security (CAVPASS)

The programme was launched in 2019 in response to the Law Commissions' first consultation paper on safety, which was part of their multi-year review of legislation and self-driving vehicles and continues with their current review into remote driving.

The objectives of CAVPASS are to:

- develop technical standards and regulations to ensure the safe and secure trialling, adoption and ongoing roadworthiness of self-driving vehicles
- develop processes to authorise a vehicle, thereby permitting the vehicle to drive itself, and ongoing requirements to maintain the validity of this authorisation
- develop and/or adapt rules on the safe use of self-driving vehicles, such as through the Highway Code, driver, vehicle and service licencing, and insurance
- ensure the government has the skills, capabilities, and access to assets to deliver safe and secure use of self-driving vehicles
- support safe trialling of prototype self-driving vehicles on our roads and ensure the UK is industry's trialling destination of choice, building on the Code of Practice: automated vehicle trialling
- design and implement processes to ensure that self-driving vehicles have resilience and can respond to cyber-attacks, and that the data they hold is secure.

The CAM solution being considered in this report has been reviewed and found to be comply with cyber security standards. This supports the goal of CAVPASS

Code of Practice: automated vehicle trialling

The code of practice is primarily intended to be used by organisations or individuals planning to trial or pilot automated vehicle technologies and services. The code is also useful to inform local authorities and others on engaging in trials.

The code aims to:

- support and promote the safe trialling and use of automated vehicle technologies and services on public roads or in other public places in the UK and build public confidence in automated vehicle technologies and services
- support cooperation between trialling organisations and those responsible for the management of traffic, infrastructure, law enforcement, and other areas to support maximum road safety
- encourage sharing of information to help uphold and develop the highest standards of safety in the UK and internationally

If the service being analysed in this report were go to trial stages, the code of practice would be adhered to closely.

3. EBNS Strategic Context

A review of national, regional, and local policy to support the delivery of change.

3.1 National Policy

The Highway Code

From the 1st July 2022, the Highway Code added a section to the Introduction that discusses Self-Driving Vehicles. This section specifically refers to

"Vehicles [that] are capable of safely driving themselves when the self-driving function is correctly turned on and the driver follows the manufacturer's instructions. While the vehicle is driving itself, you do not need to monitor it."

It can be inferred from the above, the section is only discussing Level 4 and Level 5 autonomy and clearly states that the driver of such a vehicle must be prepared to take control when requested by the vehicle.

Additionally, in February 2023 the Law Commission issued advice to the UK government on Remote Driving advising that operating a vehicle with a remote driver must either be within line-of-sight. If the remote driver is beyond line-of-sight, there must be a safety driver in the vehicle. However, this advice does not affect a vehicle where a person cannot take direct control of vehicle manoeuvres and only advises the vehicle to perform a manoeuvre.

Connected & Automated Mobility 2025: Realising the benefits of self-driving vehicles in the UK

This document, published in August 2022, sets out the UK government's goals and the potential benefits of the CAM industry. It covers all of the Law Commission's recommendations for legislation to allow the safe deployment and operation of CAM vehicles on UK roads.

It also discusses the societal and economic benefits of making the UK a driving force in the development and deployment of the CAM industry.

The King's Speech 2023

On 7th November 2023 at the State Opening of Parliament, His Royal Highness King Charles III gave the King's Speech. In this speech was the Automated Vehicles Bill with the scope of:

Set a rigorous safety framework for self-driving vehicles:

- Aims to set the threshold for self-driving vehicles in law.
- Hold companies firmly accountable once vehicles are on roads.
- Investigate and learn from incidents.
- Digitalise Traffic Regulation Orders.

Ensure clear legal liability:

- Create new organisations responsible for self-driving.
- Protect users from being unfairly held accountable.

Protect the Consumer:

- Clamp down on misleading marketing.

3. EBNS Strategic Context

A review of national, regional, and local policy to support the delivery of change.

3.2 Regional Policy

Reimagining transport in the West Midlands: Local Transport Plan 5 (LTP5)

The West Midlands Local Transport Plan 5, dubbed ‘Reimagining transport in the West Midlands’, has been approved by the WMCA board in February 2023 and can be found within its board papers. The document is based around the ‘Six big moves’ – which are detailed areas of thematic policy for the whole region. These are detailed and explained in Figure 3.2.

Specific to the corridor, the LTP5 proposes a high quality integrated public transport system and complementary shared mobility services to help achieve a 45-minute region and 15-minute neighbourhoods without the need to use a car. This is where the whole of the WMCA will be accessible within 45 minutes of anywhere in the WMCA, and all essential amenities will be within 15 minutes’ walk for local residents.

A set of rapid transit corridors has been identified by the WMCA to help achieve the high quality integrated public transport system, of which the EBNS corridor is highlighted in Figure 3.1.

The proposal would support the LTP5 goals by extending the links to the corridor from Birmingham city centre, which to currently served, to Birmingham Business Park, the NEC, Resort World Birmingham Airport, Birmingham International rail station and HS2 Interchange station. This support would help achieve the 6 big moves shown in Figure 3.2.

Figure 3.1: West Midlands Priority Rapid Transit Corridors

Figure 3.2: The 6 big moves for the West Midlands

Behaviour change
- This policy sets out the need to tackle the high level of car dependency in the West Midlands, and the danger of not meeting the core goals of the LTP if the big move is not met.
- The vision is that wherever you live in the West Midlands, you do not need to own a car to live a full life.

Accessible and inclusive places
- This policy sets out the vision of creating more accessible places where people don't require a car to live a good life.
- This includes the introduction of more careful placemaking with accessibility in mind.

Safe, efficient and reliable network
- This policy sets out the vision to develop and manage the highway network in the region in a way that improves reliability, and better supports travel by sustainable modes.

Walk, wheel, cycle and scoot
- This policy sets out that people should be able to walk, wheel, cycle or scoot when and where they want, with safety and convenience in mind.
- The aim is for half of the trips in the West Midlands to be made by active modes by 2030.

Public transport and shared mobility
- The ambition of the policy is to deliver a high-quality and affordable public transport system (including fixed services and DRT), branded as a single system.
- This policy will deliver on the West Midlands' ambition for a 45-minute region and 15-minute neighbourhoods.

Green transport revolution
- According to this policy, the whole transport system (including its infrastructure) should have a significantly lessened effect on the environment. For example, by installing new EVCI infrastructure.

3. EBNS Strategic Context

A review of national, regional, and local policy to support the delivery of change.

3.2 Regional Policy

Midlands Connect Strategic Transport Plan

The Midlands Connect Strategic Transport Plan acts as the statutory STP for the Midlands Connect area, of which the West Midlands is contained. It was published in 2022 (five years after their initial one was published in 2017) and sets out three 'Grand challenges' as well as three priorities. These are shown in Figure 3.3 and Table 3.1 respectively.

This proposal would support this plan by allowing residents to link in to the wider Midlands network and beyond.

Figure 3.3: Midlands Connect Grand Challenges

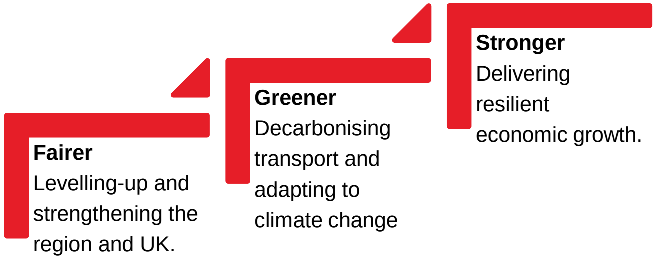


Table 3.1: Midlands Connect Three Priorities

Mode	Description	Example Priorities
Rail	Encouraging more people to use the rail network, including by taking forward the Midlands Engine Rail programme which includes a series of improvements to the network across the region.	Establishing a direct rail service between Coventry, Leicester and Nottingham Acceleration of Midlands Rail Hub schemes at Kings Norton and Snow Hill
Road	Looking into investing in roads in a sustainable way, reducing congestion-related emissions and improving the infrastructure road users need to travel via alternative modes such as bus or alternatively fuelled vehicles.	Improvements to the A46, A5 and A50/A500. Enhancing access to important junctions on M1, M6 and M5.
Innovation	Working to secure a future where digital technologies make roads more efficient, alongside public charging points becoming available more widely as well as developing new innovative mobility solutions to connect isolated communities.	Supporting the roll-out of public EV chargers across the Midlands. Creating a network resilience map to understand how transport, tech and energy generation interventions can work together to address climate change.

3. EBNS Strategic Context

A review of national, regional, and local policy to support the delivery of change.

3.2 Regional Policy

West Midlands Bus Service Improvement Plan

The West Midlands Bus Service Improvement Plan (BSIP), was published in November 2021, and envisions a world-class integrated, reliable, zero emission public transport system providing inclusive travel across the West Midlands. The BSIP sets out the objectives shown in Figure 3.5.

Part of the plan includes the introduction of an additional 106km of bus lanes across the region and the development of a wider bus priority programme ready for delivery beyond 2025. Six cross-city bus routes have been proposed, including West Bromwich to East Birmingham in 2024, and the Outer Circle which run through the study area. Further to this, bus priority measures are planned across the study area with Sprint forecast for completion along the A45 in the period 2022-2025 as well as other bus priority measures along the 97 Route from Birmingham to Chelmsley Wood, via Heartlands Hospital, and the X12 route via Castle Bromwich and Smiths Wood.

From 2025 onwards the BSIP proposes bus priority measures along the corridor that broadly follows the 94 bus route via Ward End. The proposed bus priority routes and timescales are shown in Figure 3.4. It should be notes that some of these plans are under review as the scale of BSIP is being rescoped.

Figure 3.4: West Midlands Bus Priority Network

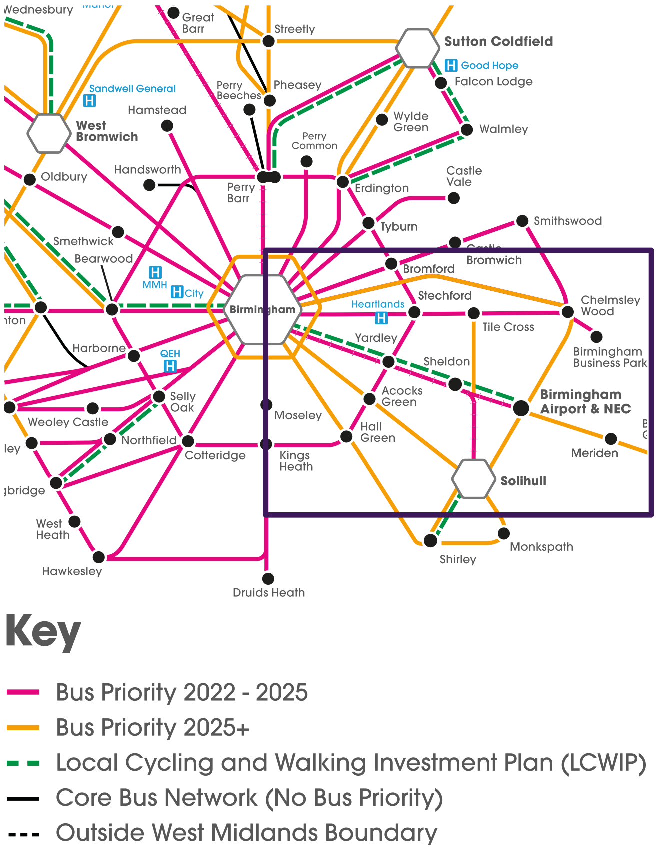


Figure 3.5: West Midlands BSIP objectives

- Fewer private car journeys, by making bus the mode of choice.
- Evolve the network to support the 24/7 thriving economy.
- Fully integrated bus network including DRT and integration with rail, coach and Metro.
- Simple, convenient and easy to use payment options.
- Younger people supported by discounted travel.
- Accountable network performance management.
- World-leading customer information.
- A safe, secure and accessible mode for all.
- UK leading low emission bus fleet.

3. EBNS Strategic Context

A review of national, regional, and local policy to support the delivery of change.

3.3 Local Policy

Birmingham City Council Transport Plan (2021)

Adopted in October 2021, the Birmingham City Council Transport Plan's purpose is to outline how the city's transport network needs to be transformed to meet the challenges of the 2020s. The Council have set out the following key objectives of the plan:

- Sustain economic success and support the creation of new jobs, development of new skills, and inward investment.
- Support, empower and connect communities to create a healthier and just society, and a better quality of life for all citizens.
- Reduce the negative impacts of transport on the environment to make Birmingham a great place to live, grow up, and age in.
- Urgently and drastically reduce carbon emissions from transport to contribute to the City Council's and the region's decarbonisation commitments.

According to the plan, the climate emergency 'underpins' the objectives for Birmingham and therefore is the 'driver' for the plan.

The four main principles of the plan are:

- Reallocating road space;
- Transforming the city centre;
- Prioritising active travel in local neighbourhoods;
- Managing demand through parking measures.

3. EBNS Strategic Context

A review of national, regional, and local policy to support the delivery of change.

3.3 Local Policy

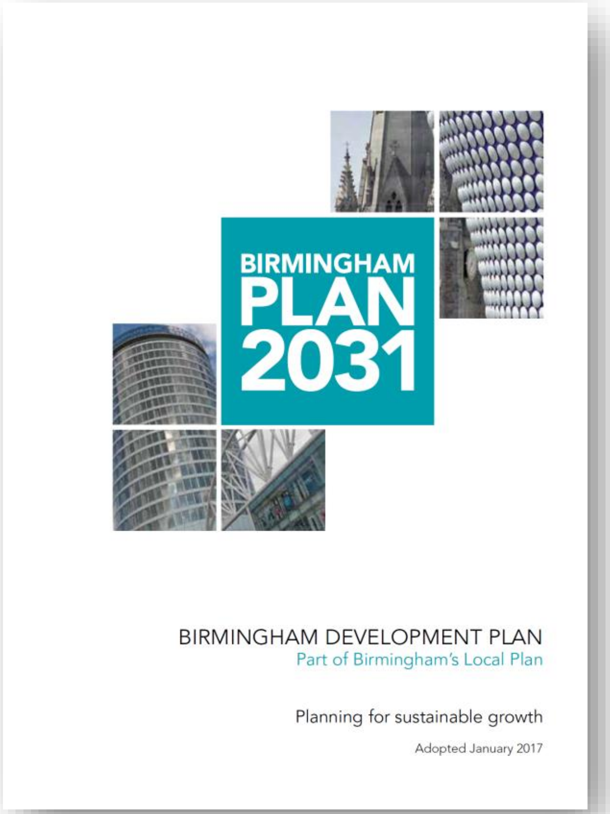
Birmingham Development Plan (2017)

The Birmingham Development Plan is the statutory framework for Birmingham which governs planning framework, guiding decisions on all development and regeneration activity from 2011 to 2031.

It lays out detailed policy surrounding new housing and business developments, alongside how they should be served by transport. Most of these policies are set out in the 'Connectivity' section:

Policy TP39 governs walking, creating 'safe and pleasant walking environments' throughout the city.

- Policy TP40 governs cycling, which will be encouraged through 'a comprehensive city-wide programme of cycling infrastructure improvements' supported by a 'programme of cycle promotion, accessible cycling opportunities, training and travel behavioural change initiatives'.
- Policy TP41 governs public transport:
    - According to the plan, bus remains the most important mode of public transport in Birmingham. BCC will work with Centro (TfWM) to improve the bus network in a variety of ways.
    - BCC will support plans to enhance the City's rail network, such as reopening the Camp Hill and Sutton Park lines, alongside the delivery of the Camp Hill Chord and expansion of park and ride sites and railway stations.
- BCC will support the following Metro and BRT schemes in particular:
    - A new Metro station at All Saints;
    - An extension of the Metro from New Street to Edgbaston Village (completed 2022);
    - An extension of the Metro from the City Centre to Eastside and Curzon Street;
    - Additional Sprint corridors with cross city centre links on a number of key corridors. Specifically in relation to this project:
    - Birmingham City Centre – Airport (via East Birmingham).
    - Birmingham City Centre – Airport (via A45).



3. EBNS Strategic Context

A review of national, regional, and local policy to support the delivery of change.

3.3 Local Policy

East Birmingham Inclusive Growth Strategy (2021)

The East Birmingham Inclusive Growth Strategy, published by Birmingham City Council in February 2021, is the strategy responsible for growth and development of the East Birmingham and North Solihull corridor. Inclusive growth is defined by the West Midlands Combined Authority as:

"A more deliberate and socially purposeful model of economic growth – measured not only by how fast or aggressive it is; but also by how well it is created and shared across the whole population and place, and by the social and environmental outcomes it realises for our people – an economy that shares the values of its citizens"

It discusses opportunities and challenges in East Birmingham, alongside five 'Big moves', including discussion around:

- West Midlands Metro East Birmingham to Solihull extension
- Discusses the proposals made by Transport for West Midlands on a Metro extension from East Birmingham to Solihull via Birmingham Airport, UK Central, Birmingham Business Park and both new HS2 stations (Interchange and Curzon Street). The route would also pass through key existing locations, such as Bordesley Park, Heartlands Hospital and the Meadway redevelopment.
- Specifically, the strategy proposes the following measures:
  - Birmingham City Council and 'East Birmingham Board' will work with Transport for West Midlands to bring forward the Metro extension as soon as possible, including the development of a strong business case to UK government;
  - Ensure that stops on the extension work efficiently alongside other transport enhancements and link with active travel routes; and
  - Ensure that the social value benefits of Metro will be maximised, such as apprenticeships and training as well as links with supply chain.
- Heavy rail network

The strategy explains that there are three railways running through East Birmingham, which provide connections to Central Birmingham alongside regional and national destinations. HS2 at Curzon Street and Interchange will also pass through the area.

- According to the strategy, rail travel in East Birmingham is less popular and more difficult to use than in other parts of the city because of the difficulty of getting to a station and comparatively long waiting times between trains, outside Birmingham International Station.
- There are major plans in the pipeline to improve the rail services in East Birmingham over the lifetime of this strategy. For example, HS2 will provide a new connection between Central Birmingham and Birmingham International, meaning space will be freed up on existing routes and allow the operation of more frequent services.
- Midlands Connect are also making the case for new rail services across the region – through the Midlands Rail Hub scheme.

3. EBNS Strategic Context

A review of national, regional, and local policy to support the delivery of change.

3.3 Local Policy

Solihull Connected Transport Strategy (2023)

The Solihull Connected Transport Strategy 2023 identifies how those within the borough travel, and sets out the changes that should be made in the coming years to achieve four key objectives:

- To make the transport network accessible to all people;
- To help the economy grow in a way that is equal and fair for everyone;
- To be safe and secure for all users; and
- Transport will contribute to improving the quality of life in our borough.

Within the Council Plan itself, there are nine key things to do which these objectives underline:

- Being part of revitalising our towns and local centres;
- Being part of bringing forward UK Central and maximising the opportunities from the new HS2 railway line and Birmingham Interchange railway station;
- Providing access to areas of new housing;
- Enhancing the natural environment;
- Improving air quality;
- Reducing net carbon emissions;
- Improving life chances in our most disadvantaged communities by improving access; and
- Enabling our communities to thrive.

Solihull Local Plan (2013)

The Solihull Local Plan (2011-2028) is the statutory development plan for the borough of Solihull. It's responsible for setting out the long-term vision for how its towns, villages and countryside will be developed and how they will change over the plan period above.

By 2028, the vision for Solihull is to build on its reputation as an 'aspirational' place to live, learn, work and play. It would like to maintain its strong links with Birmingham and the GBSLEP area, alongside Warwickshire to the south and Coventry to the east – where the potential for 'managed growth within the M42 Economic Gateway' is unlocked.

Transport-wise, it is said that it is crucial that there is easy access to services and facilities such as 'jobs, education, fresh food retailers and open space' by all transport modes, be it active or public. Proposed housing development should be:

- Within an 800m walk distance of a primary school, doctor surgery and food shop; and
- Within a 400m walk distance of a bus stop served by high frequency bus services; and/or
- Within an 800m walk distance of a rail station providing high frequency services (3tph in each direction during peak periods).

Solihull Local Plan Review (May 2021)

On the 13th May 2021, SMBC submitted an updated Local Plan to the Secretary of State through the Planning Inspectorate so that it can be independently examined. The plan sets out updated growth and development proposals for the Borough out to 2036 responding to the opportunities provided by HS2 as well as wider challenges of accommodating economic growth and housing needs within the plan area.

The latest update to this process was on March 16th 2023, when the examination was paused while pending updates to the NPPF are made.

3. EBNS Strategic Context

A review of strategic developments to support the delivery of change.

3.4 Strategic Developments

Midlands Future Mobility (MFM)

Midlands Future Mobility is a major CAM testbed based in the West Midlands and covers over 200 miles of public roads. The testbed includes installed CCTV, weather stations, communications units, and accurate GPS roadside units (RSU) either at fixed locations or as part of mobile units that can be configured and deployed as required.

The testbed is a member of the CAM Testbed UK administered by ZENZIC. The intention of CAM Testbed UK is to develop programmes, ensure cooperation between the testbeds and help grow the CAM supply chain.

Other members of CAM Testbed UK are:

- AssuredCAV,
- ConVEx
- Millbrook-Culham
- Smart Mobility Living Lab London

Greater Birmingham and Solihull Local Enterprise Partnership (GBSLEP)

Greater Birmingham and Solihull Local Enterprise Partnership (GBSLEP) is a partnership of local authorities, businesses and further/higher education leaders committed to driving the inclusive economic growth of the Greater Birmingham and Solihull city-region. This is done by creating jobs and increasing the quality of life for all communities.

From the latest report, the GBSLEP have supported 7,189 businesses and boasts £16.37 of value generated from every £1 invested. The mechanism for this growth is through the Growth Hub where businesses can get business support and advice to help them grow. The GBSLEP also invested in the Enterprise Zone Investment Plan (EZIP) (2019) that consolidated the City Centre EZIP (2014) and the Curzon Investment Plan (2016)

It should be noted that the area of interest is wholly within the GBSLEP region, but this region extends far beyond the area of interest.

Enterprise Zone Investment Plan (EZIP)

The EZIP 2019 consolidates the two existing investment plans: City Centre EZIP (2014) and the Curzon Investment Plan (2016) with a strategy that focusses on delivering a phased programme of £460m of projects in the period 2019-2028.

The programme will unlock the major growth opportunities by removing barriers to development, creating a supportive environment for investment, job creation and growing the city and regional economy. It will be supported by a set of financial principles by which investment decisions to allocate EZ resources are made and robust governance arrangements to oversee the programme.

The key areas for investment will be:

- Strategic site investment.
- Infrastructure.
- Business support.

Areas that benefited from the EZIP Phase 1 are:

- Paradise
- Metro Extension (New Street to Centenary Square)
- Centenary Square
- Birmingham Smithfield
- Snow Hill

3. EBNS Strategic Context

A review of strategic developments to support the delivery of change.

3.4 Strategic Developments

UK Central Hub

Supported by Solihull Metropolitan Borough Council (SMBC) and the West Midlands Combined Authority (WMCA) as a critical catalyst for growth, ensuring that ambitions for the area is fully realised by coordinating investment plans and growth opportunities.

The UK Central Hub main aim is to unlock potential using a set of place-making principles to deliver a comprehensive Hub Growth and Infrastructure Plan (HGIP).

UK Central Hub is a large-scale project and investment opportunity comprising of the following developments:

- Arden Cross
- Birmingham International Station
- Electricity Supply
- NEC/Airport Connectivity and Parking Strategy

Arden Cross

Solihull Council and HS2 are working together to fund, design and build additional elements at the HS2 Interchange Station site at The Hub, known as Arden Cross.

This will support Solihull's growth agenda and create a new, sustainable mixed-use destination with HS2 at its heart, incorporating additional public transport connectivity and making better use of land for quality development to support the delivery of thousands of new jobs and homes.

Arden Cross will be a global destination for innovation, business, commerce, learning and living, across more than 140 hectares (346 acres). It will help the Midlands and the entire country compete on the international stage by increasing the amount of high value products, jobs, and skills we create and share with the world.

Birmingham International Station

An integrated transport exchange bringing together existing rail, future high-speed rail, trams, buses, rapid transit, private vehicles, taxis, bicycles, and an automated people mover is planned. This will link seamlessly to Birmingham Airport and the forthcoming HS2 Interchange Station.

It is anticipated that the redevelopment of Birmingham International Station and the improvements to local and regional transport connectivity will bring an additional 200,000 commuters to within a 45-minute commute of The Hub by public transport.

The station concept of the redeveloped station is being taken to the next stage of detailed design.

Electricity Supply

Key stakeholders from the public and private sectors are brought together to look at sustainable ways to meet the expected demand for power across The UK Central Hub, above and beyond the demand generated by HS2 alone.

NEC/Airport Connectivity and Parking Strategy

Alongside new and improved public transport, is coordinating improvements to the local and strategic highway network.

It is also bringing together major stakeholders like the Airport and the NEC to make best use of the 40,000+ existing car parking spaces across The Hub and ensure that future provision factors in changing patterns of car use and ownership.

There is the potential for parts of the car park and other areas of the NEC's estate to become a major redevelopment.

3. EBNS Strategic Context

Overview of policies and proposals considered during this study

3.5 Development Proposals Review

The following policies and proposals have been considered for the purposes of this feasibility Study:

National Policies & Proposals	Regional Policies & Proposals	Local Policies & Proposals
Decarbonising transport: a better, greener Britain	West Midlands Local Transport Plan 5	Birmingham City Council Transport Plan
Gear change: A bold vision for cycling and walking	Midlands Connect Strategic Transport Plan	Walking & Cycling Strategy alongside an LCWIP
Cycling and Walking Investment Strategy 2	The Integrated Rail Plan (IRP)	The Birmingham Development Plan
Future of mobility: urban strategy	The West Midlands Rail Investment Strategy	The East Birmingham Inclusive Growth Strategy
The National Planning Policy Framework (NPPF)	Midlands Rail Hub	The Solihull Connected Transport Strategy 2023
The NPPG, or National Planning Practice Guidance,	The West Midlands Local Cycling and Walking Infrastructure Plan	The Solihull Local Plan (2011-2028)
UK Connected & Autonomous Vehicle Research & Development Projects 2018	The West Midlands Local Cycling and Walking Infrastructure Plan	Solihull Local Plan Review
Automated and Electric Vehicles Act 2018	Midlands Future Mobility	Solihull Local Cycling and Walking Infrastructure Plan
Connected and automated vehicles: process for assuring safety and security (CAVPASS)	Greater Birmingham and Solihull Local Enterprise Partnership (GBSLEP)	The Solihull Cycling & Walking Strategy
The Highway Code	Enterprise Zone Investment Plan (EZIP)	https://www.birmingham.gov.uk/info/20054/local_plan_documents/1050/poolway_shopping_centre_compulsory_purchase_order
The Law Commission's advice to government on Remote Driving	The King's Speech 2023	https://www.investinukcentral.com/projects/the-hub/

3. EBNS Strategic Context

Summary of policies and proposals considered during this study

3.6 Summary

3.1 National Policy Summary

The national policy context shows UK government commitment to decarbonisation by improved public transport and active travel provision.

In addition, the UK government is taking a proactive approach to enabling the safe deployment of automated vehicles and is looking to promote the development of a robust CAM industry.

3.2 Regional Policy Summary

Regional policy supports the provision of a high-quality rapid transit route through the study area, improvements to the bus network in the BSIP and walking and cycling improvements within the study area. Increases to rail frequencies are also supported by the various rail strategies and policies.

3.3 Local policy summary

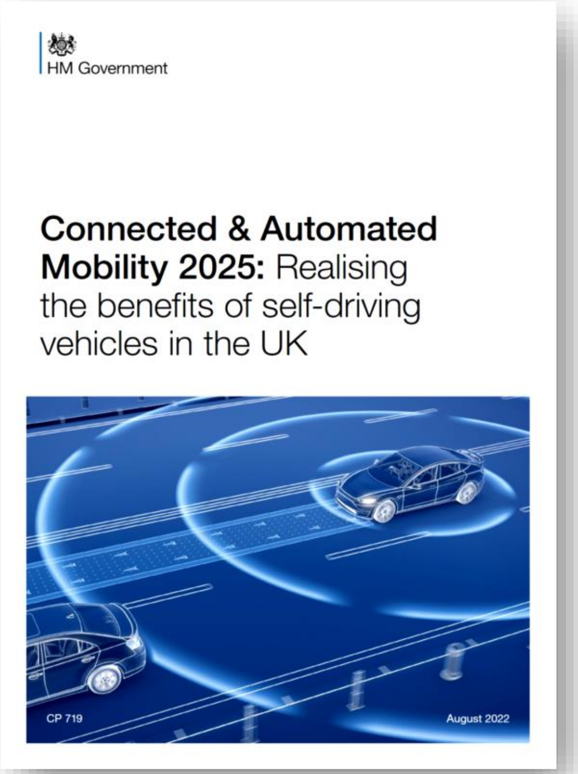
Local policy in Birmingham and Solihull supports active travel through various LCWIP routes in the study area and supporting active travel at a neighbourhood level. Policies support the use of transport to increase accessibility, inclusion and to tackle air quality and climate change. Specific mention is made of poor use of rail connectivity within the study area due to access to rail stations and infrequent service patterns.

3.4 Strategic Developments

Multiple strategic developments have taken place in the region including the creation of a key CAM Testbed in the form of MFM. Additionally, investment into local small businesses has helped the region recover from the pandemic as quickly as possible. These developments support the need for improved public transport linking under privileged residential areas to the revitalised commerce centres.

Chapter Summary

The policies mentioned in this chapter demonstrate the ambition at a national, regional and local level to provide better public transport links which integrate with active travel measure. The proposal would allow for a more reliable and frequent service that support the public transport and active travel networks.



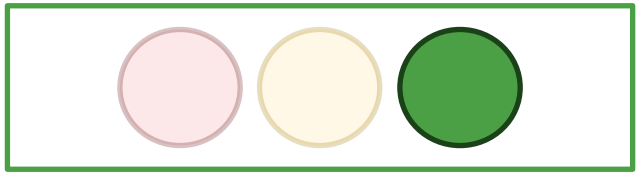
3. EBNS Strategic Context

Performance against the Feasibility Question

3.6 Summary

Feasibility Question 2:

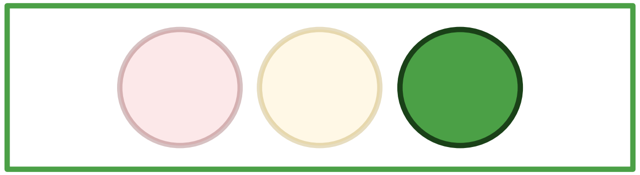
Is this route supported by local, regional and / or national strategy and policy?



The policies and aspirations from the UK government, regional authority and Local government presented here supports both the delivery of a public transport link on this route, and the deployment of innovative systems, such as a CAM solution.

Feasibility Question 3:

Do future plans on this route support its viability?



The future plans for the region support the deployment of a CAM solution along this route by allowing for greater connections to and throughout the region.

4. Constraints and Opportunities

FQ4 Is a new service along this route needed?

4. Constraints and Opportunities

We will examine the local context within which the proposal is set

4.0 Introduction

4

Chapter four examines the local dynamics of the route, covering the nature of users currently on the route, the impacts of 'business as usual', and finish by providing an overview of plans in the vicinity that should be expected to impact this proposal – either positively or negatively

4. Constraints and Opportunities

Population changes in Birmingham and Solihull

4.1 Population Projections

Table 4.1 and Table 4.2 show the population projections for Birmingham and Solihull, respectively and has been derived from Office of National Statistics (ONS) 2018 data. The tables show that for both Birmingham and Solihull, pensioners will be the largest population increase, with a small increase of children in Solihull and a decrease of children in Birmingham.

However, as described by Councillor Ian Ward in the East Birmingham Inclusive Growth Strategy (2021)

"[East Birmingham is] a young place where a third of residents are under 16 years old - one of the highest proportions of children in the country."

When compared to the proportion of children in Birmingham as a whole (22%), the EBNS corridor is likely to grow skewed to a younger demographic.

Solihull generally has older population when compared to the rest of the West Midlands and England in general. However, like Birmingham, the wards in the north of Solihull tend to skew younger when compared to the rest of the borough.

In addition to the information shown in table 4.1 and Table 4.2, analysis of PRISM data was performed to determine the projected population growth of people living within 1.5km of a stop proposed by the corridor plans. It was found that in the base year of 2016, 933,563 lived in this area and this is projected to grow to 993,555 by 2036, a 6% (59,992) increase.

From this we can say that the population along the EBNS corridor has a relatively high proportion of young people who are more likely to embrace new technology. We can also note that there is a, not insignificant, increase number of people living within walking distance of a proposed stop.

Table 4.1: 2018 Population growth projections by age for Birmingham

Age Group	Base Year	Projection Year		Change		Change	
	2018	2028	2038	2018 to 2028		2018 to 2038	
Children (0 to 15)	259,800	254,600	256,800	-5,200	-2.0%	-3,000	-1.2%
Working Age (16 to 64)	733,600	764,800	781,600	31,200	4.3%	48,000	6.5%
Pensioner (65+)	147,900	166,600	191,600	18,600	12.6%	43,700	29.5%
Total	1,141,400	1,186,000	1,230,000	44,600	3.9%	88,600	7.8%

Table 4.2: 2018 Population growth projections by age for Solihull

Age Group	Base Year	Projection Year		Change		Change	
	2018	2028	2038	2018 to 2028		2018 to 2038	
Children (0 to 15)	42,004	44,330	45,037	2,326	5.54%	707	1.59%
Working Age (16 to 64)	127,679	129,243	131,366	1,564	1.22%	2,123	1.64%
Pensioner (65+)	58,702	60,542	71,252	1,840	3.13%	10,710	17.69%
Total	214,909	225,601	235,746	10,692	4.98%	10,145	4.5%

4. Constraints and Opportunities

Modal availability and destination choices

4.2 Mode Split

This section discusses the current modal split for commuters in the EBNS corridor. The corridor encompasses both the Birmingham and Solihull local authority areas and draws data from Middle-layer Super Output Areas (MSOA) to characterise travel behaviours in distinct areas.

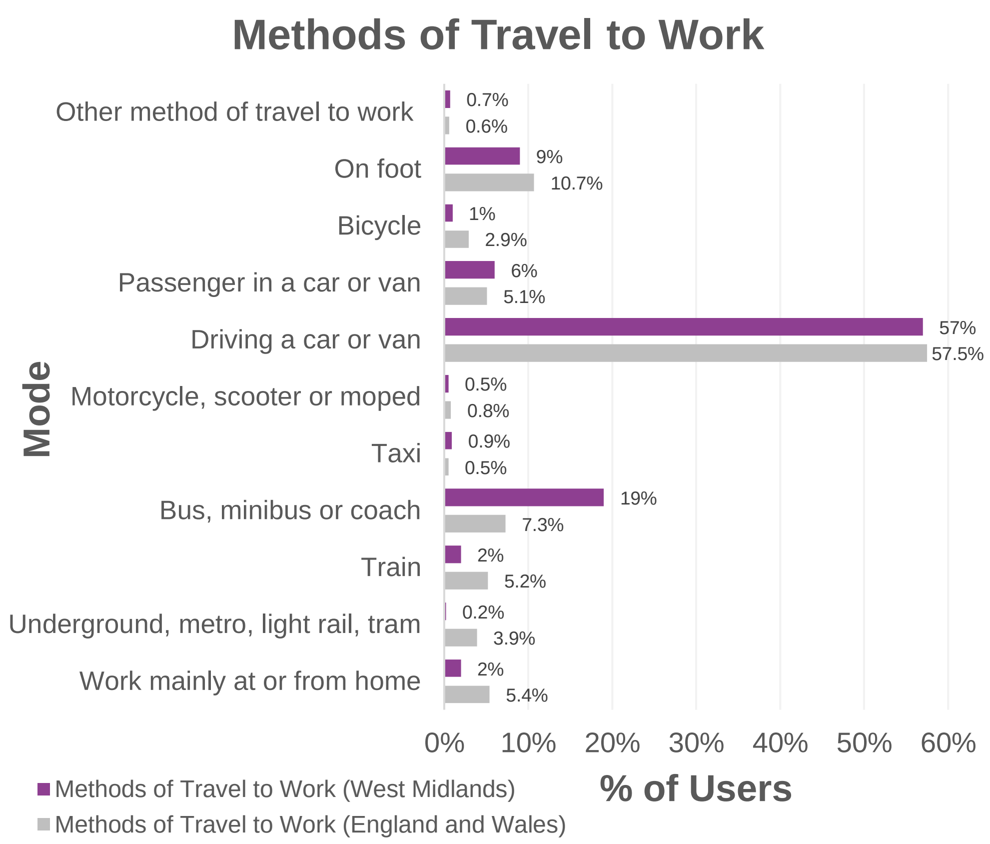
It is important to note that we have utilised Census 2011 data for this analysis since we believe it is the most representative of current board travel patterns – which are fairly well established in the area but were significantly disrupted at the time of the COVID-19 pandemic which has impacted the 2021 Census data.

Chart 4.1 shows the percentage breakdown of different methods of travel that people in the EBNS corridor use to travel to work in comparison to the population of England and Wales. As shown, driving a car or van is the largest method used to travel to work in the study area. A combined 63.5% of people are shown to use some form of private motor vehicle to travel to work, either as a driver or as a passenger of a car or van or motorcycle/scooter/moped, compared to 40% as a national average.

The next most popular mode of travel to work in the study area is bus, minibus, or coach (19%), followed by foot (9%), train (2%), and bicycle (1%). The least used modes of transport used to travel to work are taxi (0.9%), and motorcycle, scooter or moped (0.5%). Taking in to account the higher bus usage over England and Wales figures, policy objectives nationally and locally are to increase cycling and walking to 50% of all journeys (albeit the mode share is for commuting), and to make mass transit the mode of choice (aside from walking and cycling).

All images and charts in this section are available in larger formats in Appendix Chapter 4

Chart 4.1: Methods of Travel to Work throughout the study area. Source : Census 2011 data



4. Constraints and Opportunities

Modal availability and destination choices

4.3 Origins and Destinations

This section discusses the current travel patterns and habits of commuters in Solihull and Birmingham in terms of where commuters travel to and from.

It should be noted that the data used in this section is from the 2011 census. This is due to the 2021 Census taking place during the COVID-19 pandemic affecting travel habits which was reflected in Census 2021. The NOMIS website, through which the census data is accessed, states a disclaimer as shown below:

"Quality information: As Census 2021 was during a unique period of rapid change, take care when using this data for planning purposes.

Comparability with 2011: Not comparable. It is difficult to compare this variable with the 2011 Census because Census 2021 took place during a national lockdown. The government advice at the time was for people to work from home (if they can) and avoid public transport.

People who were furloughed (about 5.6 million) were advised to answer the transport to work question based on their previous travel patterns before or during the pandemic. This means that the data does not accurately represent what they were doing on Census Day. This variable cannot be directly compared with the 2011 Census Travel to Work data as it does not include people who were travelling to work on that day. It may however, be partially compared with bespoke tables from 2011."

Table 4.3 and Table 4.4 show the different local authority areas that people travel to and from for work outside of Birmingham City Council and Solihull Metropolitan Borough Council (SMBC). Table 4.3 shows that of the people who live in Solihull but work outside Solihull, most people travel to and from Birmingham followed by Coventry, Warwick, and other areas in Warwickshire. This is not surprising given Solihull's close proximity to these areas and the economic influence that Birmingham has in the region. Origin/Destination data from the 2021 census has not been made available, presumably due to the effects of the pandemic on the census data. We have therefore reverted to 2011 data for the purposes of this report, noting that there may be some changes to travel behaviours post-pandemic that this data may not accurately reflect.

Table 4.4 shows that the majority of people who live in Birmingham but do not work in Birmingham, work in Solihull and Sandwell; followed by Walsall and Dudley. This is likely due to these local authorities being in close proximity to Birmingham and each being urban in nature. Note that Birmingham has a much larger number of inbound commuters (166,272) than Solihull (51,403) which is likely due to it being a larger economic centre. However, even though Birmingham is a larger economic centre than Solihull, more people (101,467) travel outbound to local authorities outside of Birmingham compared to Solihull (49,415). This is likely due to Birmingham City Council having a considerably larger population than Solihull MBC.

4. Constraints and Opportunities

Modal availability and destination choices

4.3 Origins and Destinations

Table 4.3: Journeys for work in and out of Solihull - Census 2011. Source: Census 2011 data

Traveling to/from	Inbound into Solihull	% Inbound into Solihull	Outbound out of Solihull	% Outbound out of Solihull
Birmingham	26,479	52%	29,458	60%
Coventry	3,072	6%	3,654	7%
Warwick	1,800	4%	2,327	5%
N. Warwickshire	1,679	3%	2,301	5%
Stratford-on-Avon	1,387	3%	1,612	3%
Sandwell	1,511	3%	909	2%
Bromsgrove	1,896	4%	828	2%
Redditch	1,282	2%	804	2%
Walsall	967	2%	461	1%
Dudley	1,075	2%	415	1%
Other LAs	10,255	20%	6,646	13%
Total	**51,403**		**49,415**	

Table 4.4: Journeys to work in and out of Birmingham - Census 2011. Source: Census 2011 data

Traveling to/from	Inbound into Birmingham	% Inbound into Birmingham	Outbound out of Birmingham	% Outbound out of Birmingham
Solihull	29,458	18%	26,479	26%
Sandwell	28,088	17%	13,661	13%
Walsall	16,037	10%	5,872	6%
Dudley	14,057	8%	4,547	4%
Bromsgrove	9,996	6%	5,073	5%
Lichfield	6,076	4%	2,207	2%
Wolverhampton	5,842	4%	2,760	3%
Tamworth	4,672	3%	1,432	1%
Coventry	4,472	3%	4,596	5%
North Warwickshire	4,238	3%	5,151	5%
Other LAs	43,336	26%	29,689	29%
Total	**166,272**		**101,467**	

4. Constraints and Opportunities

Modal availability and destination choices

4.4 Bus

The study area is relatively well served by local and regional buses with numerous express services running along the study areas peripheries and a selection of local buses which bisect the area primarily east to west but also from the north to the south.

An analysis of TfWM-provided open data on the bus network within the scoping area has been completed to show the bus routes that pass through the area of scope. Many of these buses connect into the rail facilities within the study area. However, there are other direct services to places such as Birmingham City Centre, Sutton Coldfield and Solihull.

There is a higher bus frequency rate within Central Birmingham and on the Birmingham orbital roads, as well as along Alum Rock Road and the A45 Coventry Road compared to those in the central area of the study area which tend to be less frequent. Table 4.5 provides more detail on the key bus routes in the study area. The corridor is currently served by a primary bus route comprising route 97 operated by National Express West Midlands between Birmingham City Centre and Chelmsley Wood. This route largely parallels the previous tram extension proposals.

Table 4.5 shows that there are frequent bus services into Birmingham City Centre across the study area with up to ten buses an hour on routes such as the 94 and 95. However, journey times on routes such as the 97 from Chelmsley Wood to the City Centre can be up to 50 minutes in peak hours. It is noted that these times are scheduled journey time rather than real journey times. The Real Journey Time tool did not show data for the 97-route meaning a real vs timetabled journey time comparison was not possible at the time of writing.

It should also be noted that a CAM service can help alleviate the bus driver shortage that has been a prominent issue since 2021

Table 4.5: Key Bus Routes in the study area

Bus Service	Locations Served	Buses Per Hour
X1	Birmingham – Coventry via Yardley, Sheldon, Birmingham Airport, Meriden & Allesley	6 buses per hour
11A/11C	Birmingham Outer Circle (Yardley, Stechford, Erdington, Handsworth, Bearwood, Selly Oak, Kings Heath)	6 buses per hour
X12	Birmingham – Solihull via Bromford Bridge, Chelmsley Wood & Birmingham Airport	2 buses per hour
17	Birmingham – Tile Cross via Hob Moor Road, Yardley & Garretts Green	5 buses per hour
28	Great Barr – Heartlands Hospital via Erdington, Pype Hayes & Ward End	5 buses per hour
60	Birmingham – Cranes Park via Small Heath, Yardley & Sheldon	6 buses per hour
72	Solihull – Chelmsley Wood (Bluebell Drive) via Sheldon, Garretts Green & Marston Green	7 buses per hour
94	Birmingham – Chelmsley Wood via Saltley, Washwood Heath, Ward End, Castle Bromwich, and Smiths Wood	10 buses per hour
95	Birmingham – Chelmsley Wood via Saltley, Washwood Heath, Shard End and Kingshurst	10 buses per hour
97	Birmingham – Chelmsley Wood (Helmswod Drive) via Heartlands Hospital & Kitts Green	8 buses per hour

4. Constraints and Opportunities

Modal availability and destination choices

4.5 Metro

The West Midlands Metro tram system currently operates on a regular basis from Edgbaston Village to Wolverhampton Pipers Row via Birmingham City Centre, Soho, West Bromwich, Wednesbury, and other urban areas in the Black Country.

The system initially opened in 1999 as Midland Metro (Now West Midlands Metro), running between Snow Hill and Wolverhampton St George's, but was extended in 2015 to serve the central areas of Birmingham. A further extension took place in 2022 to serve Edgbaston Village along Broad Street via Brindley Place and services to Wolverhampton rail station, on Pipers Row, was completed in 2023.

Extensions are currently under construction between:

- Bull Street – Digbeth High Street via Albert Street, Curzon Street and Meriden Street
- Wednesbury Great Western Street – Brierley Hill via Dudley Bus Station and Merry Hill

The Bull Street – Digbeth High Street extension (Eastside Extension) is important to the study as it would be prudent to link any proposed CAM service to the terminus point for the metro to avoid conflict and redundancy between the two services.

As noted earlier in this document, the route considered was originally proposed as a metro extension.

While this is still the aspiration set out in multiple local strategies including being identified as a priority rapid transit corridor in the LTP5 Core Strategy, the significant funding required for development and funding of delivery is not currently available.

4.6 Rail

The West Coast Main Line between London and Glasgow, one of the busiest railway lines in Europe runs through the study area between Adderley Park and Birmingham International, with five stations located at Adderley Park, Stechford, Lea Hall, Marston Green and Birmingham International. There is no north to south provision and no service to areas on the periphery of the study area such as Chelmsley Wood, Castle Bromwich, Yardley and Bordesley Green.

Birmingham International is well connected with various regular options to travel to Birmingham New Street and other services across the UK. However, International rail station is relatively inaccessible for those who do not own a car as only the X1 and 96 bus routes provide access currently, connecting to Kingstanding via Chelmsley Wood, Castle Bromwich and Birmingham.

The stations that lie more central to the study area (Stechford, Lea Hall, and Marston Green) are served by two trains per hour which is lower than the four trains (on average) provided to the Birmingham Cross City Line.

A relief route is also in place between Aston and Stechford, avoiding Birmingham New Street, used during engineering works. This route doesn't see a regular rail service.

4. Constraints and Opportunities

Modal availability and destination choices

4.7 Road

Strategic Road Network

The M42 and M6 motorway routes frame the study are to the north and east. Key motorway junctions allow access to East Birmingham corridor include M6 Junctions 4, 5, 6 and M42 Junction 6.

Primary Road Network

Several important A and B-roads pass through the area of scope. This section acts as a summary for these major roads aside from the Key Route Network which is assessed in more detail below. *More detail on this section can be found in Appendix Chapter 4*

A45 (Coventry Road)

The A45 is the primary A-road running from Birmingham City Centre via Birmingham International Airport to the M42.

A38

The A38 provides access to Birmingham City Centre and the western end of the study area and links Birmingham with regional destinations.

A47

The A47 east of Birmingham City Centre, near to the HS2 Curzon Street Station site, and continues east through Castle Bromwich, The Fort and Water Orton.

A452

The A452 runs just north of Birmingham to the south via Sutton Coldfield, Castle Bromwich, Chelmsley Wood and Birmingham Airport.

A4040

The A4040 functions as a suburban informal Outer Ring Road for Birmingham, and passes through the area, providing connections to the north and south of the city without traveling via central areas.

Key local routes in the study area

Like the previous section, the following is a summary of the key local routes that run through the area of interest. *More detail on this section can be found in Appendix Chapter 4*

B4128 Bordesley Green Road/Meadway

The road is a primary east-west connector within the study area and has featured as the primary movement corridor in several previous proposals for mass transit solutions through the study area. The nature of the road changes considerably from the West to the East ranging from wide single carriageway, narrow single carriageway, multilane for turning residential streets, to a dual carriageway and back to narrow single carriageways.

B4114 Washwood Heath Road/Coleshill Road/ Chester Road

The road is a primary east-west connector across the north of the study area but also provides an alternative and connector route for the A47 and A452. The road is generally a wide single carriageway with sections of narrow single carriageway and dual carriageway

Alum Rock Road/Cotterills Lane (Unclassified)

The roads forms a secondary east-west connector across the west of the study area; linking Alum Rock, Pelham and Stechford. The road is a narrow single carriage way that runs alongside local commercial sites and terraced residential. It becomes more difficult to navigate to the east as informal parking becomes more common.

Coventry Road (Unclassified)

The road forms a secondary east-west connector and central shopping area for Small Heath, tying into the north-south B4145 connector road. It is a key place in the study area for shopping and community amenities. The road is a mostly narrow single carriage way that runs alongside local commercial sites and terraced residential. Linking roads act as ‘rat-runs’ for local traffic.

4. Constraints and Opportunities

The impact on the local environment

4.8 Environmental Considerations

All images and charts in this section are available in larger formats in Appendix Chapter 4

It is well known that a stationary running internal combustion engine (ICE) vehicle emits more emissions that one that is moving. When there is stationary congestion, this issue is multiplied by the number of vehicles involved. Additionally, the stationary vehicles increase the base noise levels which makes the environment unpleasant and has been linked to chronic stress issues. Also, with congestion comes higher probability of Road Traffic Collisions (RTC) with injuries to people and making congestion worse. Finally, it should be noted that it is assumed that the CAM vehicle will an electric vehicle (EV) with no direct exhaust emissions.

PRISM data

The 2016 Base Year PRISM model has been consulted to show the average peak hour modelled levels of traffic congestion based on link delay and junction volume over capacity. Figure 4.1 shows modelled link volume over capacity (V/C) across the study area whereas Figure 4.2 shows modelled node volume over capacity. Links and junctions that are modelled as over 100% capacity are shown in red and junctions and links nearing capacity shown in yellows and oranges. 'Capacity' is considered to be 100% but anything over 85% is usually considered to be an issue.

Figure 4.1: PRISM Model Link Volume/Capacity across the EBNS Study Area

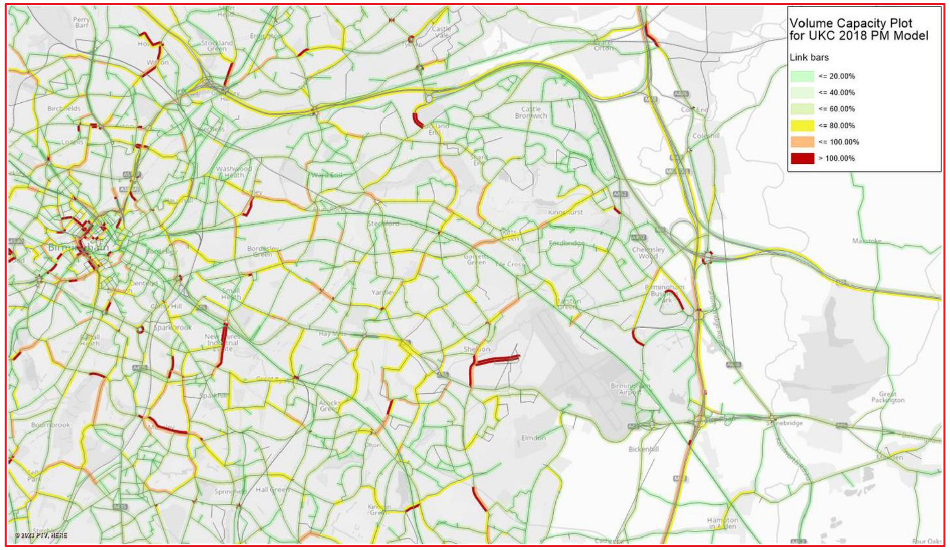
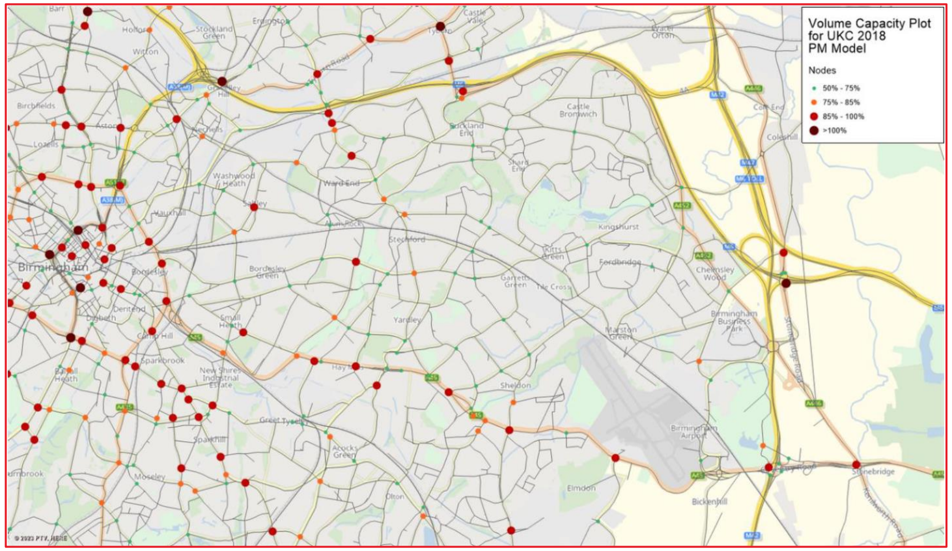


Figure 4.2: PRISM Model Node V/C across the EBNS Study Area



4. Constraints and Opportunities

The impact on the local environment

4.8 Environmental Considerations

KRN dashboard journey times

The Key Route Network (KRN) Monitoring Dashboard was used to identify journey times and traffic hotspots across the EBNS study area. Please note, the monitored KRN routes are on the periphery of the study area in the form of A452 to the North, the A47 Heartlands Parkway to the West and the A45 to the south.

Figure 4.3 shows journey times between Birmingham Airport and Brownhills via the A452. The average Castle Bromwich to Kingshurst journey time, on the edge of the EBNS study area, is shown to perform poorly compared to other sections of the route.

Figure 4.4 shows journey times between Northfield and Gravelly Hill via the A47. The average A47 Heartlands Parkway journey times, on the edge of the EBS study area, are shown to perform well compared to other sections of the route.

Figure 4.5 shows journey times between Birmingham and Coventry via the A45. The average A45 journey times between Small Heath and Sheldon are shown to be the worst performing along the corridor.

Increased journey times (JT) are an indication of slower traffic moving along the link. From this information it can be inferred that road is reaching a saturation point and it cannot carry any more vehicles. This increases the risk the congestion forming and as mentioned on the previous page, this increases localised pollution in the form of gases a noise.

Figure 4.3: Journey Times for the A452 Birmingham Airport to Brownhill

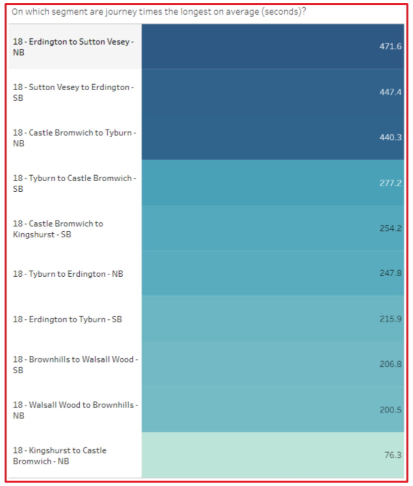


Figure 4.4: Journey Times for the A47 Heartlands Parkway

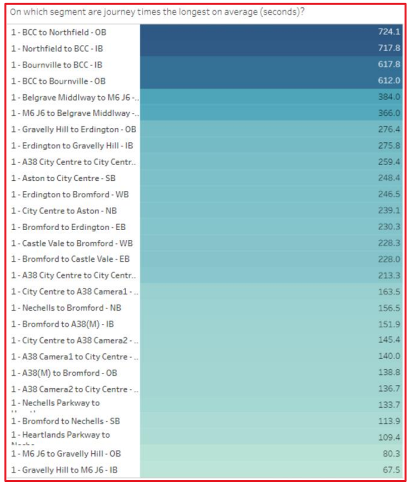
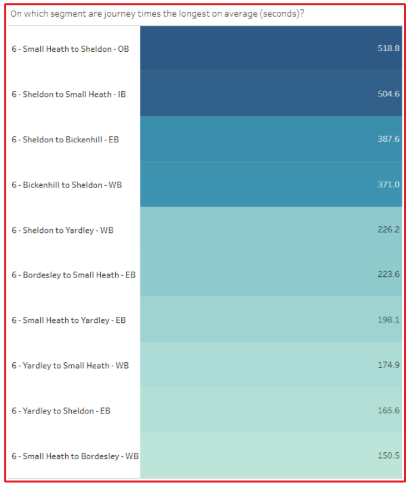


Figure 4.5: Journey Times for the A45 Coventry to Birmingham



4. Constraints and Opportunities

The impact on the local environment

4.8 Environmental Considerations

Corridor journey times

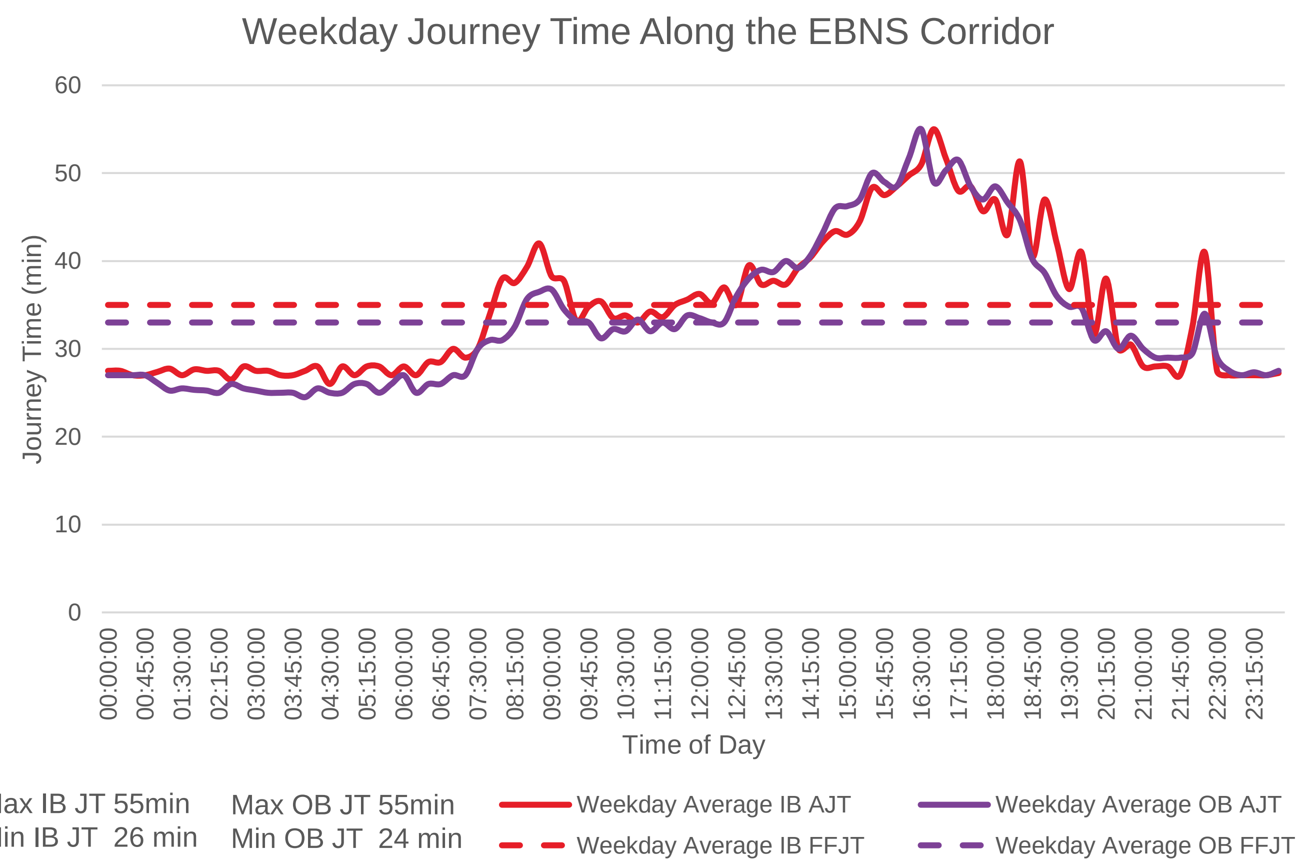
High level data collection of the journey times along the corridor are shown in Chart 4.2 opposite. In the scenario shown in Chart 4.2, the inbound (IB) journey is from Birmingham International Rail station to High Street Deritend. The outbound (OB) journey is the opposite running of the inbound journey. The dashed lines show the journey time with no traffic, i.e. free flow journey time (FFJT), which remains constant through over the day. The solid lines show the actual journey time (AJT) along the route.

The source for this processed data from Google Floating Vehicle Data sets via an API. It should be noted that this is an approximation as certain parts of the corridor could not be captured as the datasets only include road users.

As can be seen there is a delay caused by the expected peaks in both directions with free flow time being achieved during the inter-peak period. The journey time dipping below the free flow time lines shows that traffic is travelling faster than the speed limit and is only during nighttime.

Reducing the amount of traffic on this route would reduce the peaks closer to the free flow journey times

Chart 4.2: Weekday average journey times along the EBNS Corridor



4. Constraints and Opportunities

The impact on the local environment

4.8 Environmental Considerations

Arcadis Network Statistics

The Arcadis East Birmingham to Solihull Corridor Medium-Term Options Study looked at network performance data such as 2019 AM and PM Trafficmaster Data, 2015/16 AM Peak Average Speeds, and Junction Capacity Assessments.

Trafficmaster data was used to identify Average delay (in seconds) on the SRN and locally managed A roads in the EBNS Corridor study area during the AM and PM peaks of 2019. 2015/16 AM Peak Average Speeds were used to identify the average speed on the roads in the eastern area of the EBNS Corridor between 08:00 and 09:00 in 2015 and 2016. Junction Capacity Assessments were undertaken to show which junctions operate close to or above capacity, i.e. where ratio of flow/ capacity exceeds 0.85 (or for signal-controlled junctions, where capacity utilisation exceeds 90% (or 0.90)). From combining this data, a set of network hotspots were identified including:

- Junctions on the B4128 Bordesley Green Road and Meadway;
- A45 Coventry Road to the southwest of the study area;
- A4040 to the north of the study area; and
- Along the B4438 Bickenhill Parkway between the NEC and Birmingham Business Park.
- M42, Coventry Road and Bickenhill Lane around Birmingham Airport.

Road Traffic Collisions (RTC)

The Arcadis East Birmingham to Solihull Corridor Medium-Term Options Study looked at the location and severity of Road Traffic Collisions (RTCs) that occurred in the EBNS study area between 31/01/2016 and the 31/01/2021. Using TfWM Data Insight traffic collision data it was shown that there were collision hotspots on Alum Rock Road, Washwood Heath Road, around Sheldon, north of Sheldon, and on the Coventry Road near Bordesley Green and Small Heath.

The article Safety impacts and benefits of connected and automated vehicles: How real are they? completed a high-level meta study of five studies looking into the safety of CAM systems against human drivers. The outcome of this review is that multiple automated driver aids do show an improvement in driving safety. However, this is caveated that the systems must be working reliably, and the driver understand their operation.

While this review was focused on systems up to Level 3 autonomy, it is reasonable to expect a Level 4 and Level 5 CAM vehicle will have further improvements in safe operation and reduce the number of RTC's.

As mentioned, an increase in traffic will also increase the likelihood of an RTC. If an RTC occurs it will likely lead to worse congestion as a significant amount of road space is made unavailable for traffic. This compounds the issues around the environmental effects of congestions further. This is in addition to the safety of pedestrians and drivers who will be involved in the RTC.

4. Constraints and Opportunities

The impact on the local environment

4.8 Environmental Considerations

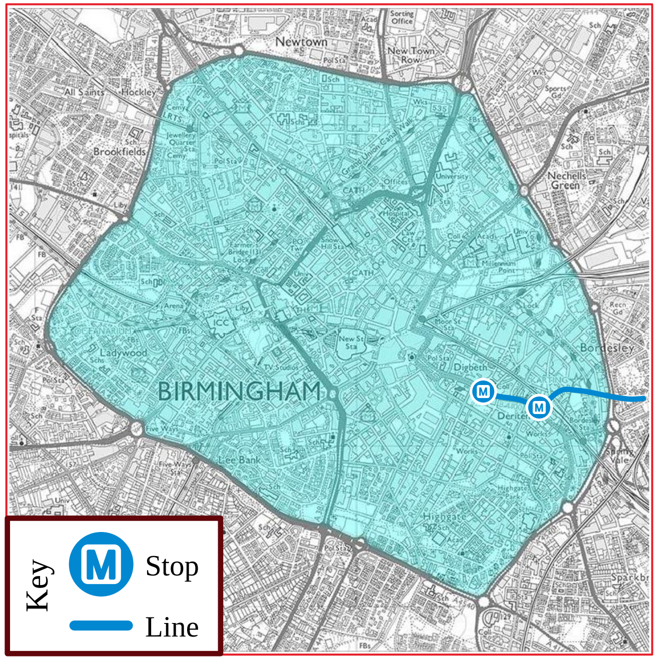
Air Quality

The whole of the Birmingham City Council area has been designated an Air Quality Management Area (AQMA). This is because the council have identified places where the national air quality objectives, linked to PM10, PM2.5, Nitrogen Dioxide, Sulphur Dioxide, Carbon Monoxide and other pollutants, are not likely to be achieved. The western half of the study area falls within this AQMA.

To help solve its poor air quality issues, Birmingham City Council has set up a Clean Air Zone (CAZ) in the centre of the city. A Clean Air Zone is an area where targeted action is taken to improve air quality, in particular by discouraging the most polluting vehicles from entering the zone. No vehicle is banned in the zone, but vehicles that do not meet the emission standards for the zone are subject to a daily fee. The Clean Air Zone is in operation 24 hours a day, 365 days a year and covers an area of the city centre within the A4540 Middleway.

Detailed air quality survey data for the EBS Study area has not been available for consideration as part of this report, however there are known causal and militating factors that suggest localised issues may be likely to arise as concentrations of air quality issues are known to arise disproportionately within inner city urban areas. The western part of the corridor, which experiences high levels of traffic congestion, and has characteristically higher density historical development patterns also limited green space opportunities to disperse emissions.

Figure 4.6: Map of the Birmingham Clean Air Zone (CAZ)



4. Constraints and Opportunities

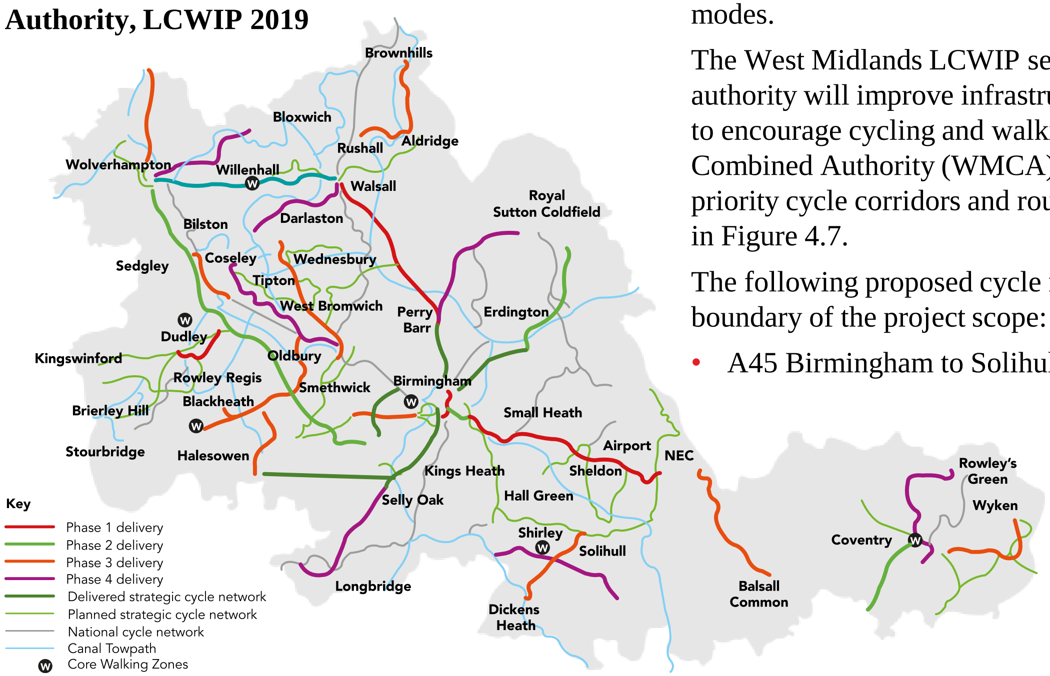
Consideration of the effect of future proposals

4.9 Future Transport Proposals

This section outlines key proposals emerging from policy and planning documentation reviewed in Chapter 3 .

All images and charts in this section are available in larger formats in Appendix Chapter 4

Figure 4.7: Proposed Priority Cycle Corridors and Routes. Source: West Midlands Combined Authority, LCWIP 2019



West Midlands Local Cycling and Walking Infrastructure Plan (LCWIP) (2019)

LCWIPs are developed by Local Authorities to identify a coherent network of improvements that can be made to encourage cycling and walking in a strategic, consistent way across the region, aligning with national goals to increase the use of active modes.

The West Midlands LCWIP sets out how the local authority will improve infrastructure within the region to encourage cycling and walking. West Midlands Combined Authority (WMCA) set out potential new priority cycle corridors and routes, which can be seen in Figure 4.7.

The following proposed cycle route is within the boundary of the project scope:

- A45 Birmingham to Solihull

The following proposed cycle routes and cycle corridors are in the surrounding area of the scope and may bring more cyclists into the study area.

- B4102 Dickens Heath to Solihull town centre
- Balsall Common to Stonebridge via B4152

A strategic cycle network is also planned to connect the areas of Smiths Wood, Kingshurst and Chelmsley Wood to the Airport, NEC and beyond to Solihull.

The West Midlands LCWIP also sets out seven Core Walking Zones (CWZ), which are listed below. WMCA identifies that these CWZs required interventions and improvements to allow walking to be more desirable. None of the following CWZs are within the scoping area, however 'Solihull – Shirley High Street' is near to the area and might benefit the project scope area.

- Birmingham – Ladywood Circus
- Coventry – A4053
- Dudley – Dudley Town Centre
- Sandwell – Cradley Heath
- Solihull – Shirley High Street
- Walsall – Willenhall
- Wolverhampton - Bilston

4. Constraints and Opportunities

Consideration of the effect of future proposals

4.9 Future Transport Proposals

Sprint

Sprint is a proposal for a new bus priority corridor in the West Midlands, linking Walsall to Solihull and Birmingham Airport. Phase 1 of Sprint involved a new bus priority corridor with extended bus lanes and prioritised signalling along the A34 and A45 between Perry Barr, Birmingham City Centre, and Sheldon. This phase of infrastructure is complete with existing bus services utilising the new highway infrastructure and shelters.

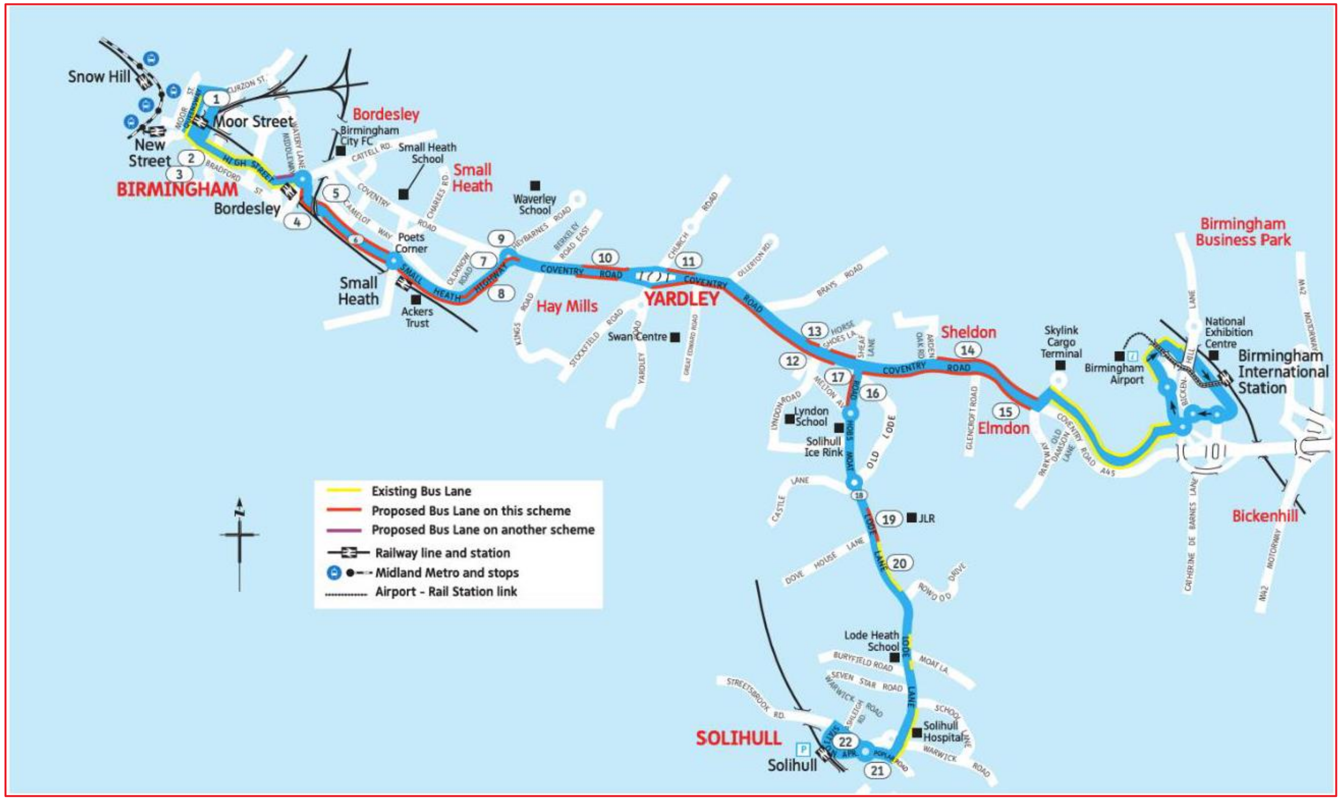
Phase 2 involves the construction and extension of a bus priority corridor between Walsall, Birmingham City Centre and Solihull/Birmingham Airport on the A34 and A45 Coventry Road. Figure 4.8 shows the proposed route of Sprint between Birmingham City Centre, along the ENBS corridor, to the Airport and Solihull Town Centre. All references in the image are to the Sprint project.

New, modern bus shelters will be introduced at:

- Old Walsall Road
- Gainsborough Road
- Hatfield Road
- Newtown Baths/Rodway Close
- Keswick Road
- Wheatsheaf

The work on Sprint Phase 2 will begin in 2024.

Figure 4.8: Sprint Phase Two map. Source: Sprint public transport routes consultation - Transport for West Midlands



4. Constraints and Opportunities

Consideration of the effect of future proposals

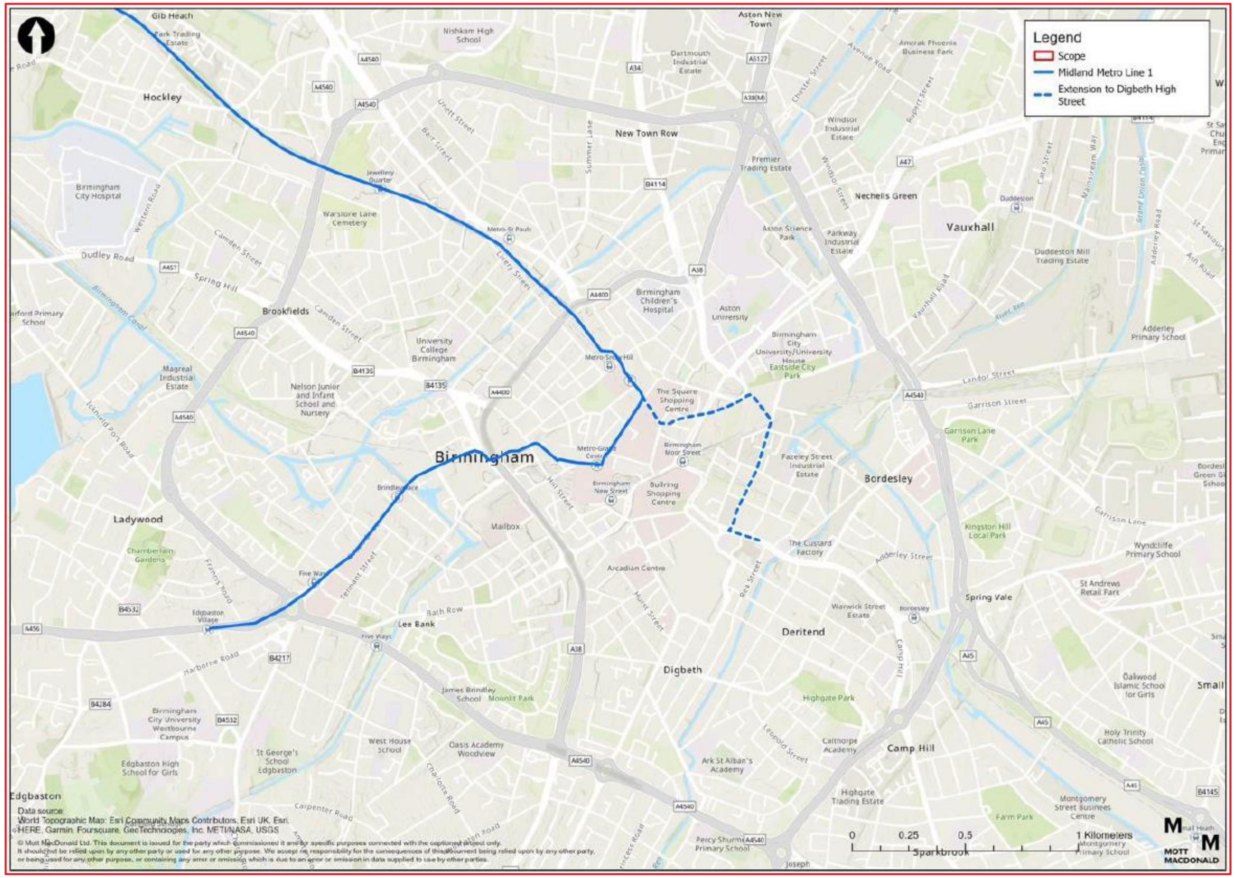
4.9 Future Transport Proposals

Tram extension to Digbeth High Street

A tram extension is currently in construction between Bull Street and Digbeth High Street, known as Birmingham Eastside Metro Extension. The extension would run via Albert Street, Curzon Street Station, Meriden Street and finally terminate at Digbeth High Street.

Funding has been secured and the extension is due to begin operations in 2027 (however, trams would run fast through Curzon Street until at least 2029 when HS2 Phase One opens). Figure 4.9 shows the route of the extension, in the dotted line.

Figure 4.9: West Midlands Metro extension to Digbeth High Street. Source: Mott MacDonald, based on Midland Metro Alliance and TfWM data



4. Constraints and Opportunities

Consideration of the effect of future proposals

4.9 Future Transport Proposals

Rail Investment Strategy

The draft West Midlands Rail Investment Strategy identified several interventions post-HS2 that could be made once capacity is available on the West Coast Main Line. These include:

- Replacing the existing Rugeley Trent Valley – Birmingham International services with Rugeley Trent Valley – Coventry services, running fast between Birmingham New Street and Birmingham International, then all stations to Coventry.
  - This would also replace calls on the Birmingham New Street – London Euston stopping service, so that the service runs fast between Coventry and Birmingham New Street aside from calls at Tile Hill and Birmingham International.
- Replacing the calls at Adderley Park, Stechford, Lea Hall and Marston Green with 4tph Birmingham International – Birmingham New Street, 2tph of which would continue to Wolverhampton. Only half of these services (2tph) will call at Adderley Park.
  - This will mean a doubling in stopping service provision along this corridor.

Figure 4.10 below shows the indicative service pattern of delivering these improvements, with the aim of delivery by 2040.

New stations are also proposed nearby the area of scope, located at Castle Bromwich and The Fort on the CrossCountry route.

2040 Indicative Service Pattern

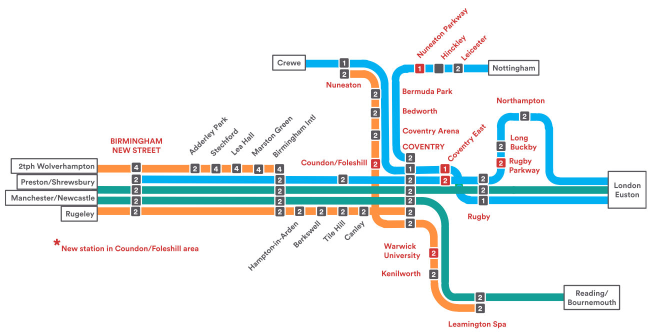


Figure 4.10: 2040 Indicative Rail Service Pattern Source: West Midlands Rail Executive (Right)

Table 4.6: Future Rail Service Changes and Infrastructure Enhancements

	Service Changes	Main Infrastructure Enhancements
By 2026	New West Coast Main Line timetable structure from December 2022 moving services to regular 30-minute pattern	Coventry bay platform
2026-2031	Recast of services post-HS2 Phase 1 Reading – Newcastle service to serve Coventry and Birmingham International New Coventry - Leicester - Nottingham services	HS2 Phase 1 Birmingham - London Nuneaton dive-under Line speed improvements Coventry – Nuneaton Kenilworth – Leamington doubling.
2031-2040	Higher frequency local service to Birmingham International Increased frequency Coventry – Leamington. New stations: Coundon/Foleshill, Coventry East and Warwick University	Kenilworth – Coventry doubling
2040-2050	Further increase in local services	Four-tracking Birmingham International – Stechford

4. Constraints and Opportunities

Consideration of the effect of future proposals

4.9 Future Transport Proposals

High Speed Two (HS2)

High Speed Two Limited (HS2 Ltd) was created by the government in January 2009 and approval of the Phase One plans for a route between Birmingham and London was given Royal Assent in February 2017 following parliamentary scrutiny of the Hybrid Bill.

HS2 will provide a new high-speed railway between London Euston and Birmingham Curzon Street via London Old Oak Common and Birmingham Interchange (shown in Figure 4.11), is due to be delivered and operational by 2033. HS2 will create a brand-new high-speed connection from the Birmingham Airport complex to London, completing the journey in just 38 minutes.

As noted above, two new HS2 stations will be built in Birmingham – one located at Birmingham Curzon Street in Central Birmingham and another at Birmingham Interchange, located in close proximity to Birmingham Airport, The NEC, Resorts World and the existing Birmingham International station alongside the Arden Cross development and Birmingham Business Park.

This report has not been able to take account of the changes in passengers due to the announcement on the 4th October cancelling the northern sections of the line.

Figure 4.11: HS2 Phase 1 Route Source: OpenStreetMap contributors, CC0, via Wikimedia Commons

It's also important to note that a new Automated People Mover is proposed to be constructed, operated by HS2, connecting Birmingham Interchange to Birmingham Airport, Birmingham International railway station, and the National Exhibition Centre

Figure 4.12: West Midlands Rail Investment Strategy Network Map Source: West Midlands Rail Investment Strategy

Figure 4.12 above shows High Speed Two (in blue) interacting with other rail routes in the West Midlands.

4. Constraints and Opportunities

The success factors the CAM solution should deliver

4.10 Critical Success Factors

The critical success factors have been derived from high level aspirations to provide the service to customers. Further studies will need to refine these factors further and lead on to a set of defined requirements for the service. please note that the Relevant column in Table 4.7 is linked to the 6 Big Moves described in the West Midlands LTP5. More information on this can be found in section 3.2.

Table 4.7: Success factors an CAM service should deliver linked to the relevant sections in this chapter

Critical Success Factor	Category	Current Services	Specific	Measurable	Achievable	Relevant	Time-Bound
Allow for commuters to travel to commercial areas	Accessibility	Bus, Rail, Road, Active	Provide a viable alternative to private vehicles	Reduced number of travellers reporting travelling by private vehicle to work	Public information campaign Public exposure to the service	Supports the goal of green transport revolution and behaviour change	Within 3 months of service launch
Allow leisure trips to entertainment areas	Accessibility	Bus, Rail, Road, Active	Provide a viable alternative to private vehicles	Reduced number of travellers reporting travelling by private vehicle to entertainment centres	Public information campaign Public exposure to the service	Supports the goal of green transport revolution and behaviour change	Within 3 months of service launch
Maintain access to residential areas and local businesses	Accessibility	Bus, Rail, Road, Active	Do not have a negative impact on residents and businesses day to day lives	Ensure local business do not report reduced patronage. Ensure residents do not report frustration with access to their homes through Targeted surveys of residents and businesses	Consider surveys as part of the service design constraints	Supports the goal of accessible and inclusive places	Within 3 months of service launch

4. Constraints and Opportunities

The success factors the CAM solution should deliver

4.10 Critical Success Factors

Table 4.7: Success factors an CAM service should deliver linked to the relevant sections in this chapter

Critical Success Factor	Category	Current Services	Specific	Measurable	Achievable	Relevant	Time-Bound
Comparable level of service	Service	Bus, Rail, Tram	Offer the same service as other modes	Benchmark the existing bus, rail and tram services for frequency, punctuality, cleanliness, features (USB charging, Wi-Fi)	Benchmarking exercise and data analysis	Supports the goal of public transport and shared mobility	At launch of the service
Offer an improved service	Service	Bus, Rail, Tram	Offer improved service availability	Create service that is more frequent, more punctual, cleaner, and with same or improved feature set	Comparative data analysis	Supports the goal of safe, efficient and reliable network	At launch of the service
Link into the existing service networks	Service	Bus, Rail, Tram, Road, Active	Ensure network links	Review existing connectivity plan Refresh connectivity plan if needed	Connectivity plan for the corridor is being created as part of a separate project	Supports the goal of public transport and shared mobility	At launch of the service
Supplement the existing services	Service	Bus, Rail, Tram, Road, Active	Offer travel efficient travel options	Map the number of mode changes needed for point-to-point journeys	Desktop exercise to review the number of connections needed	Supports the goal of safe, efficient and reliable network	At launch of the service

4. Constraints and Opportunities

The success factors the CAM solution should deliver

4.10 Critical Success Factors

Table 4.7: Success factors an CAM service should deliver linked to the relevant sections in this chapter

Critical Success Factor	Category	Current Services	Specific	Measurable	Achievable	Relevant	Time-Bound
Reduce congestion in the area	Environment	Bus, Rail, Road, Active	Improve traffic flow	Reduce the corridor journey time closer to the free flow time	Monitor JT along the corridor over time and compare to pre-launch JT	Supports the goal of green transport revolution	Within 6 months of service launch
Reduce the number of RTC's in the area	Environment	Bus, Rail, Road, Active	Improve the safety of environment	Monitor and reduce the number of RTC's reported	Compare the number of RTC's report pre and post launch	Supports the goal of safe, efficient and reliable network	Within 6 months of service launch
Reduce pollution (gasses and noise) levels in the area	Environment	Bus, Rail, Road, Active	Improve AQ and noise levels	Monitor the improvement of AQ Monitor the reduction of environmental noise	Deploy AQ sensors and microphones to capture data	Supports the goal of green transport revolution	Within 12 months of service launch

4. Constraints and Opportunities

A summary of the chapter

4.11 Summary

Much of the information in this chapter has been taken from a report created by traditional transport EBNS feasibility study team, where full credit should be given.

4.1 Population Projections

While both Birmingham and Solihull in general are both project to gain an aging population, the EBNS corridor skews younger and thus more likely to embrace new technology.

4.2 Mode Split

Current mode selection for journeys to work are nearly two thirds private vehicle usage, either as a driver or passenger. Buses, the second largest mode, is a fifth of all journeys. Future goals include shifting mode usage to active travel or public transport over private vehicles.

4.3 Origins and Destinations

The current origin and destination data, most travel occurs between Birmingham and Solihull. This is more pronounced in the data from Solihull where many commuter trips are made to and from Birmingham. It should be noted that this section as it uses data from the 2011 census due the unreliability of the 2021 census data.

4.4 Walking and Cycling

The walking and cycling routes through the study are relatively sparse with only two routes covering any reasonable distance. Furthermore, the propensity to cycle is below national average at either end of the study area and only matches the average in the central part of the area. This is far below the ambitions to grow active travel to 50% of local journeys by 2030.

4.5 Bus

There are many bus services that run through the study area. However, these either run north south or around the periphery of the area. The exception is the 97 service which matches the route closely but terminates in Chelmsley Wood, approximatly 4.3km away.

4.6 Metro

The West Midland Metro currently runs between Wolverhampton and Edgbaston, with a plan to extend the metro to High Street Digbeth. There have been proposals to extend the metro to Birmingham International rail station and beyond, along the route considered in this study. However, there is no current path to secure funding for this extension.

4.7 Rail

There is a high frequency of rail services between Birmingham International rail station and Birmingham New Street rail station with 4 local stops in between. These local stops are reasonably close to the route through the study area. However, services that stop at the local stations are a fraction of the frequency of services that run direct between International and New Street.

4.8 Road

There are two major motorways that frame the north and east of the study area, linking to Birmingham via the Aston Expressway. In addition to this part of the Strategic Road Network, there are several key routes that run through the study area that are viable routes.

4.9 Environmental Considerations

From traffic monitoring data, it can be shown that the study area suffers from congestion leading to high levels of pollution from gases and noise. The area also includes accident hotspots which can exacerbate the congestion in the area. Finally, Birmingham City Council (BCC) have launched a Clean Air Zone.

4.10 Future Transport Proposals

Several future proposals have been put forward which cover all modes mentioned in this chapter and include projects such as HS2.

Chapter Summary

From the sections in this chapter, it has been shown that there is a need for a transport link along this route that expands the current services in place. The following sections of this report will demonstrate the feasability of a CAM service to operate along this route.

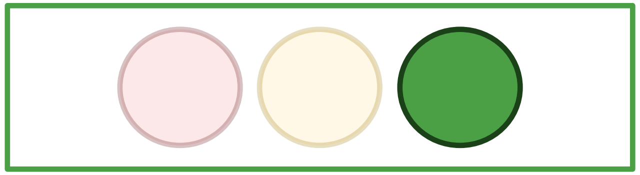
4. Constraints and Opportunities

Performance against the Feasibility Question

4.11 Summary

Feasibility Question 4

Is a new service along this route needed?



The corridor currently acts as a main artery through the region and is prone to congestion through the daytime. Additionally, there are many rail and bus links in the area, but the full route is not frequently catered for residents. The proposed solution would enhance public and active travel options.

.

5. Route Feasibility Overview

FQ5 Is an automated solution (SAE Level 4) the optimal technology for this route?

FQ6 Based on the agreed 'Solution Requirements', can a self-driving solution be delivered within this urban context?

FQ7 Can appropriate levels of segregation be provided along the route?

5. Route Feasibility Overview

Comparison of the original route against a revised route

5.0 Introduction

5

Having ascertained the need for a mass transit intervention, Chapter 5 examines the likely scale of the required intervention; the nature of the technology to deliver such a service and a summary of an automated technology companies proposed system solution. The chapter concludes with an independent view of deliverability

5. Route Feasibility Overview

Comparison of the original route against a revised route

5.1 Route Option Precedents

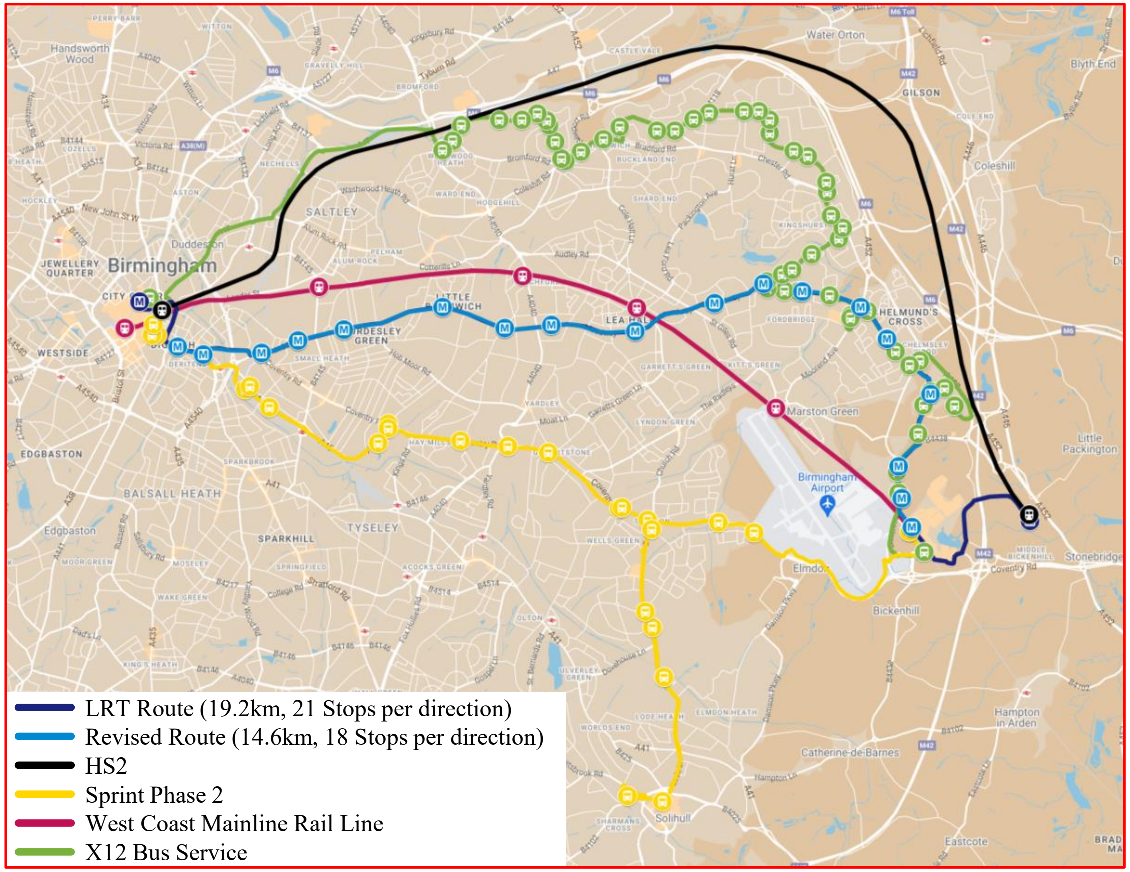
Figure 5.1 shows a comparison the original proposed route from the East Birmingham to Solihull Tramway Business Case and the revised route considered in this study. The figure also includes an approximation of the HS2 route between Interchange station and Curzon Street, the planned Sprint Phase 2, rail connection and X12 bus route for context.

The 2016 business case states that three routes were considered for the tramway. However, two of the routes were discounted as they did not serve any intermediary locations between the terminus points, which were expected to generate service demand. For this study we have taken the selected route as presented by the IOBC.

Since the 2016 report, multiple developments have occurred. The two key events are the proposed tram extension to Digbeth High Street and the planned, high-capacity, people mover linking Birmingham Interchange HS2 station with Birmingham International Rail Station. The revised route shown considers these developments, shortening the route by approximately 4.6km from 19.2km to 14.6km one way. See Chapter 4 for more details on these developments.

A larger version of this image is available in Appendix Chapter 5

Figure 5.1: Comparison of the originally proposed metro extension route and the revised route considered in this study



5. Route Feasibility Overview

Comparison of the original route against a revised route

5.1 Route Option Precedents

Figure 5.2 shows the study area in relation to the nearby West Midlands core bus network. This image is taken form the TfWM Bus Service Improvement Plan published in 2021.

There are areas that the corridor would connect, allowing for travel which may not otherwise be possible. The context of the route should be taken between Figure 5.1 and Figure 5.2.

As can be seen in Figure 5.1 and Figure 5.2, the study corridor does have a bus service that partially runs along the route. However, this services does not link to Birmingham Business Park or Birmingham International rail station. Through the original IOBC and prior, this corridor has been identified for regeneration and a key route to improving connectivity through the region. Alternative routes already have transport development plans in place but are considered too geographically distant from the residents of the study route to be considered a realistic transport option.

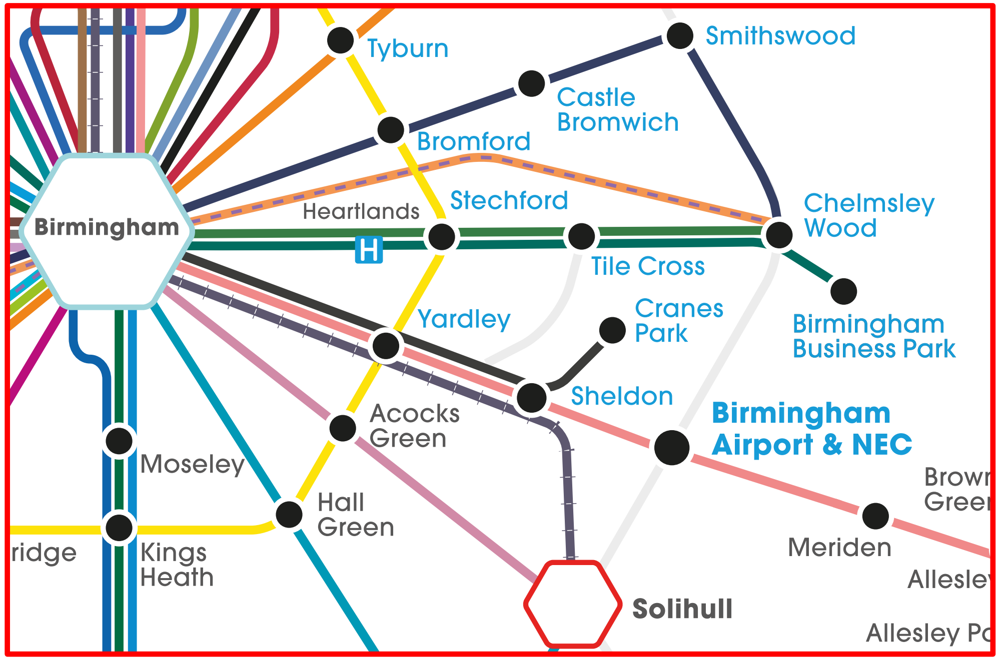
As will be explored in Section 5.4, due to the nature of this route it is unfeasible to meet the condition

'proposed services must run on physically segregated infrastructure - routes that are not open to public access: for vehicles, pedestrians, cyclists and other road users.'

Additionally, the Traditional Transport EBNS will be completing a detailed connectivity plan that will demonstrate how the route will integrate with the existing network and highlight where the route can be made more effective.

A larger version of this image and an image of the full network are available in Appendix Chapter 5

Figure 5.2: Study area network map in relation to the core bus network



5. Route Feasibility Overview

Demand for a CAM service is projected to be close to that of an LRT system

5.2 Initial Patronage Assessment

The primary mechanism through which public transport improvements translate into higher demand and benefits for users is through adjustments to the actual or perceived cost of travel.

Generalised journey times (GJT) combine the costs of different elements of a journey – in this case wait time, in-vehicle time and reliability – into a single overall measure of journey time.

The case for a proposed CAM shuttle versus the previously proposed light rail system has positive and negative GJT impacts. The higher frequency of the CAM shuttle minimises wait time, having a positive impact on demand, although this is offset by the need to interchange at Adderley Street for onward travel towards the City Centre and at Birmingham International for onward travel to the NEC or Birmingham Interchange – which was not the case under previously proposed light rail.

These demand impacts are captured by comparing the GJT in each scenario, using the following formula:

$GJT = IVT + S + R + Q$

Where:

- IVT is the 'in-vehicle' travel time;
- S is the service interval penalty;
- R is the reliability of bus services; and,
- Q is a service quality factor.

The resultant change in demand is calculated by applying an elasticity of demand with respect to GJT (i.e. a parameter which determines the relationship between changes in GJT and changes in demand.

The change in GJT is modelled and applied to the previous LRT business case demand to calculate the demand for the proposed CAM shuttle. A demand elasticity value of -1.1 has been used, per TAG Guidance. This process is illustrated below:

Step 1: Base demand from LRT business case *(see Table 5.2)*

↓

Step 2: Demand Multiplier based on GJT comparison *(see Table 5.3)*

↓

Step 3: Estimated CAM Shuttle Demand *(see Table 5.4)*

Whilst the formula outlined allows for amendments to the GJT to account for service quality or reliability changes, no alteration has been made – meaning that the analysis assumes that the service quality and reliability of the CAM proposal is the same as LRT. More evidence could be used to refine this assumption at subsequent project stages, although this is likely to require primary research about how passengers perceive the shuttles in comparison to bus or LRT vehicles.

Table 5.1 summarises the results, with more detail shown over the next few pages. Essentially, whilst there would be need for additional interchange for trips to key trip attractors at the city centre, NEC and Birmingham Interchange, the higher service frequency of CAM solution minimises wait time which offsets negative impacts, resulting in a similar demand profile for each modal option .

Table 5.1: EBNS Corridor Demand Summary

	Daily	Annual
LRT	22,432	6,798,299
CAM	21,641	6,558,770

Table 5.2: EBNS Corridor Origin-Destination Daily Demand for LRT (Passengers per Day)
(Note: cells shared red would require interchange with onward transport mode)

Destination → Origin ↓	City Centre	Adderley Street	St Andrews	Bordesley Green	South & City College	Heartlands Hospital	Richmond Road	Station Road	Meadway	Lea Hall	Cooks Lane	Kingshurst	Chelmsley Wood	Carisbrooke Avenue	Birmingham Business Park	Starley Way	Elmdon Trading Estate	Birmingham International	NEC	Birmingham Interchange
City Centre	0	27	79	231	214	205	82	77	55	73	35	169	78	64	460	0	0	317	0	240
Adderley Street	75	0	0	2	2	2	3	6	1	1	1	9	1	2	0	0	0	1	0	0
St Andrews	115	0	0	31	26	28	13	6	5	5	2	8	7	12	52	0	0	143	0	14
Bordesley Green	365	3	11	0	7	19	16	24	11	7	3	22	11	7	10	0	0	13	0	0
South & City College	236	1	8	6	0	8	5	12	4	3	2	14	7	6	10	0	0	16	0	0
Heartlands Hospital	257	2	8	19	8	0	3	12	2	4	2	15	10	9	16	0	0	30	0	1
Richmond Road	127	5	5	23	12	4	0	2	4	6	2	10	11	14	65	0	0	119	0	31
Station Road	77	3	4	23	10	17	3	0	5	13	5	15	15	34	214	0	0	472	0	144
Meadway	109	2	4	8	4	5	3	8	0	2	1	7	6	11	26	0	0	38	0	7
Lea Hall	108	1	4	11	5	4	4	19	1	0	1	10	43	18	41	0	0	126	0	36
Cooks Lane	50	6	6	41	27	11	8	10	3	3	0	0	1	14	7	0	0	42	0	10
Kingshurst	70	1	2	5	3	8	4	17	3	4	0	0	4	78	254	0	0	581	0	146
Chelmsley Wood	107	2	3	11	8	19	7	23	7	28	3	7	0	87	75	0	0	254	0	65
Carisbrooke Avenue	91	1	4	5	6	8	6	30	11	22	30	66	124	0	35	1	0	130	0	41
Birmingham Business Park	454	2	7	8	9	9	13	101	31	26	16	160	47	34	0	4	0	199	0	71
Starley Way	214	1	3	3	4	5	6	49	16	12	7	73	22	16	8	0	0	835	0	9
Elmdon Trading Estate	1	0	0	0	1	1	0	2	1	1	6	10	13	8	2	7	0	4	0	0
Birmingham International	26	2	7	23	34	32	12	52	25	31	47	156	113	95	37	1552	20	0	102	5508
NEC	0	0	0	0	0	0	0	1	3	1	4	13	23	12	4	7	0	336	0	0
Birmingham Interchange	29	0	0	0	0	0	1	11	0	13	14	53	19	28	11	3	0	2286	0	0

Table 5.3: LRT → CAM Demand Multiplier based on GJT Analysis

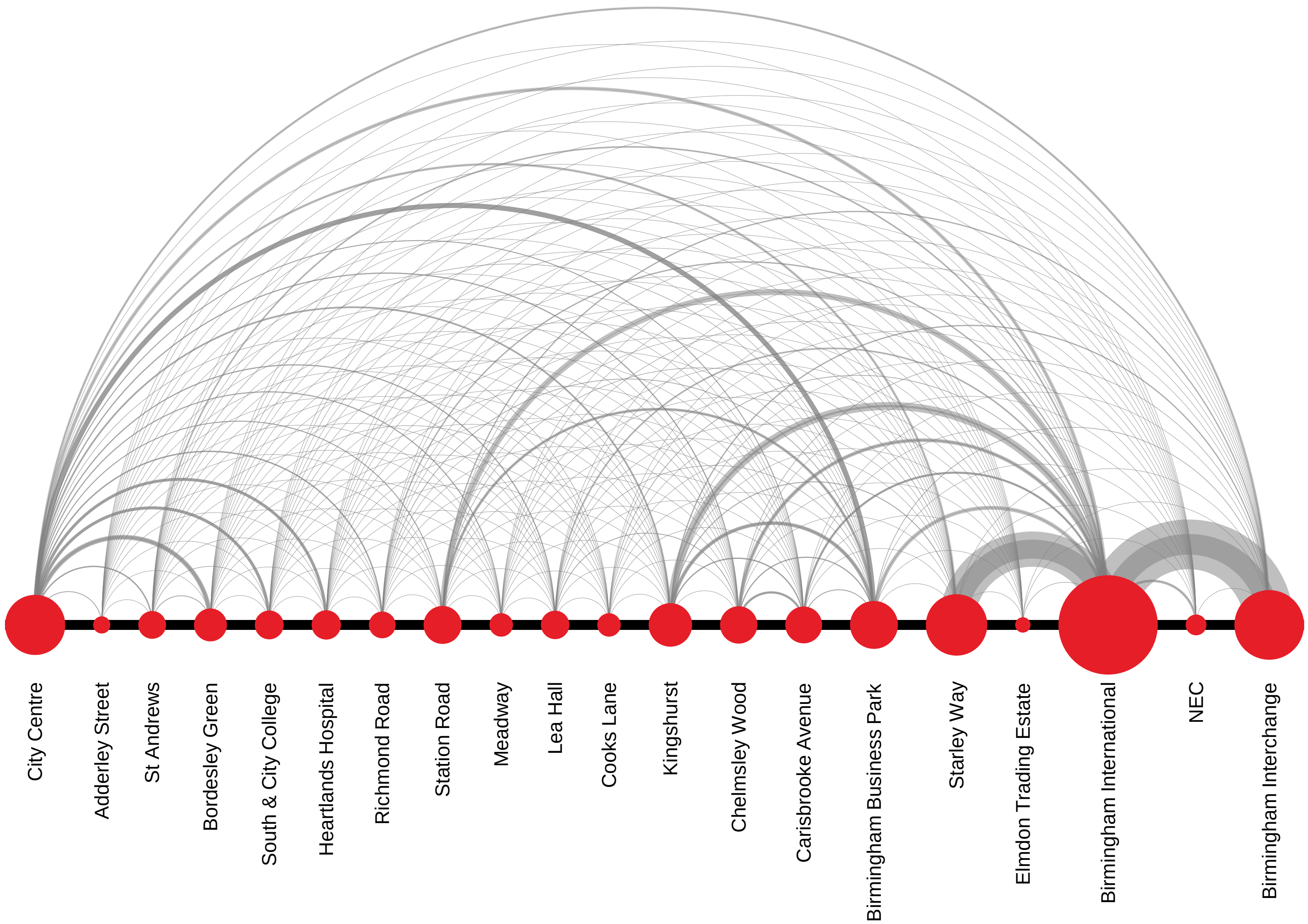
Destination → / Origin ↓	City Centre	Adderley Street	St Andrews	Bordesley Green	South & City College	Heartlands Hospital	Richmond Road	Station Road	Meadway	Lea Hall	Cooks Lane	Kingshurst	Chelmsley Wood	Carisbrooke Avenue	Birmingham Business Park	Starley Way	Elmdon Trading Estate	Birmingham International	NEC	Birmingham Interchange
City Centre	1.00	0.62	0.64	0.68	0.68	0.65	0.65	0.63	0.63	0.63	0.64	0.65	0.64	0.63	0.63	0.64	0.64	0.64	0.53	0.55
Adderley Street	0.62	1.00	2.84	2.41	1.96	1.41	1.26	1.12	1.05	1.00	0.99	0.98	0.94	0.88	0.87	0.86	0.85	0.85	0.62	0.64
St Andrews	0.64	2.84	1.00	3.16	2.29	1.49	1.29	1.13	1.05	0.99	0.98	0.97	0.93	0.87	0.86	0.85	0.84	0.84	0.61	0.63
Bordesley Green	0.68	2.41	3.16	1.00	2.67	1.51	1.27	1.10	1.01	0.96	0.95	0.94	0.90	0.84	0.83	0.83	0.81	0.82	0.58	0.60
South & City College	0.68	1.96	2.29	2.67	1.00	1.77	1.41	1.17	1.06	0.99	0.98	0.97	0.92	0.86	0.84	0.83	0.82	0.83	0.58	0.60
Heartlands Hospital	0.65	1.41	1.49	1.51	1.77	1.00	2.27	1.59	1.32	1.17	1.13	1.10	1.03	0.93	0.90	0.89	0.88	0.88	0.59	0.62
Richmond Road	0.65	1.26	1.29	1.27	1.41	2.27	1.00	2.19	1.58	1.33	1.25	1.20	1.10	0.98	0.94	0.93	0.91	0.90	0.59	0.62
Station Road	0.63	1.12	1.13	1.10	1.17	1.59	2.19	1.00	2.25	1.65	1.49	1.39	1.24	1.07	1.01	0.99	0.96	0.96	0.60	0.63
Meadway	0.63	1.05	1.05	1.01	1.06	1.32	1.58	2.25	1.00	2.28	1.87	1.66	1.41	1.17	1.08	1.04	1.01	1.00	0.60	0.63
Lea Hall	0.63	1.00	0.99	0.96	0.99	1.17	1.33	1.65	2.28	1.00	2.77	2.16	1.68	1.30	1.17	1.11	1.06	1.05	0.60	0.63
Cooks Lane	0.64	0.99	0.98	0.95	0.98	1.13	1.25	1.49	1.87	2.77	1.00	2.82	1.94	1.39	1.22	1.14	1.09	1.07	0.58	0.62
Kingshurst	0.65	0.98	0.97	0.94	0.97	1.10	1.20	1.39	1.66	2.16	2.82	1.00	2.41	1.52	1.28	1.18	1.11	1.09	0.57	0.60
Chelmsley Wood	0.64	0.94	0.93	0.90	0.92	1.03	1.10	1.24	1.41	1.68	1.94	2.41	1.00	1.96	1.49	1.32	1.23	1.19	0.57	0.61
Carisbrooke Avenue	0.63	0.88	0.87	0.84	0.86	0.93	0.98	1.07	1.17	1.30	1.39	1.52	1.96	1.00	2.24	1.73	1.53	1.45	0.59	0.64
Birmingham Business Park	0.63	0.87	0.86	0.83	0.84	0.90	0.94	1.01	1.08	1.17	1.22	1.28	1.49	2.24	1.00	2.42	1.95	1.76	0.58	0.63
Starley Way	0.64	0.86	0.85	0.83	0.83	0.89	0.93	0.99	1.04	1.11	1.14	1.18	1.32	1.73	2.42	1.00	2.84	2.30	0.55	0.61
Elmdon Trading Estate	0.64	0.85	0.84	0.81	0.82	0.88	0.91	0.96	1.01	1.06	1.09	1.11	1.23	1.53	1.95	2.84	1.00	3.11	0.55	0.62
Birmingham International	0.64	0.85	0.84	0.82	0.83	0.88	0.90	0.96	1.00	1.05	1.07	1.09	1.19	1.45	1.76	2.30	3.11	1.00	0.53	0.60
NEC	0.53	0.62	0.61	0.58	0.58	0.59	0.59	0.60	0.60	0.60	0.58	0.57	0.57	0.59	0.58	0.55	0.55	0.53	1.00	3.13
Birmingham Interchange	0.55	0.64	0.63	0.60	0.60	0.62	0.62	0.63	0.63	0.63	0.62	0.60	0.61	0.64	0.63	0.61	0.62	0.60	3.13	1.00

Table 5.4: EBNS Corridor Origin-Destination Daily Demand for CAM Shuttle (Passengers per Day)
(Note: cells shared red would require interchange with onward transport mode)

Destination ➔ Origin ↓	City Centre	Adderley Street	St Andrews	Bordesley Green	South & City College	Heartlands Hospital	Richmond Road	Station Road	Meadway	Lea Hall	Cooks Lane	Kingshurst	Chelmsley Wood	Carisbrooke Avenue	Birmingham Business Park	Starley Way	Elmdon Trading Estate	Birmingham International	NEC	Birmingham Interchange
City Centre	0	16	51	156	145	134	53	49	35	46	22	110	50	40	291	0	0	204	0	131
Adderley Street	46	0	1	6	3	3	4	6	1	1	1	9	1	1	0	0	0	1	0	0
St Andrews	73	1	0	98	60	41	17	7	5	5	2	8	7	10	45	0	0	120	0	9
Bordesley Green	247	7	35	0	19	28	21	27	11	6	3	20	10	6	9	0	0	10	0	0
South & City College	160	3	18	17	0	14	7	14	4	3	2	14	6	5	8	0	0	13	0	0
Heartlands Hospital	167	3	12	28	15	0	7	19	2	4	3	16	11	8	14	0	0	26	0	1
Richmond Road	82	6	6	30	17	8	0	5	6	8	3	12	12	14	62	0	0	108	0	19
Station Road	49	4	4	25	12	27	6	0	11	21	7	21	19	37	217	0	0	452	0	91
Meadway	69	2	4	8	4	6	5	18	0	4	3	11	9	13	28	0	0	38	0	4
Lea Hall	68	1	4	10	5	5	5	31	2	0	4	22	72	23	48	0	0	133	0	23
Cooks Lane	32	6	6	39	26	12	10	14	6	9	0	1	1	20	9	0	0	45	0	6
Kingshurst	45	1	2	5	3	9	4	24	5	8	0	0	9	118	324	0	0	636	0	89
Chelmsley Wood	69	1	3	10	7	19	8	28	10	48	6	17	0	171	112	0	0	303	0	40
Carisbrooke Avenue	57	1	4	4	5	7	6	32	13	28	42	99	242	0	79	2	0	189	0	26
Birmingham Business Park	287	2	6	6	7	9	13	103	34	31	20	204	71	77	0	10	0	350	0	45
Starley Way	137	1	3	3	3	5	6	48	17	13	8	86	29	27	19	0	0	1919	0	6
Elmdon Trading Estate	1	0	0	0	1	1	0	2	1	1	7	12	16	12	4	19	0	13	0	0
Birmingham International	17	2	6	19	28	28	11	50	25	32	50	171	135	138	66	3564	63	0	54	3288
NEC	0	0	0	0	0	0	0	1	2	1	2	7	13	7	2	4	0	178	0	0
Birmingham Interchange	16	0	0	0	0	0	0	7	0	8	9	32	12	18	7	2	0	1365	0	0

Figure 5.3: EBNS CAM Shuttle Origin-Destination Passenger Demand Visualisation

The arc diagram below presents a visualisation of demand for the CAM shuttle along the EBNS corridor, based on GJT analysis and demand for the formerly proposed LRT service. The size of the nodes displayed on the horizontal axis represents proportional demand for those stations, whilst the arcs represent connections between stations. The width of arcs are based on the size of travel demand. Arcs representing travel without an origin or destination at an EBNS station (e.g., NEC to Birmingham Interchange) have been excluded.



5. Route Feasibility Overview

A number of existing and emerging 'alternative' technologies are available as options

5.3 Automated Technology Overview

Although Heavy Rail, Light Rail (Tram) and bus and by far the most common, and therefore well understood, mass transit solution found in towns and cities across the globe, there are a host of additional modes that are seeking to challenge the supremacy of rail and bus. These alternative modes are split between those that have been in operation for some time, but have not become common-place yet, and those that are still emerging. What they each have in common is the aim of removing the physical driver from the vehicle.

A brief, high-level overview of seven of the alternative technologies is provided within this section, including Connected Automated Mobility (CAM), the focus of this study. The section concludes with a table that summarises their respective strengths and weaknesses (as far is understood, with several of the technologies still under development).

Note: Capacity given in ***people per hour per direction*** *(pphpd)*

Larger versions of the images in this section are available in Appendix Chapter 5

Personal Rapid Transit (PRT)

Description:

PRT systems use small vehicles (1 – 6 passengers) that can operate only when needed (on-demand) and provide non-stop, point-to-point service between origin and destination stations on some form of guideway infrastructure. Vehicles are equipped with sensors and GPS technology to direct the vehicle to react to obstacles and traffic control signals. Docking at stations can also make use of fixed guidance infrastructure, such as in-pavement magnets

Guideway Technology:

Rubber on tarmac; Suspended / Supported steel rail

Commercial Example:

Heathrow Pods

Typical System Capacity:

1,000 – 2,500 pphpd

Group Rapid Transit (GRT)

Description:

GRT systems are similar to PRT but feature larger vehicles (10-25 passengers) that may operate on-demand or may also operate on a fixed schedule.

Guideway Technology:

Rubber on tarmac; Suspended / Supported steel rail

Commercial Example:

Rivium, Rotterdam

Typical System Capacity:

2,500 – 5,000 pphpd

5. Route Feasibility Overview

A number of existing and emerging 'alternative' technologies are available as options

5.3 Automated Technology Overview

Very Light Rail (VLR)

Description:

Similar to Light Rail but making use of batteries to avoid installing overhead line equipment along much of the route, along with a new, thinner track system that is theoretically easier to install and repair.

Guideway Technology:

Shallow steel rail

Commercial Example:

No commercial example currently (Nov 2023)

Typical System Capacity:

5,000 – 10,000 pphpd

EBNS Study Focus:

Connected Automated Mobility (CAM)

Description:

CAM systems are fully automated vehicles, equipped with all relevant sensors and processing hardware on board to navigate in mixed traffic autonomously, without need for physical guidance infrastructure or segregation. There are various types and levels of automation, from low speed fixed-path, up to "go anywhere at any time". Service concepts vary from robo-taxis to full-size automated buses.

Guideway Technology:

Rubber on tarmac – onboard sensors provide guidance

Commercial Example:

Trial deployments worldwide, inc. CAVForth & Cruise / Waymo

Typical System Capacity:

1,000 – 15,000 pphpd

Automated People Mover (APM)

Description:

Automated people mover systems operate similarly as automated metros, on fixed schedules, stopping at all stations, but with shorter trains (typically consisting of one to three cars). These shorter lengths, combined with reduced station and guideway requirements, gives the technology the flexibility to serve medium-sized markets, such as to/within airports or within resort complexes.

Guideway Technology:

Straddle beam mono-rail; Suspended mono-rail; Steel rail; Cable pull

Commercial Example:

Birmingham Airport AirRail

Typical System Capacity:

2,500 – 10,000 pphpd

5. Route Feasibility Overview

A number of existing and emerging 'alternative' technologies are available as options

5.3 Automated Technology Overview

Autonomous Rail Transit (ART / "Trackless Trams")

Description:

ART is a lidar (light detection and ranging) guided articulated bus system for urban passenger transport. Models currently in operation are optically guided and feature a driver on board

Guideway Technology:

Rubber on tarmac with optical sensing to follow guideway in tarmac

Commercial Example:

Zhuzhou, China

Typical System Capacity:

15,000 – 20,000 pphpd

Automated Light Metro (ALM)

Description:

Automated metro systems require robust guideways and station infrastructure but offer the greatest capacity of automated transit technologies. Automated metros operate on fixed schedules as long trains (typically consisting of four or more cars), stop at all stations, and are most appropriate to serve major urban corridors, similar to traditional heavy rail or light rail

Guideway Technology:

Steel rail

Commercial Example:

Docklands Light Railway (DLR)

Typical System Capacity:

10,000 – 30,000 pphpd

5. Route Feasibility Overview

CAM compares favorably against the various alternative technology options

5.3 Automated Technology Overview

Table 5.5: High-Level overview, illustrating respective pros and cons of the differing modes of automated transport

Mode	Pro	Con
Personal Rapid Transit (PRT)	Perceived personal safety More private cabin Reliable journey times Small station requirements Proven system (short distance only)	Low passenger carrying capacity Slow vehicle speed Specific infrastructure required Restricted scalability options Long distance transport options unproven
Group Rapid Transit (GRT)	Reliable journey times Proven system (short distance only) Small station requirements	Slow vehicle speed Specific infrastructure required Restricted scalability options
Very Light Rail (VLR)	Ride quality	Specific infrastructure required Restricted scalability options Unproven system
Connected Automated Mobility (CAM)	Can be scaled easily Low specific infrastructure requirements Small station requirements Tight turning radius	Current deployments are trials
Automated People Mover (APM)	Reliable journey times High passenger carrying capacity High vehicle speed Ride quality	Specific infrastructure required Large stations required Restricted scalability options Only deployed for short distances
Autonomous Rail Transit (ART / "Trackless Trams")	High passenger carrying capacity Proven system	Relatively large stations required Relatively large turning radius
Automated Light Metro (ALM)	Reliable journey times High passenger carrying capacity Ride quality	Specific infrastructure required Large stations required Restricted scalability options Relatively large turning radius

- Ride quality is considered as the level of noise, vibration and harshness (NVH) experienced by the passenger. Good ride quality is a reduction in NVH, while poor ride quality is an increase in NVH.
- Ride quality is regarded as being higher when the mode involves steel wheel on steel track.

5. Route Feasibility Overview

Entirely removing public access from the route would be difficult

5.4 Segregation solution

Route Segregation

Following a review of the preceding LRT IOBC designs, a desktop study of satellite imagery of the route was completed. This was carried out to assess if the route could be segregated in a way that satisfied the significantly higher level of segregation requested within CCAV study funding condition, specifically:

'proposed services must run on physically segregated infrastructure - routes that are not open to public access: for vehicles, pedestrians, cyclists and other road users.'

It was determined segregation to this level could theoretically be delivered through a combination of:

- Fencing between CAM (positioned centrally) and other traffic along corridor
- Platform edge doors
- Barriers at crossings
- Tunnels / Viaducts

However, introduction of these solutions would significantly negatively impact:

- Road Width
- Access to a major sports venue
- Access to business entrances
- Access to residential entrances
- Access to residential cross streets
- Financial viability of the scheme

This was further confirmed following a drive of the route as part of the hazard analysis work that makes up Section 7.4 of this document. While major junctions could be catered for, there are a high number of side streets, home access points (driveways, access alleys, etc.), business access points (Car park entrances, warehouse entrances, etc) in significant sections of the route. It would be impossible to install crossing controls for each of these and if not installed, would effectively split the communities apart.

The images on the following page show examples of areas and features that cannot be readily segregated to the extent of entirely removing public access from the route and would therefore require elevated sections / some other interventions. The images show Google Earth satellite imagery of the area along with inset images taken from the recorded drive of the route. The approximate location of inset images are shown by leader lines.

Introducing a fully physically segregated corridor was assessed to have the following knock-on issues:

1. Increased carbon footprint due to residents needing to back track to their homes if approaching from the wrong direction
2. Increased carbon footprint due to delivery drivers (from small vans to HGVs) needing to back track to businesses if approaching from the wrong direction.
3. Restricted turning space for large vehicles (HGVs, tour coaches, etc).
4. Restricted ability for emergency services to respond to emergencies.
5. Limited capability for crowd control at entrances/exits of the sports venue and shopping centres
6. Division of communities by placing a physical barrier through that community
7. Reduction in public realm aesthetics from additional street furniture

The following images will reference the above list of issues by indicating the relevant number. ZF have confirmed that the proposed CAM shuttle, used as an example in this report, has been designed to safely operate with reduced level of segregation than that being defined within the project scope. With this being the case, it was deemed unfeasible to develop the route with a level of segregation that fully excluded any potential for public access on to the route.

All images in this section can be found as larger version in Appendix Chapter 5

5. Route Feasibility Overview

Areas indicating impracticality of full segregation

5.4 Segregation solution

Figure 5.4a: EBNS Route Section 1 Satellite Image

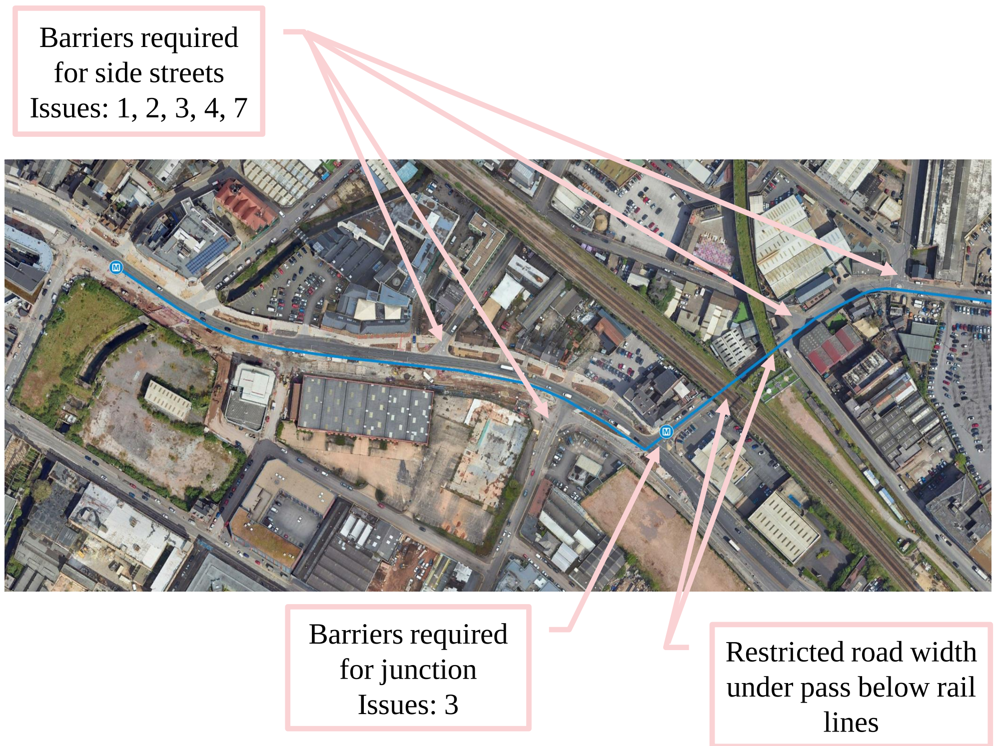
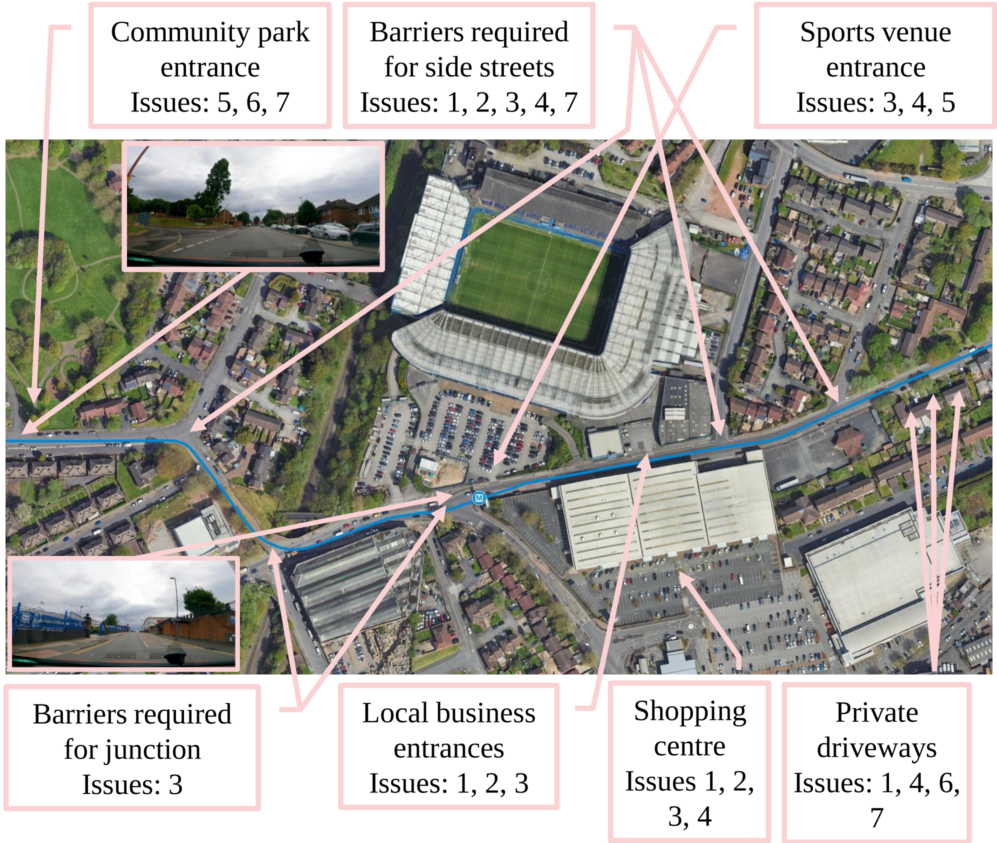


Figure 5.4b: EBNS Route Section 2 Satellite Image and Street Level View



5. Route Feasibility Overview

Areas indicating impracticality of full segregation

5.4 Segregation solution

Figure 5.4c: EBNS Route Section 4 Satellite Image and Street Level View

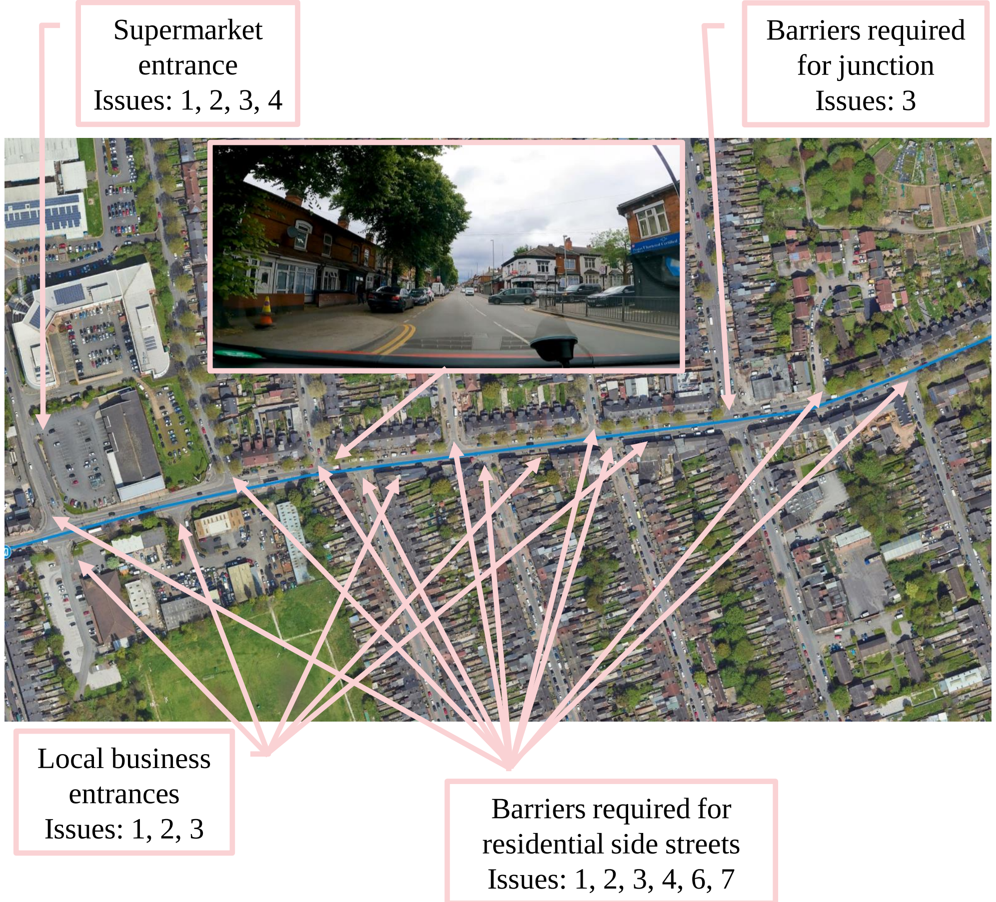
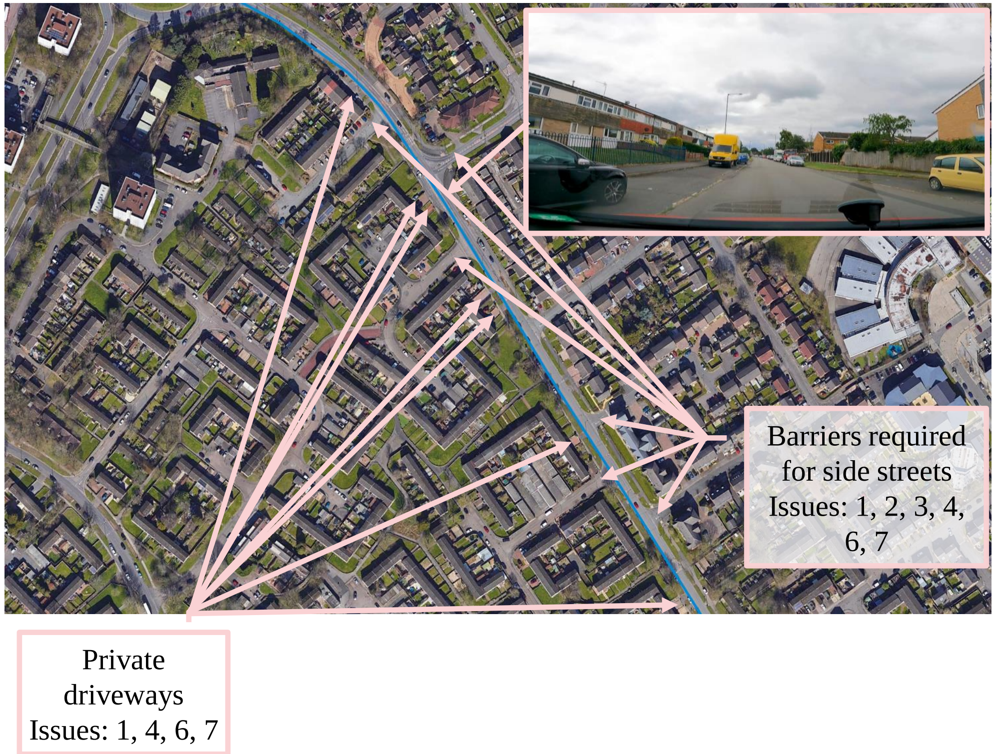


Figure 5.4d: EBNS Route Section 14 Satellite Image and Street Level View



5. Route Feasibility Overview

Levels of Segregation

5.4 Segregation solution

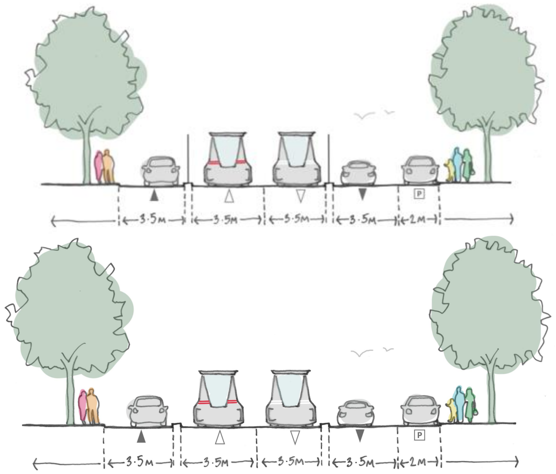
As mentioned earlier in this section, in the context of this study the initial definition of segregation is *'proposed services must run on physically segregated infrastructure - routes that are not open to public access: for vehicles, pedestrians, cyclists and other road users.'* However, it has been shown in this section that strict adherence to this definition would be impossible on the entirety of this route.

To achieve a consistent level of segregation across the length of the route (as discussed in section 5.1), a minimum 4-lane configuration has been considered. In this configuration, the CAM shuttle corridor will be positioned in the centre of two conventional mixed traffic lanes with kerbing / vegetation / fencing segregating the corridor from mixed traffic and other road users. Other road vehicles will be unable to make a right turn to cross into the CAM shuttle lanes, while active travellers would be informed that they should not access the route. By positioning the corridor in the middle of the 4-lanes, interactions with pedestrians can be minimised, increasing physical protection from accidental or intentional damage.

Remaining design features which cannot be fully segregated are station platforms and intersections. An unfeasible amount of infrastructure would be required to achieve the above definition of segregation at these locations. Open station platforms and traffic-controlled intersections have been identified as a more feasible alternative, while maintaining safe and secure operations. This is in line with our expectation of CAM technology maturity at the time of service delivery. If CAM technology maturity is not proven in the required time frame, then further consideration of platform edge doors and intersection barriers will be required. Cost saving opportunities become apparent if CAM technology development surpasses expectation, enabling safe operations in mixed traffic and therefore reduced required levels of segregation along the route. Note that a reduced level of segregation is preferable to allow pedestrians to more easily cross the corridor and minimise severance, but mixed traffic operation will affect journey times, service reliability and associated benefits.

The 4-lane configuration may require additional land take in comparison with the previous LRT IOBC. The assumed 3.5m width of the CAM shuttle lane includes some additional allowances for greater flexibility in future corridor use. This provides some opportunities to reduce lane acquisition requirements at more constrained sections along the route. The impact of the considerations discussed above on costings require further analysis. Additionally, while the proposed corridor cross section incudes spacing for segregation via kerbing / vegetation / fencing, further study is required to identify the most appropriate approach across the length of the route, and to calculate associated costs.

Figure 5.4: CAM Shuttle Corridor Cross Section. Full segregation (top) partial segregation (bottom)



Larger versions of these images are available in Appendix Chapter 5

5. Route Feasibility Overview

The Operational Design Domain is the operating conditions under which the system will operate

5.5 Operational Design Domain

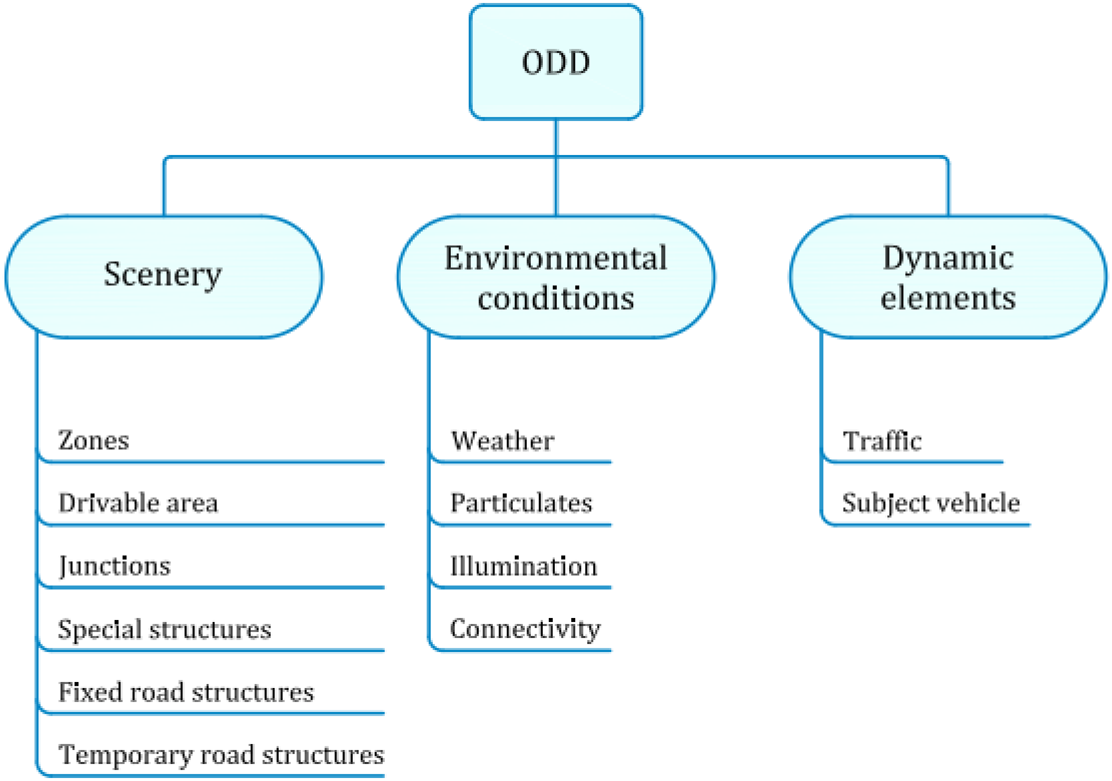
Operational Design Domain (ODD) is defined in BSI PAS1883 as *"Operating conditions under which a given driving automation system or feature thereof is specifically designed to function. Including, but not limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or road characteristics."*.

The term ODD plays a significant role in determining the parameters against which the feasibility of an automated vehicle can operate.

The image to the right illustrates the component parts of a route ODD. An ODD could be specified as simply as one vehicle on one stretch of tarmac running at 5mph in good weather conditions on private land not accessed by members of the public. This could then reasonably be assessed as being easily achievable; however, such an ODD would add little value in the context of a mass transit solution.

This study's ODD is perceived to be as close to a tram service as possible, bringing with it significantly more complexity than the example offered.

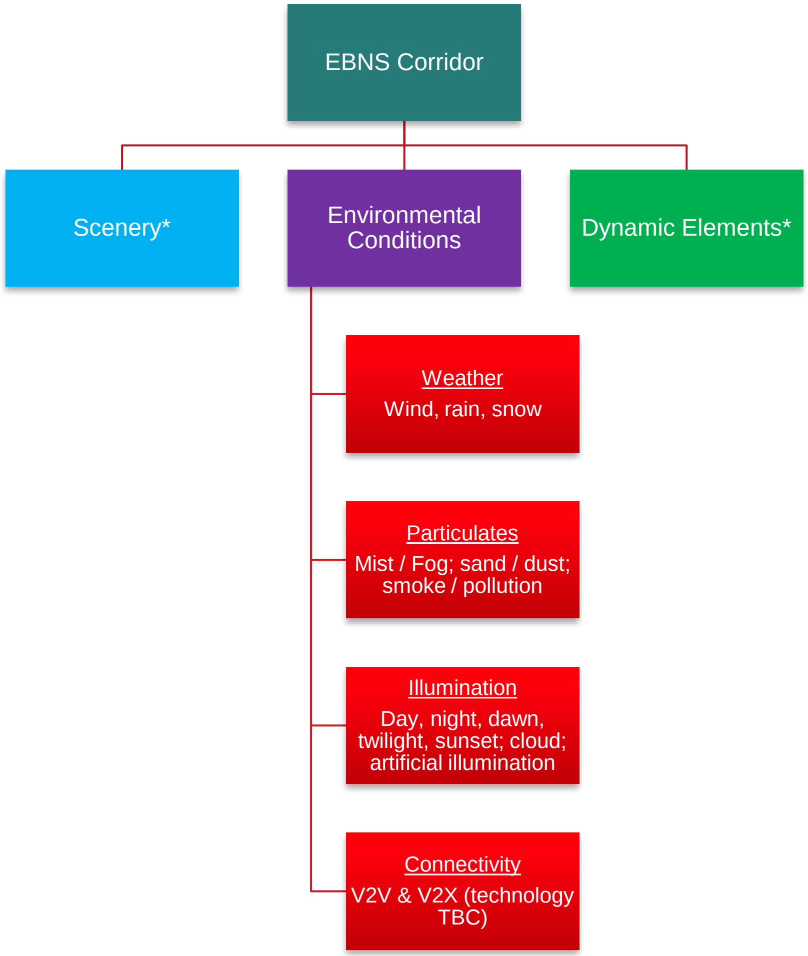
To assist with the exploration of feasibility, a high-level ODD is provided within this section. It is not detailed at this stage due to the high level nature of the feasibility study, but is illustrative of the expected nature of route / service requirement, to allow for initial route assessment.



5. Route Feasibility Overview

The high-level overview of the EBNS ODD is presented here

5.5 Operational Design Domain



*To be specified at next stage of route development, informed by findings of this study

5. Route Feasibility Overview

CAM System Provider Proposed Solution

5.6 CAM Route Assessment - Background to Calculations

Calculating an autonomous Level 4 shuttle route involves a combination of real-time data processing, sensor input, and sophisticated algorithms. The process includes:

Sensor Input: The shuttle uses various sensors like lidar, radar, cameras, and GNSS to perceive its surroundings in real-time. Lidar helps in creating a 3D map of the environment, radar detects objects, cameras provide visual data, and GNSS helps with localization.

Environment Mapping: The collected sensor data is processed to create a detailed and up-to-date map of the shuttle's environment. This map includes information about roads, obstacles, traffic signals, and other relevant details.

Path Planning: Algorithms analyse the mapped environment to plan a safe and efficient route. This involves determining the optimal path, considering factors like traffic conditions, road rules, and potential obstacles.

Decision-Making: The system continuously makes decisions based on real-time data. It assesses the environment, predicts the behaviour of other vehicles and pedestrians, and adapts the planned route accordingly.

Communication with Infrastructure: In some cases, the shuttle may communicate with smart infrastructure using V2X technology, such as traffic lights or other connected vehicles, to optimize its route and make informed decisions.

Redundancy and Safety Measures: Level 4 autonomy implies that the vehicle can handle most driving scenarios, but it still requires human intervention in exceptional situations. The system incorporates safety measures and redundancy to ensure reliability.

Machine Learning and Adaptation: The system may utilize machine learning to improve its performance over time. It can learn from past experiences and adapt its behaviour to changing conditions. Safety is the top priority in the design of this system.

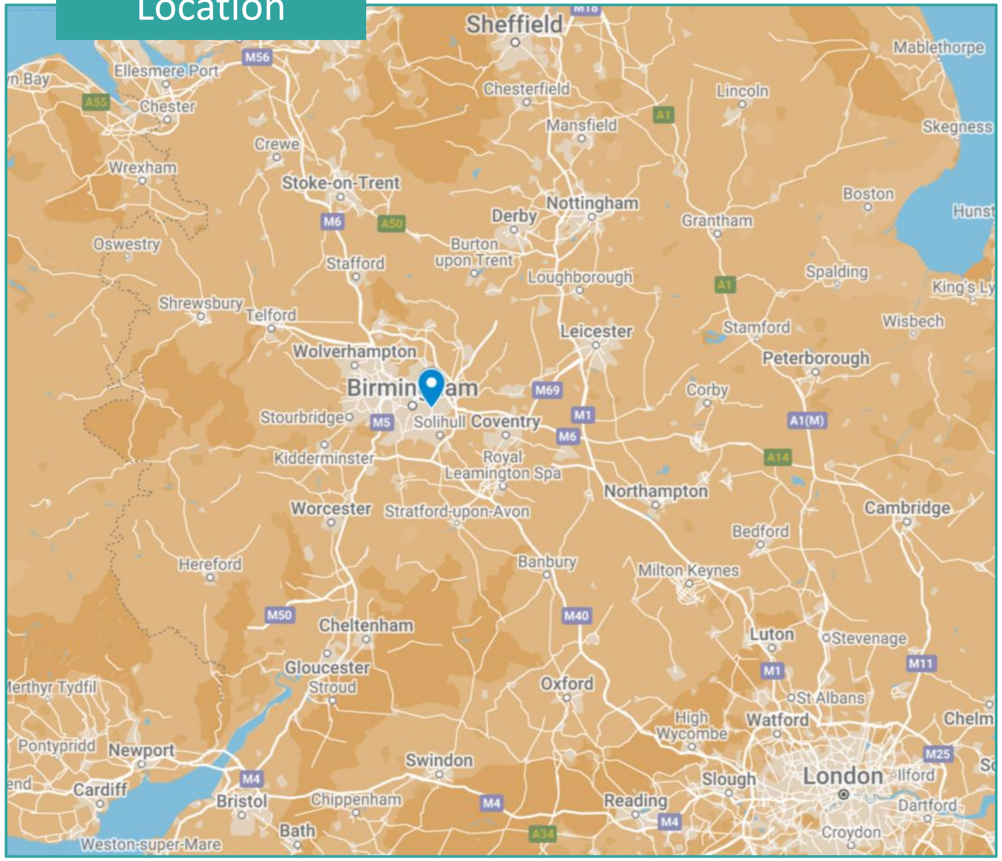
Route definitions: For travel the inbound route and outbound routes are considered separate routes and so there are 36 stations, 18 for each route. For charging the route is considered an open loop and so there are 35 chargers as a terminus station is not double counted

5. Route Feasibility Overview

CAM System Provider Proposed Solution

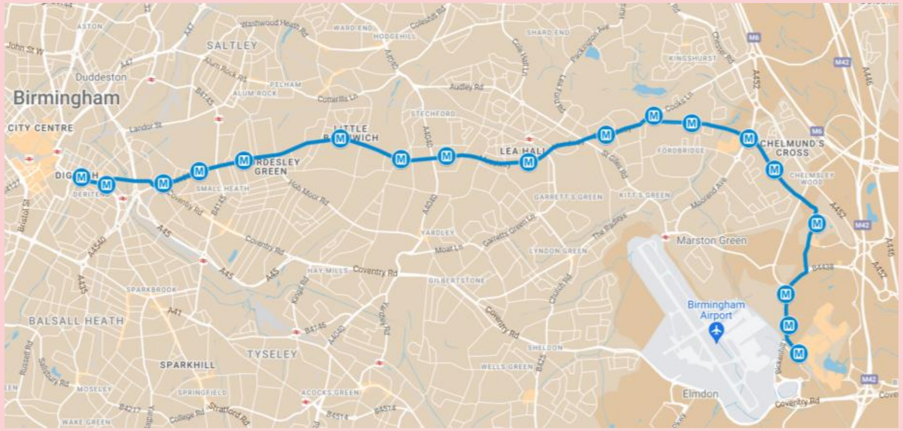
5.6 CAM Route Assessment

Location



Description

- Located in the southeast of Birmingham, UK
- Autonomous Transport System (ATS) will connect Birmingham Airport with Birmingham city centre
- Loop length: 29.2 km
  Station count: 36 stops



5. Route Feasibility Overview

CAM System Provider Proposed Solution

5.6 CAM Route Assessment – System Parameters

Parameters

Boundary Conditions	Speed restrictions	Dwell time (per stop)	Buffer time per return journey	Operational hours	Headway
	40 kph in AD mode 10 kph at VRU crossings 15 kph at obstructed areas 20 kph at junctions	36 s (simulated: shuttle stops at every stop, on demand stops likely)	5 min	19 h/day Monday to Sunday	1min 30sec headway 600 pphpd seated only

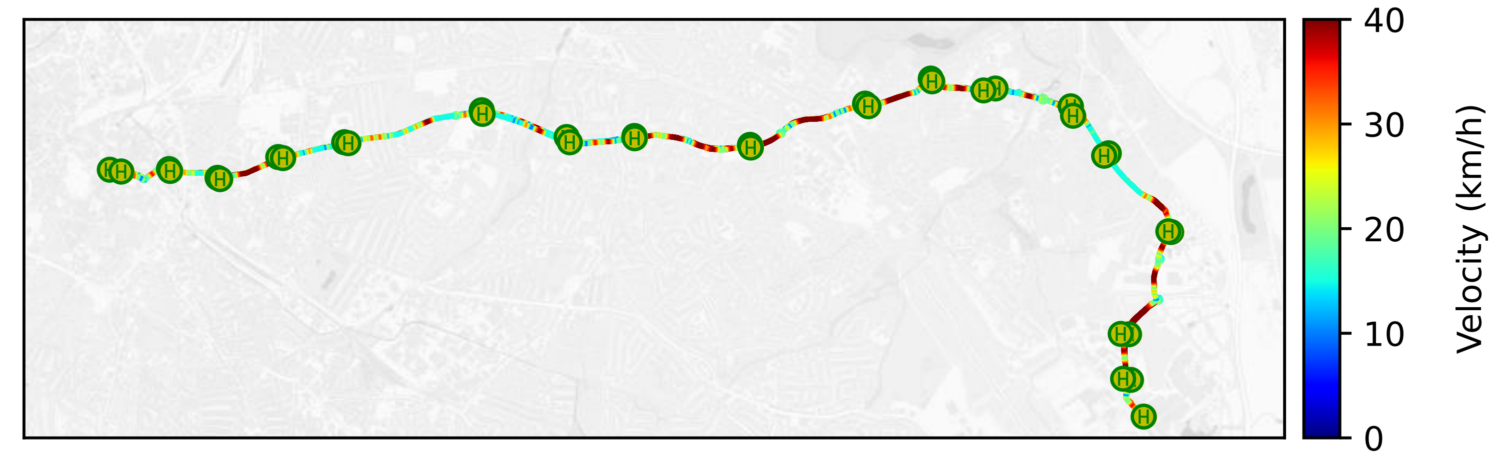
Vehicle parameters	Acceleration	Deceleration	Lateral acceleration	Battery capacity	Charging technology	Seating configuration
	0.8 m/s²	0.8 m/s²	1.0 m/s² (limits cornering speed)	~80 kWh	Opportunity charging (150 kW)	15 seats (Additional capacity 7 standees, 22 passengers total)

5. Route Feasibility Overview

CAM System Provider Proposed Solution

5.6 CAM Route Assessment – System Overview

Velocity profile



Remarks

Trip time can be improved by prohibiting parking right next to the shuttle lane

On-demand stops can be used to reduce overall dwell time per loop

Each direction is considered as a separate route

Return journey travel time (excl. dwell time at stops)
1h 31m

Dwell time (at intermediate stops)
20m 24s

Buffer time (e.g. at traffic lights)
5m

Sum trip time per return journey = **1h 56m** (excluding charging time)

A larger version of the Velocity Profile is available in Appendix Chapter 5

5. Route Feasibility Overview

CAM System Provider Proposed Solution

5.6 CAM Route Assessment – Energy Consumption

Consumption

Per loop: 19.63 kWh (driving), 2.72 kWh (at stops)
22.35 kWh total

Per km: 0.765 kWh/km

Charging location

A fast charger is placed at 35 stations

If the shuttle stops at every station for 36 s, 30.33 kWh can be recharged per loop.

Buffer (e.g. if shuttle is not recharged at every stop):
30.33 kWh - 22.35 kWh = 7.98 kWh (~ 9 stops without charging)

Additional chargers in the maintenance facility/depot are required for overnight/maintenance charging

Consumption model

The consumption values on the left include:

- battery loss
- drivetrain loss
- brake loss
- drag loss
- roll loss
- recuperation
- auxilliaries (thermal, AD-system) while driving.

When the shuttle is stationary (e.g. at stops), an idle power of 8 kW is assumed.
When the shuttle is stationary for more than 15 minutes, a standy power of 1.5 kW is assumed.
The stationary consumption is calculated during fleet planning (not included in the figures on this slide)

5. Route Feasibility Overview

CAM System Provider Proposed Solution

5.6 CAM Route Assessment – Scenarios

Fleet planning

Based on the headway for each scenario, a line blocking plan is calculated, showing the different activities the fleet performs during one day of operation.

Assumptions:

- Operational hours: 19h daily (05:00 - 00:00)
- Charger power: 150 kW
- Charging efficiency: 80%
- Dwell time at stations (per station): 36 seconds
- Buffer time per loop (e.g. traffic lights): 5 min

For each scenario, operational KPIs are extracted and added to a table for comparison

Scenario

According to demand calculations performed in Section 5.2 by the project consortium, **600 seated passengers per hour per direction** is an optimal level for fleet planning.

Next Shuttle Generation (NSG) can transport 15 seated passengers, thus the following headway can be derived:

600 pphpd / 15 seated pax = 40 trips/h
60 min / 40 trips/h = **1 min 30 s headway**

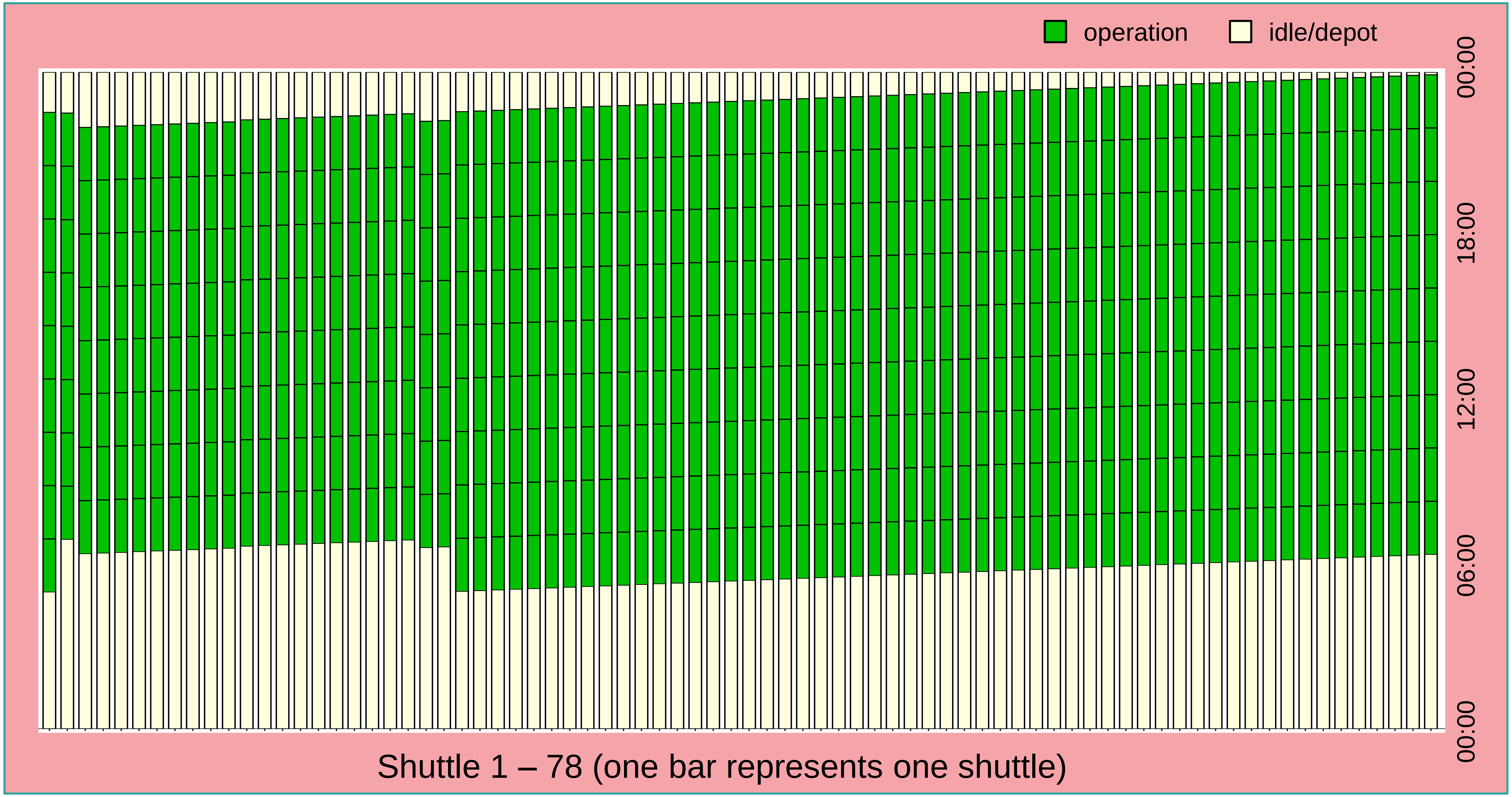
Max. transport capacity (incl. standing passengers):

40 trips/h * 22 pax = 880 pphpd

5. Route Feasibility Overview

CAM System Provider Proposed Solution

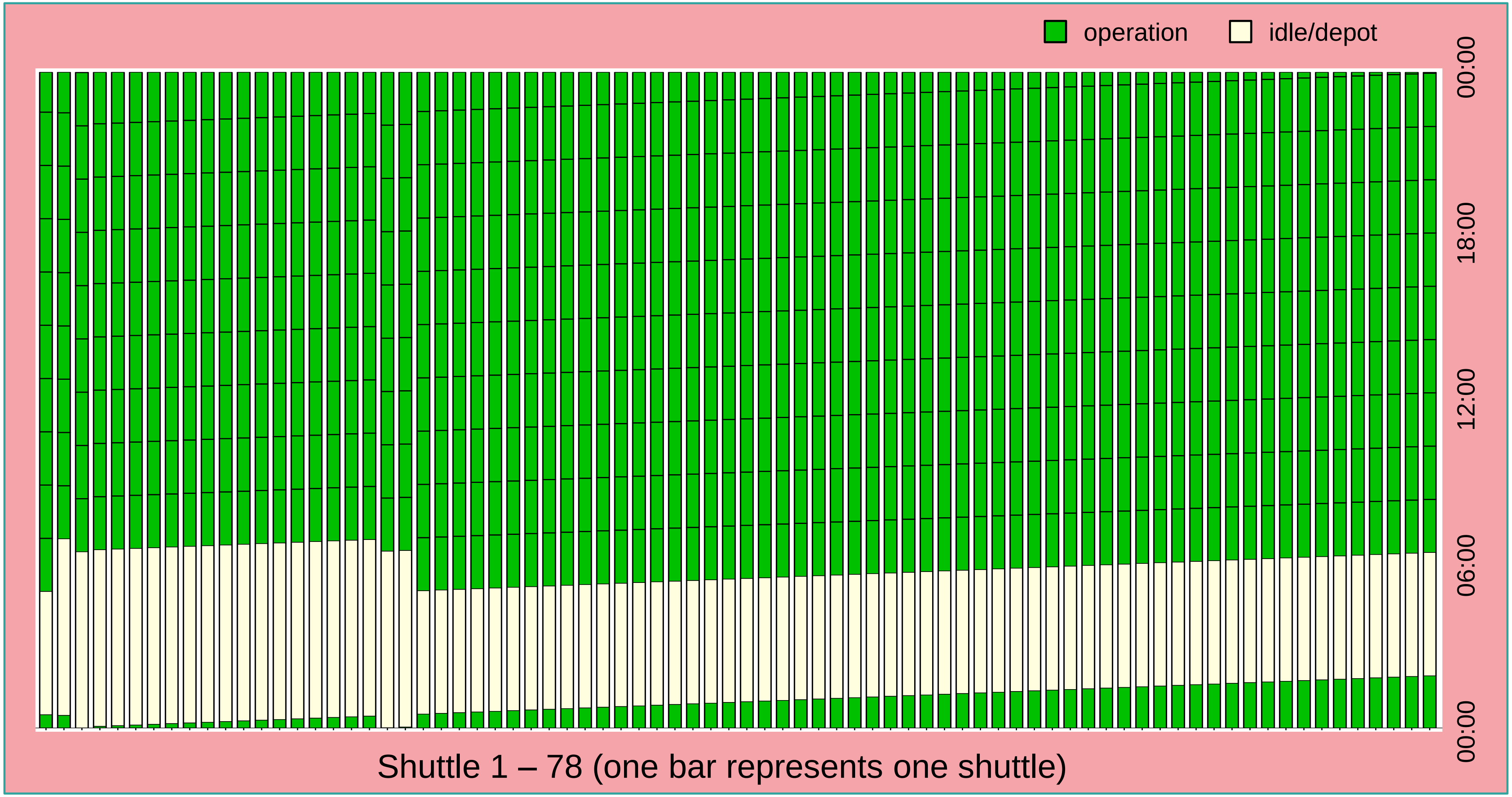
5.6 CAM Route Assessment – System Calculation – Line Blocking



5. Route Feasibility Overview

CAM System Provider Proposed Solution

5.6 CAM Route Assessment – System Calculation – Line Blocking



5. Route Feasibility Overview

CAM System Provider Proposed Solution

5.6 CAM Route Assessment – System Calculation – Operational KPIs overview

Boundary Conditions

Scenario	Fleet size	Charger count	Trips count	Transport capacity	Charging activity count
600 pphpd seated (1 min 30 s headway) last trip ending at 24:00	78 shuttles	35 fast chargers	680 trips/day	600 pphpd (seated only) 880 pphpd (incl. standing)	min. 35 per return journey
600 pphpd seated (1 min 30 s headway) last trip starting at 24:00	78 shuttles	35 fast chargers	760 trips/day	600 pphpd (seated only) 880 pphpd (incl. standing)	min. 26 per return journey

Remarks

- Calculation results are preliminary and based on assumptions
- Additional scenarios can be provided

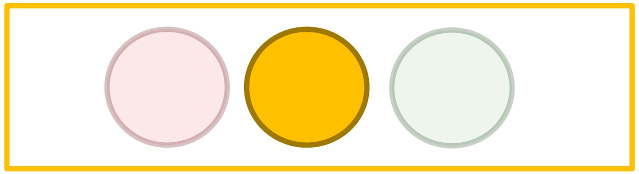
5. Route Feasibility Overview

Performance against the Feasibility Questions

5.7 Summary

Feasibility Question 5

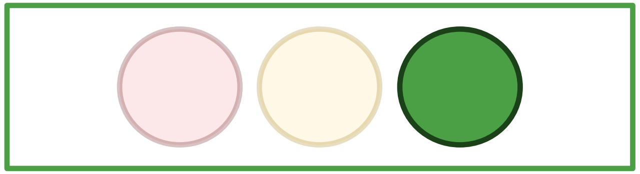
Is an automated solution (SAE Level 4) the optimal technology for this route?



Following a high-level assessment of emerging / non-standard mass transit modes no red flags have been identified. With the levels of global investment and development in the CAM sector, CAM is considered a mode that presents value to assess alongside traditional modes in the medium term. A deeper level assessment of alternative modes is recommended at the next stage to confirm initial findings.

Feasibility Question 6

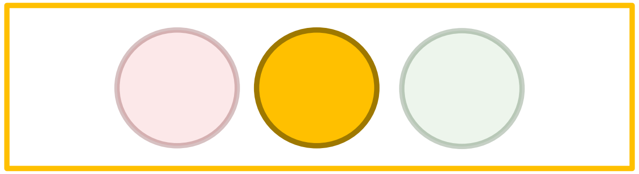
Based on the agreed 'Solution Requirements', can a self-driving solution be delivered within this urban context?



A leading multinational CAM supplier has analysed the identified route, and subject to the agreed levels of segregation detailed within the report stated that they are confident their technology will be able to deliver within the timeframes identified within this study. Case studies support this finding.

Feasibility Question 7

Can appropriate levels of segregation be provided along the route?



CAM technology is projected to be capable of running in 'mixed' traffic, not requiring segregated lanes. This would not however deliver a core requirement of mass transport interventions - Journey Time Reliability. The introduction of a segregated 'at-grade' CAM corridor is deemed to offer the optimum balance, based on expected future capability of CAM systems and associated communication technologies. Specific measures for full physical segregation 'at-grade' including fencing / upstands, platform edge doors and barriers at intersections have been considered but are not all recommended due to their impact on cost, severance and frequency, ergo demand. Further detailed designs of the full route will provide further assurance of the deliverability.

6. Capital Costs

FQ8 Could a CAM solution be delivered at a lower CAPEX when compared to LRT?

6. Capital Costs

We will examine the capital costs relating to a CAM system

6.0 Introduction

6

A critical aspect of every transport intervention is of course cost. Chapter six provides a high-level assessment of the capital cost of the installation of a CAM system along the identified route, offer a comparison with Light Rail in doing so.

6. Capital Costs

Setting out the basis of cost build up

6.1 Route Description and Cost Appraisal

Route Overview

This study considers a route of approximately 14.6km (one way) from Adderley Street in Birmingham City Centre to Birmingham International Rail Station via Bordesley Green. The route is broadly consistent with previous LRT business case proposals serving key destinations and intermediate trip attractors, including Heartlands Hospital and Chelmsley Wood Shopping centre and St Andrew's football stadium. The route has been shortened by approximately 2km at the western extent to account for the proposed HS2 Automated People Mover (AMP) system which will move passengers between HS2's Interchange Station, the NEC and , Birmingham International Airport.

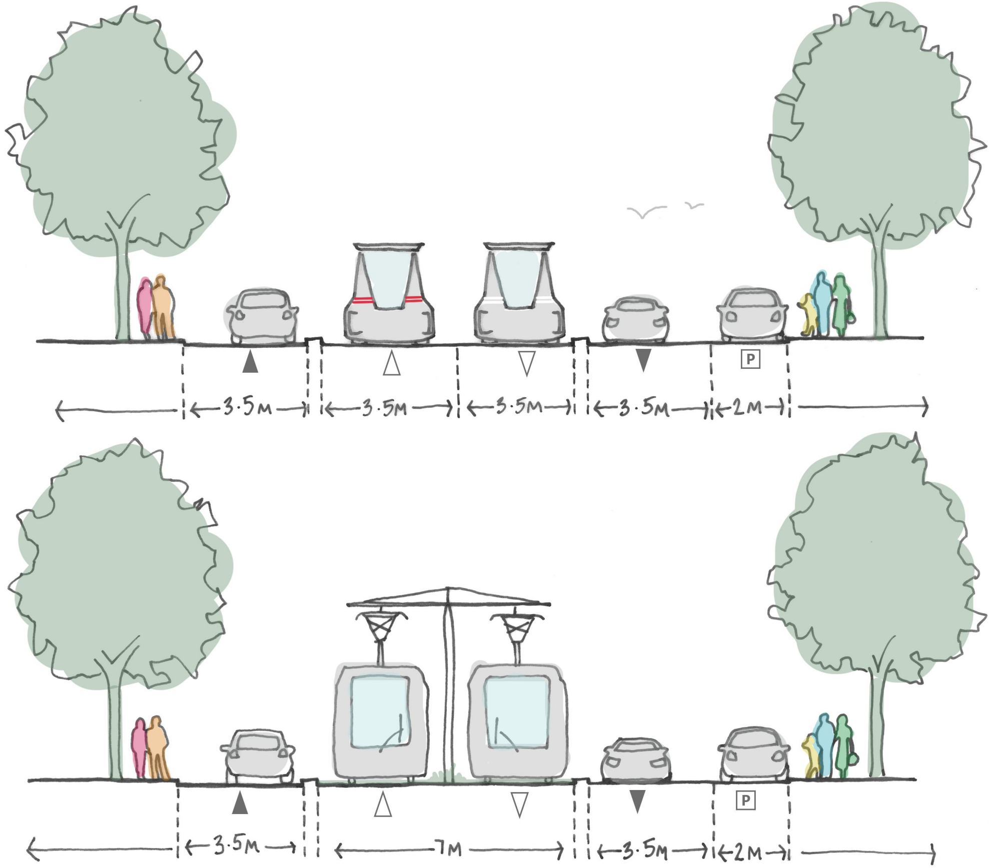
Typical Cross Section vs LRT Proposals

The previous LRT route design included various arrangements of road layouts with light rail lanes alongside traffic lanes, parking bays, active travel lanes, etc. For the purposes of this study, and to allow a like-for-like comparison, the arrangements for the proposed CAM shuttle are assumed to be broadly consistent, with automated shuttle lanes replacing the light rail lanes. Typical cross sections are shown in Figure 6.1.

ZF's shuttle has a width of 2.4m, and requirement for lateral movement of 0.3m in either direction, meaning that lane width could be reduced to 3m (6m corridor with for bi-directional lanes). However, for costing purposes, an allowance of 7 metres width has been made on the basis that this would allow some flexibility for larger shuttle operation, or future-proofing for alternative modes of public transport (e.g. bus or LRT) to operate on the corridor, rather than limiting to the requirements of ZF's current solution.

Larger versions of Figure 6.1 can be found in Appendix - Chapter 6

Figure 6.1: Typical CAM Shuttle Corridor Cross Section (top) vs LRT proposals (bottom)



6. Capital Costs

Setting out the basis of cost build up

6.1 Route Description and Cost Appraisal

Active Travel Provision

The existing light rail route design includes separate provision for active travel, so the automated shuttle lane does not need to be designed to accommodate active travellers along with the automated shuttle, and has been excluded from capital cost development, and the benefits excluded from the economic appraisal.

Cost Summary and Key Assumptions

Table 6.1 overleaf summarises a high-level capital cost exercise, proportionate to this early-stage feasibility study. The route is expected to cost of the order of **£235m** in 2023 prices, inclusive of 46% optimism bias, an allowance of 25% works costs for utilities and 15% works costs for traffic management. Development costs of 12.5% have been included to account for the costs of developing the scheme, including costs to TfWM / WMCA and for business case work, scheme design and engineering consultant costs – this assumption is consistent with the previous LRT business case. These cost are based on the route described earlier in this document.

The carriageway widening includes allowance for material excavation, disposal, drainage and kerbs. The footway replacement assumes that this would be undertaken on one side of the carriageway only.

Costs for Stops

An assumption of £100,000 for each stop has been made. It is envisaged that the infrastructure requirements for stops will be similar to an enhanced bus stop. Comparisons have been drawn with the Belfast Glider stops, shown in Figure 6.2 which cost approximately £70,000 per stop (uplifted to 2023 prices). The higher estimate accounts for potential requirement for longer stops/canopies relevant for more frequent arrival/departure of shuttles, passive provision for convoys of shuttles and associated with additional stop spacing assumed on the proposed route (as per previously proposed LRT stop spacing versus every 400m in the Glider system).

Figure 6.2: Belfast Glider Stop (Source: Translink)

Requirement for Third Party Land

Parts of the route currently suffer from chronic road congestion and a narrow highway corridor without width to enable segregated running, particularly at the eastern end of the route.

Delivering a 7m wide corridor through the route would require the demolition of several commercial and residential premises, as well as historic buildings including a Snooker Hall and Fire Station. Table 6.2 outlines a high-level estimate of third-party land costs used to inform the economic appraisal, equivalent to acquisition of 165 land/property parcels at an average cost of £250,000, resulting in an additional cost of **£53.6m**, inclusive of 30% contingency.

It is noted that this is a very high-level estimate that requires further assessment and refinement at subsequent project stages. The potential for significant land take on parts of the route to develop a segregated corridor could potentially be offset as the route is considered in more detail, to find the right balance between land acquisition and level of segregation.

Table 6.1: CAM Segregated Route Construction Cost Estimations, 2023 prices. (Note: Fleet costs are included within operating costs, rather than CAPEX)

Item	No.	Unit	Rate	Sum (£)
Civil works				**£91,625,000**
Bellmouth Improvement	70	nr	£100,000	£7,000,000
New / Improved Signalised Junction	30	nr	£300,000	£9,000,000
Widened carriageway	90,000	m^2	£550	£49,500,000
Linear segregation / Upstanding	25,000	per m	£100	£2,500,000
Replacement footway	45,000	m^2	£150	£6,750,000
Carriageway overlay	135,000	m^2	£125	£16,875,000
Stations and Depots				**£20,600,000**
CAM Stops (18 locations with one stop per direction)	36	nr	£100,000	£3,600,000
CAM Depots	2	nr	£5,000,000	£10,000,000
Amendments to existing structures	7	nr	£1,000,000	£7,000,000
Opportunity Charging Infrastructure				**£7,200,000**
Pantograph (one in each direction)	36	nr	£150,000	£5,400,000
Electrical installation	18	nr	£5,000	£90,000
Civils / substation works	18	nr	£60,000	£1,080,000
Transformer	18	nr	£35,000	£700,000
Depot Charging Infrastructure				**£1,700,000**
Rapid charging units (twin)*	15	nr	£75,000	£1,125,000
Electrical installation	15	nr	£5,000	£75,000
Civils works and substation	2	nr	£250,000	£500,000
		Optimism Bias	46%	£55,717,500.00
		Traffic Management	15%	£18,168,750.00
		Utilities	25%	£30,281,250.00
		Development Cost	12.5%	£15,140,625.00
		Capex Total		**£240,433,125.00**

*Two vehicles can be charged per rapid charging unit, meaning 30 vehicles can be charged at one time within the depot.

Chargers can be rotated between vehicles as required overnight manually by staff or as part of automated depot operations.

Table 6.2: CAM Segregated Route Third Party Land Acquisition Cost Estimate, 2023 prices

Item	No.	Unit	Rate	Sum (£)
Property and land acquisition	165	nr	£250,000	£41,250,000
		Contingency	30%	£12,375,000
		Property and Land Acquisition Cost Total:		**£53,625,000**

6. Capital Costs

CAM systems cost in the region of 50% of traditional Light Rail

6.2 CAM vs LRT high level CAPEX comparison

LRT capital route infrastructure costs (per km) are significantly higher than those of a CAM shuttle solution (Table 6.3). This is primarily due to the linear infrastructure required for LRT, including track, overhead line and substations along the route which are not required for CAM.

It should be noted that a CAM solution would require shuttle charging infrastructure along the route, which is not required for LRT.

There could be further optimisation of CAPEX based on the cost of stops. This requires a more robust concept of operations once there is further details on passenger demand, reliability and service frequency.

Corridor width for the CAM solution is assumed to be the same width as the LRT to ensure that the corridor can be repurposed for other transit modes in the future. As a result, land take costs along the route are similar for both solutions, however further study is required to investigate the impact of enhanced levels of segregation for the CAM solution compared to LRT, as discussed in Section 5.3.

Table 6.3: LRT vs CAM Shuttle Route Infrastructure Capex Comparison, 2023 prices

	LRT	CAM Shuttle
Construction Cost Estimate	£625m	£291m
Route Length (km)	16.5	14.6
Cost per km	**£37.9m**	**£20.0m**

Notes:
1. Includes optimism bias and land acquisition costs
2. Capex associated with Trams and CAM Shuttles excluded
3. LRT costs uplifted from 2016 to 2023 prices using average inflation of 4.5% per annum, and have been checked against typical outturn costs of LRT infrastructure in the West Midlands (typically £30-50m)
4. It is assumed that the Double Decker bus would utilise the same route as the CAM solution but further investigation should be undertaken to understand any constraint with regards to under bridges as an example. The CAPEX associated with the DD would be similar to that of the CAM solution assuming elements of the design are comparable, for example stop spacing.

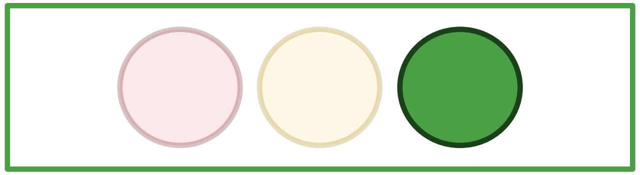
6. Capital Costs

Performance against the Feasibility Questions

6.3 Summary

Feasibility Question 8

Could a CAM solution be delivered at a lower CAPEX when compared to LRT?



Analysis indicates a cost per km of £20.0m for a CAM installation, based upon the level of segregation as detailed in Section 5.5. This is roughly half the cost of Light Rail (£37.9m) along an almost identical route. This therefore indicates a significant saving in relation to capital outlay. CAM is considered to be on par with Bus Rapid Transit in relation to CAPEX investment.

7. Operations

FQ9 Could a CAM solution be delivered at a lower OPEX when compared to LRT?

FQ10 Can the required level of system reliability be delivered?

FQ11 Can the route be delivered with acceptable safety?

FQ12 Can fares be protected, on-board riders be safe, and accessible transport all be provided pragmatically?

FQ13 Will an automated solution be legislated for and insurable?

7. Operations

We will explore all aspects of safely operating a service as designed

7.0 Introduction

7

Having established the support, need, route, mode and installation cost for a future service, focus must now turn to how such a service would be operated.
Chapter 7 begins by proposing a high-level Operational Concept to provide a set of requirements that the future service should seek to deliver. Against this concept, operational costs, safety and human-machine interfaces are then assessed

7. Operations

This is the basis of what is required within a future service along this corridor

7.1 High-Level Operational Concept

Hours of Operation

Monday – Sunday 5am – 12 midnight initially, with the option / ambition to extend to 24/7 service

365 days / year

Route & Stops

Deritend St, Birmingham to Birmingham International Train Station

18 stops one way (as detailed in 5.2). 36 second boarding / disembarking time.

Stops are 'on demand' – akin to bus, rather than train

Route Infrastructure

- Dedicated, identifiable stops throughout route with shelter and electronic service information boards
- Level boarding stops
- Cellular communications throughout
- Vehicle charging facilities

Performance Capability

On par with tram. Service operational irrespective of weather conditions (within defined parameters); time of year; events taking place along route

Service Levels

10-minute *maximum* headway

Ability to flex service patterns for short-term changes (including the addition of capacity)

Assets and Facilities

Storage & maintenance depot & control centre located at suitable premises on / very near route

Vehicles capable of 30 mph

Service capable of integration into existing Metro interchange / system

User Interfaces

- Ridership data collection
- Farebox collection
- Integration into Swift ticketing systems
- 24/7 emergency contact / support
- On-board standard and emergency call buttons; monitoring and information screens

Accessibility

The system must be capable of safely and comfortably on-boarding, conveying and disembarking wheelchair users and visually, aurally and audibly impaired customers

Service notes

This study has utilised a 1 minute 30 headway. This may not be possible / desirable due to traffic signal timing. Further work will be carried out to identify the optimum headway.

7. Operations

Similar automated systems are already in operation overseas – delivering daily services to paying customers

7.2 Operational Case Study: Rivium

To provide an illustration of an existing automated vehicle service currently in operation, the following case study offers an insight into the Rivium Business Park Shuttle in Rotterdam.

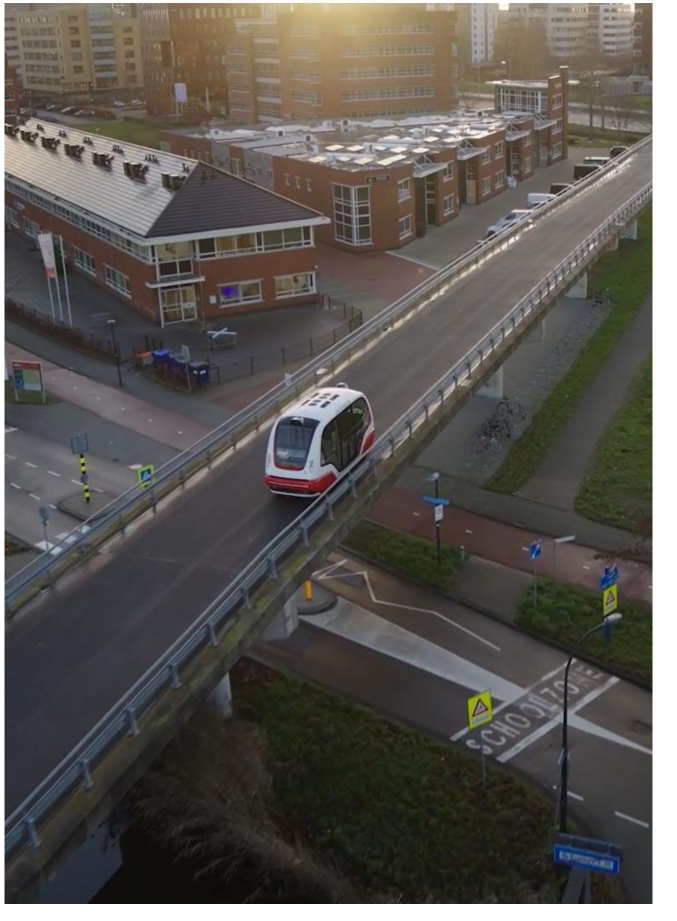
ZF's GRT3 shuttle, which is primarily designed for use in segregated lanes, is currently in operation in the Rivium business park near Rotterdam. The fleet of six shuttles transport up to 3,000 passengers per day over a 1.8 kilometre fixed route. It runs from Monday to Friday. On working days the shuttle runs between 06:00 and 21:00 hours. During rush hour you can catch a shuttle every 2.5 minutes. During off-peak hours, the ParkShuttle rides on demand. The vehicles travel at a top speed of 40kmph, but an average of 32kmph.

It is an electrically-driven, automated shuttle service that runs between Kralingse Zoom metro station in Rotterdam to the Rivium business park in Capelle aan den IJssel. The system first opened 1999 and has been extended since. It has three stops in Rivium (at the 4th, 2nd and 1st streets), a stop Fascinatio (serving the residential area in Capelle aan den IJssel and the Brainpark III business park) and finally at Kralingse Zoom metro station. In 2022 six vehicles of the third generation entered service.

The Rivium service is staffed by two operators from the Public Transport Operator (Connexxion, a subsidiary of Transdev Netherlands). Outside peak hours, it is not uncommon to only have one at the premises. The operators stay in the operating room, where they can oversee the whole system, including vehicle location, vehicle status, CCTV (in and outside the shuttle), etc. If everything runs smoothly, they have no actions. They can deploy more shuttles or remove them from operations, they can give instructions to a shuttle to start or stop, they can call for support in the case of malfunction, they can record/report any law breaking by passengers or other vehicles, also report/record any operational remarkable events (false positives, etc.).

The info panels for passenger interaction have 2-way voice communication, same as the shuttles. The whole Operational Design Domain (ODD) is supported with a communication structure. There is no other centre overseeing the operations. ZF could/can oversee it and overwrite it from their side (both from the depot for maintenance, cleaning, charging and storage, and also from our office) but ZF do not perform any operational action, nor do they have anyone checking Rivium’s operations. ZF are on-hand to provide technical support as required.

Figure 7.1: Promotional still of the Rivium Service

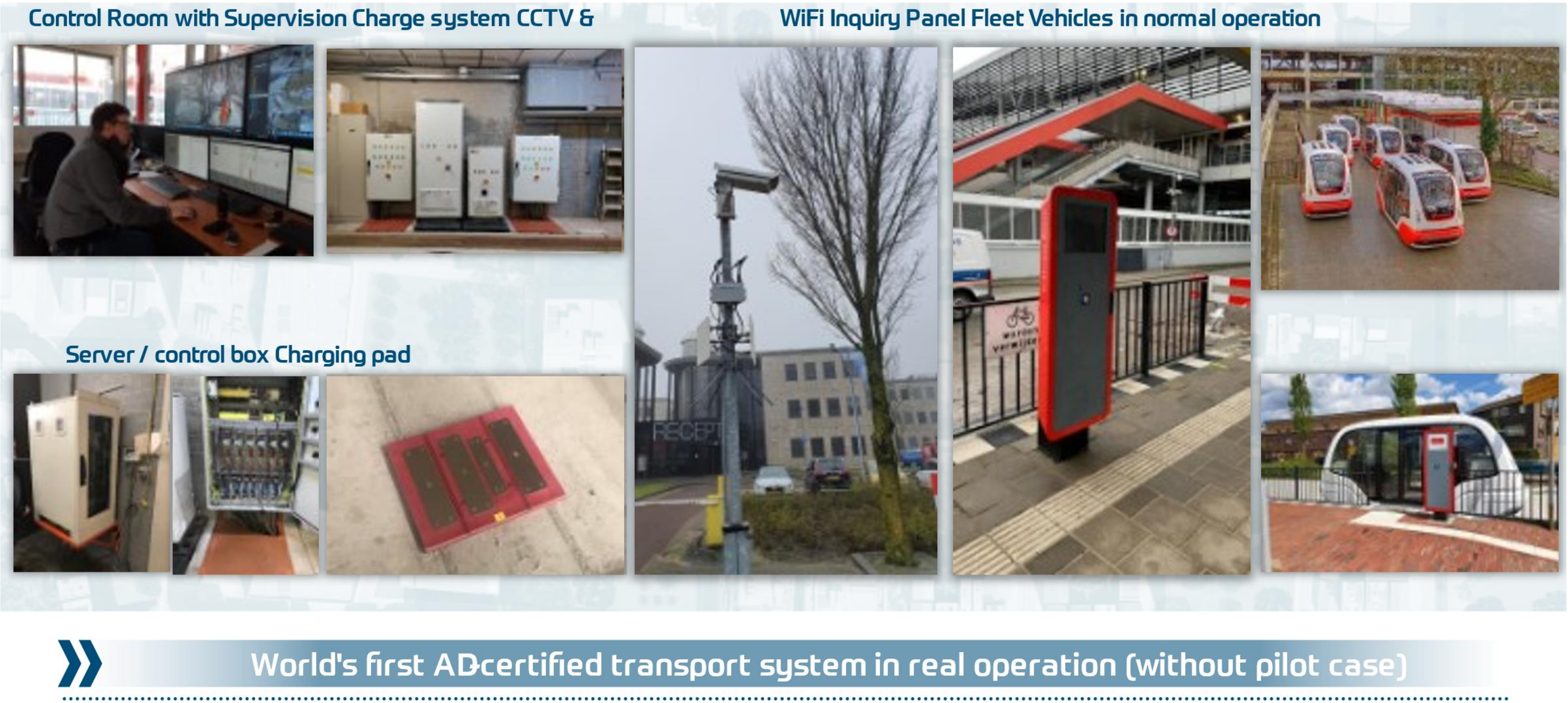


7. Operations

Similar automated systems are already in operation overseas – delivering daily services to paying customers

7.2 Operational Case Study: Rivium

Figure 7.2: Extract of Rivium service operations presentation



7. Operations

A CAM system would integrate into existing Transport for West Midlands ticketing and fare protection systems

7.3 Human Machine Interface (HMI)

Removing the driver from the mode of transport presents new challenges to areas of operation that have traditionally required / relied upon a representative from the transport company to fulfil. Identifying these touchpoints and understanding how the traditional human role will be substituted will be an important aspect of a delivering an automated transport system.

To identify these touch points, and the corresponding high-level response, the Rivium use case has been central.

Touch points:

1. Fare Collection

Solutions to public transport ticketing and enforcement vary widely across modes and jurisdictions. Table 7.1 illustrates how ticketing and enforcement across the core mass transit modes is delivered within the West Midlands Combined Authority. The final column in the table illustrates the proposed solution for fare collection on the EBNS CAM solution.

The primary strategy for enforcing fare collection will be to utilise existing fare protection officers within the Transport for West Midlands transport systems.

Table 7.1: Public transport ticketing and enforcement

	Bus	Train	Tram	CAM
Ticket purchase Location	Driver Online Payzone shops	Ticket office Platform ticket machine On train Online	On-board conductor Online Payzone shops	Online Platform ticket machine
Ticket purchase Method	Cash Contactless Swift account			
Ticket types	Single / return journey Daily / Weekly / monthly / Annual pass - mode specific Daily / Weekly / monthly / Annual pass - mode agnostic (Network Pass)			
Enforcement	Drivers Revenue protection team	Ticket barriers Revenue protection team On-board staff	On-board staff Revenue protection team	Revenue protection team
Est. fare evasion %	c. 3%	West Midlands Railway have previously estimated that ticketless travels runs at 10-15% of numbers of people carried		

7. Operations

A CAM system would integrate into existing Transport for West Midlands ticketing and fare protection systems

7.3 Human Machine Interface (HMI)

2. Boarding

Vehicles will be programmed to stop at every identified shuttle stop along the EBNS route. The vehicle doors will be opened by button pressed by those wishing to enter / exit the vehicle.

3. Incident / Accident processes

There will be continuous monitoring of vehicles (Internal and external) via the systems control room, which can engage the appropriate emergency response.

There is a means to communicate immediately with the control room from both inside and outside the Shuttle.

4. Accessibility (Wheelchair user / Partially sighted, etc)

The specification for shuttle stops will be, where possible, to provide level boarding, allowing for wheelchair users to simply roll on.

The ATS Shuttle does however have a deployable ramp, which can accommodate height differences to ensure safe boarding and alighting. Inside the cabin there are low level communication facilities to be within reach of Wheelchair users. There is a specific area within the Shuttle for Wheelchair, assistance dog or Pushchair to be located. Names of stop will be announced prior to arrival at stops.

5. Remote Supervision

See section 7.1 regarding the Rivium deployment, this will be the general procedure, scaled up or down according to the fleet size.

6. On-board advice / interaction

During the journey riders will be able to speak directly and immediately to the systems control room. On-board physical communication systems will be complemented with braille descriptions. Automated on-board station and service announcements will be standard, as per bus and light rail.

There will be information screens displaying up-coming stops.

On-board anti-social behaviour

Questions exist around whether the absence of a driver might lead to an increase in anti-social behaviour on public transport. Currently, drivers can act as a deterrent to intimidating or violent behaviour, even though they do not have a specific duty to address such conduct. By adapting adequate safety measures to promote a safe and respectful environment, the risk of increased anti-social behaviour can be mitigated.

On CAVForth trials, a "bus captain" is in place alongside a safety driver to provide reassurance to passengers throughout the journey. Down the line, it is possible that fully automate buses may have one member of staff whose remit it is to communicate with passengers while the automated systems drive the vehicle. This may help to provide a sense of security to passengers and improve overall service quality. This provision is not expected within the EBNS service, however a ‘floating’ driver system, whereby representatives of the operator ride the system throughout the day to check tickets / provide guidance / assurance may be deemed worthwhile, especially in the early period of a service.

As plans for this CAM system develop representative user groups will be engaged to ensure design is carried out in an appropriate user-focussed way.

7. Operations

Safety assessment approach

7.4 Safety – Independent Route Review

Importance of Safety Case and Hazard Analysis

Identification, evaluation, and analysis of potential hazards is integral to comprehensive safety analysis and development of a safety case to mitigate those hazards and risks. The safety case must ensure that all risks are reduced as low as reasonably practicable (ALARP) and to a socially acceptable level as part of the safety management system. The safety case also helps with confidence of wider stakeholders, including underpinning evidence for insurers.

Approach to initial domain Hazard Analysis

Background research

The proposed route description in the Project Overview and in the architectural drawings covering sections A to F is of a scale that prevented a complete at-a-glance mosaic amalgamation.

Route review using Google Maps

The proposed route was assessed using Google Maps and Streetview. This provided relatively high-quality imagery, which was useful for initial insight and main hazards identification, however, lacked sufficient detail and timeliness to complete the initial domain Hazard Analysis.

In domain drive and video capture

Greater accuracy demanded real world data collection. The proposed route was driven end to end, where possible, with a vehicle capturing video footage from both forward facing and rear facing dashcams. Both video feeds were edited to identify each individual route stage. Access to the recorded video footage was limited only to Syselek staff in respect of obfuscation of all personally identifiable information.

The recorded video footage allowed determination of:

- Condition of the current road,
- Risks identification, and
- Required infrastructure changes assessment.

Completion of the initial domain Hazard Analysis

The Google Maps and Streetview "walk through" and recorded video footage from driving the route were used to complete the initial domain Hazard Analysis, including all pertinent artifacts with route mosaic, domain analysis, and hazard descriptions.

An example of the initial Hazard Analysis contents is illustrated as an example of one of the twenty-two route sections.

Figure 7.3: Dashcam still of hazard analysis drive

Figure 7.4: Illustration of hazard analysis desktop work

7. Operations

Review of ZF's safety assessment

7.4 Safety – Independent Route Review

Review of ZF’s initial domain Hazard Analysis

Rationale

Independent, fresh eyes review of Hazard Analysis and Safety Case is necessary to ensure coverage of all hazards and underpin the confidence of wider stakeholders who will be reliant upon the Safety Case.

Syselek undertook a review of ZF’s initial domain Hazard Analysis and ZF’s planned approach to safety assurance.

Key findings

- Initial Hazard Analysis: A comprehensive initial list of general hazards had been captured by ZF. Recommendations of further hazards intended to enhance ZF's initial domain Hazard Analysis were provided.
- Safety assurance approach: ZF's approach aligns with current industry practices for safety case development, verification, and the vehicle certification evidence requirements that may reasonably be expected.
- Risk mitigation: High-level risk mitigation strategies and safety protocols had been considered by ZF against each of the identified hazards.
- Transparency and traceability: There was appropriate clarity in ZF’s initial Hazard Analysis for all relevant stakeholders.

General considerations for competitive public procurement

While ZF are the nominated supplier for the current feasibility study, alternative suppliers may be successful in a competitive public procurement. Agnostic considerations include:

- Mobile network coverage for continuous offboard monitoring,
- Road markings and road surface quality,
- Measurement and specification of operational environmental conditions and respective operational expectations,
- Overwhelming edge cases including pedestrian crowds and blue light emergency services,
- External threat assessment, including physical (vandalism) security.

Note about physical security

Malicious intent against CAM vehicles in UK is unresearched. Current CAM technology has relatively low resilience to physical security threats.

From the above independent initial domain hazard analysis of the route, Syselek have concluded that they do not foresee any unusual hazards that would prevent a mature CAM system from safely navigating the route. While future assurance and operational regulations are still unclear, Syselek expect the proposed levels of segregation will require further consideration to provide sufficient mitigation of the hazards associated with other road users. Syselek have not identified any concerns at this stage which would prevent a CAM solution within the timeframes targeted in the project assumptions.

Table 7.2: Domain Hazard Analysis

Hazard Type	Hazard Geography
Collision with pedestrian	Pedestrian Crossing, Behind parked car, Entrance/Exit from social gathering, Non-Formal crossing, Sleeping Policeman
Collision with cyclist	Narrow roads, Cycle Path, Sleeping Policemen, Roundabout, Left turn, Right turn
Collision with stationary vehicle	Traffic Lights, Pedestrian Crossing, Roundabout, Sleeping Policemen, Junction
Collision with moving vehicle (oncoming)	Narrow lane
Collision with moving vehicle (in front)	Narrow lane
Collision with moving vehicle (behind)	Narrow lane
Collision with animal/wildlife	
Collision with Infrastructure	
Collision with Object	

7. Operations

CAM is projected to be able to cope with most conditions

7.5 Operational Technology Constraints

The extent to which CAM systems can deliver a resilient, robust transport system is central to the feasibility of the technology being applied to mass transit. Systems can not be subject to frequent / persistent failure, delays or service pauses – unreliability undermines confidence in, and therefore adoption of, public transport to a greater extent than any other factor.

In this section a summary of the projected *limitations* that current ‘best in class’ systems are expected to possess is provided, which could impact delivery of the route ODD (see Chapter 5.4). The analysis is done ‘by exception’, so only where limitations are expected is it referenced. In all other conditions automated systems are projected to be able to operate.

In relation to many aspects of physical infrastructure there is expected to be reliance upon V2X systems. V2X is the umbrella term used to describe the Vehicle (V) communicating with (2) any type of roadside infrastructure (X). An example of this is a signalised crossing, where the crossing would be equipped with technology to inform the vehicle the barriers are about to drop and to therefore come to a halt.

Scenery – Drivable Areas

- Construction Areas

Such areas present risk for automated transport and will need to be closely monitored within the ODD.

- Dirt / gravel

If the ODD contains any 1m*1m square more than 30% covered by leaves or other dirt, then the operation shall be paused until the dirt is removed; If the ODD contains any 1m*1m square more than 10% and less than 30% covered by leaves or other dirt, then the operation speed shall be reduced

- Potholes

The ODD shall only contain operations on asphalt and on pavement with a height difference of less than 2cm over a 10cm distance or in-between stones; The ODD shall not contain any potholes; The ODD shall not contain ruts (deeper 5cm) on lane.

Dynamic Elements - Traffic

- Police or construction worker hand signals

A police officer / construction roadworker will be detected as obstacle by the system and required measures will be taken on ATS level (via Supervision / Control Centre).

- Wildlife

ADS will brake not more than “fast brake” for any animal between 10 - 50 cm in any dimension, and to brake up to “emergency brake” for any animal that is at least 50 cm in any dimension (identical to any person found on the route). Any animals that are smaller than 10 cm will not be reacted to to prioritise rider safety.

- Debris in the route

As long as obstacle is not over-drivable, shuttle will stop

Environmental Conditions Weather & Particulates

Vehicle ADS is likely to no functionality implemented to detect weather conditions. The ATS operator must monitor and terminate operations if exceeded.

- Maximum rainfall intensity = 0.6 mm/5min. MRM with correspondent degraded mode.
- Maximum snowfall intensity = 30mm/h.
- Maximum freezing rain intensity = 0.6 mm/5min.
- Maximum Hail fall intensity= 0.6 mm/5min.
- Maximum ice layer thickness = 0.
- Maximum snow layer thickness = 2cm MRM with correspondent degraded mode and ATS will end the service temporarily.
- Maximum standing water layer thickness = 2cm
- Smoke - Driving within the sight distance.
- Smog - Driving within the sight distance.
- Fog - Driving within the sight distance.
- Sand floating in the air = 0.1g/m^3.
- Dust floating in the air = 3.0mg(m^2xh)

7. Operations

The regulatory context is developing rapidly, with significant step changes expected by 2025

7.6 Regulatory Compliance

This section summarises matters relating to existing and forth-coming regulation, as well as expected future consideration and requirements. This report only considered on-road CAM deployments as they are the most up to date regulations. Further studies will be needed to understand the regulatory compliance on segregated routes.

What are the current legal frameworks that govern automated vehicle deployment in the UK?

The Automated and Electric Vehicles Act 2018 (AEVA) was the first piece of legislation to provide specific provision for "automated vehicles" (also commonly referred to as self-driving vehicles or autonomous vehicles). AEVA includes a definition of an automated vehicle, which is a vehicle that, in some circumstances or situations, is capable of safely driving itself without the need for monitoring or control by an individual. Part 1 of AEVA focuses on insurance and creates a new liability scheme for insurers and owners in relation to self-driving vehicles. The purpose of Part 1 is primarily to:

a) create requirements for insurance of self-driving vehicles

b) ensure that victims of a crash involving a self-driving vehicle are compensated quickly, addressing a concern that if a self-driving vehicle did not have a driver, then it may be unclear from whom the victim should seek redress.

Following the implementation of AEVA, the UK government has approved the United Nations Economic Committee for Europe's (UNECE) Automated Lane Keeping System (ALKS) Regulation, and this came into force in January 2021. ALKS is the first internationally approved system designed to control the movement of a vehicle for an extended period without further driver command.

In January 2022, the Law Commission for England and Wales published a joint report with recommendations for a new legal framework for self-driving vehicles (see responses to Q2 and Q3 for more information on this). The UK government has made clear a new legal and regulatory framework will come into force by 2025, but in the interim, has taken the following measures:

Launched the Connected and Automated Vehicle Process for Assuring Safety and Security (CAVPASS). The programme aims to develop a comprehensive safety and security assurance process for self-driving vehicles.

Updated the Highway Code. In July 2022, the UK government made changes to the Highway Code by introducing a new section relating to the safe use of self-driving vehicles. This new section stipulates that if the vehicle is driving itself, you are not responsible for how it drives, and you do not need to pay attention to the road. However, you must follow the manufacturer's instructions about when it is appropriate to engage the self-driving function.

Issued new codes of practice. The UK government in 2022 published two new codes of practices for testing self-driving vehicles. The codes provide guidance on trialling automated vehicle technologies on public roads or in other public places in the UK. They also make recommendations on how to maintain safety and minimise potential risks.

What are the proposed changes within the recently completed Law Commission review? / Are there any proposed changes to regulation within the recently completed Law Commission review?

In January 2022, the Law Commission for England and Wales and the Scottish Law Commission (the "Law Commissions") published a joint report that made recommendations for the safe and responsible introduction of self-driving vehicles. The Law Commissions' report, builds on the reforms introduced by the Automated and Electric Vehicles Act 2018 and makes 75 recommendations which, taken together, set out a new legal and regulatory framework for self-driving vehicles. Key recommendations made by the Law Commissions include:

7. Operations

The regulatory context is developing rapidly, with significant step changes expected by 2025

7.6 Regulatory Compliance

Introduce a new Automated Vehicles Act

This would specifically regulate vehicles that can drive themselves, drawing a clear distinction between features which just assist drivers, such as adaptive cruise control, and those that are self-driving.

Vehicle Approval & Oversight

A two-stage approval and authorisation process building on current international and domestic technical vehicle approval schemes and adding a new second stage to authorise vehicles for use as self-driving on UK roads.

A new system of legal accountability

Once a vehicle is authorised by a regulatory agency as having ”self-driving features”, and a self-driving feature is engaged, the following would apply:

- The person in the driving seat would no longer be a driver but a “user-in-charge.” A user-in-charge would not be prosecuted for offences which arise directly from the driving task.
- The company or body that had the vehicle authorised, known as an Authorised Self-Driving Entity (ASDE), would have primary responsibility for the vehicle if it drove in a way which would be criminal (e.g., it does not comply with health & safety laws) or unsafe if performed by a human driver
- For vehicles authorised to drive themselves without anyone in the driver seat, occupants of the vehicle would simply be passengers. Instead of having a user-in-charge, a licensed operator would be responsible for overseeing the journey. There would also be requirements for passenger services to be accessible, especially to older and disabled people.

What is, at the time of writing, the current expected timeline for transition to a new legal framework, and who needs to do what to achieve that?

The UK government plans to make self-driving vehicles operational on UK roads by 2025. Based on the Law Commission's recommendations, they have introduced a new Bill, The Automated Vehicles Act, announced in November 2023 in the Kings Speech. Primary and Secondary legislation as well as accompanying guidance, codes of practice etc. will then also follow. The legislation should follow in the next session of Parliament. New legislation and a full regulatory framework for self-driving vehicles is still expected by 2025.

7. Operations

What Insurers are looking for in relation to CAM systems

7.7 Regulatory Compliance: Under-writers Considerations

What aspects would an insurer be looking for in assessing risk which will drive safety cases, roles and responsibilities?

- Clear roles & responsibilities
- Regulatory and code of practice compliance and associated standards adhered to (i.e., ISO27001 – cyber security, ISO 45001 Health & Safety, ISO 9001 Quality Management.)
- Robust Contractor selection and Management procedures
- Vehicle (all aspects of manufacturer selection; construction; safety; integration)
- Route (area vehicles will be driven, size of vehicles, segregation / other traffic)
- Operations (Buildings; operators experience and licenses; maintenance programmes; depot arrangements)
- Cyber (risk identification, control, testing regimes)
- Incident response (appropriate levels of plans for response, investigation and business continuity)

The use of independent brokers

It is vital that operators of automated vehicles obtain the services of a suitably experienced insurance broker in assisting them placing adequate insurance coverage. As the landscape surrounding automated vehicles is developing at pace, many insurance brokers are setting up dedicated teams to develop their understanding and expertise of automated vehicles. Utilising insurance brokers, especially specialist ones, can help automated vehicle operators by informing the cover, terms and conditions sought and achieved. It will also ensure that any gaps in potential coverage, due to a carrier not offering the cover or being unable to fully fulfil them, can be sourced from alternative markets.

Engagement with UK government

Through trials, it is important to ensure there are robust feedback loops with all stakeholders to inform them in respect of their specific area of focus. Further work with the UK government would be undertaken to understand the regulatory compliance of the service.

Full collaboration with the vehicle manufacturer

For each vehicle released on the UK roads, there are numerous tests undertaken before deployment. These include but are not limited to:

- Vehicle type approval
- Euro NCAP testing
- Group rating processes.

Motor insurers rely on the testing processes, along with their own underwriting and claims information to understand the insurability of vehicles. Current prototype automated vehicles will not necessarily have undertaken all or any of these tests. Collaboration with the vehicle manufacturer is paramount at the initial trial stages as it provides the insurer with a chance to better understand the vehicle, its current abilities, and limitations. This allows the manufacturer to provide any information they have from other trials, either locally or globally. Participation in trial safety cases, risk assessments and route assessments would be a minimum requirement and will require input from the vehicle manufacturer.

Access to data

An enriched data set can and will be beneficial to the insurance industry as a whole and an insurer would look to work with the vehicle manufacturer to define new data sets, formats and frequency of provision. This will help position new ‘minimum standards or expectations’ in relation to insurance of these trials and the wider connected/automated vehicle landscape.

Understanding the efficacy of the platform/tech/ vehicle

As referenced, vehicles released for sale on UK roads are placed through rigorous testing via established processes. It is currently unknown what testing and processes will be dictated by regulations for vehicles intended to be deployed on segregated routes. These may not be in place for vehicles participating in trials and therefore it is imperative to understand the efficacy of the vehicle prior to commencement of any trial or operations.

7. Operations

How much will it cost to operate a CAM solution and how does it compare

7.8 Operational Costs

The costs of operating a ZF CAM shuttle on the EBNS corridor have been estimated by Arup, based on experience of similar cost estimations for bus services. This analysis outlines cost compared to other public transport modes for comparison purposes. In order to offer a like for like comparison, the analysis has been undertaken based on a system capacity of 600 seated passengers per hour per direction (pphpd) as outlined in Table 7.3.

Table 7.3: Vehicle Capacity Comparison and Service Interval Requirements

Vehicle Type	Seated Capacity	Standing Capacity	Service interval (min)	Hourly Capacity (pphpd)		
				Seated	Standing	Combined
ZF CAM Shuttle	15	7	1.5	600	280	880
Double Decked Bus	70	25	7	600	214	814
LRT Vehicle	120	110	12	600	550	1,150

Based on a higher vehicle capacity for bus and LRT compared with the ZF shuttle, a higher service interval is required to offer the same capacity as a public transport service, thus resulting in a significantly higher peak vehicle requirement (PVR) when compared with traditional public transport modes.

Table 7.4: Peak Vehicle Requirement and Operational Costs per annum

Vehicle Type	ZF CAM Shuttle	Double Decker Bus	LRT Vehicle
Peak vehicle requirement	86	17	9
Vehicle Cost Input [1]	£350,000	£400,000	£4,000,000
Vehicle Life (Years)	12	15	15
Annual fleet kilometers[2]	6,481,032	1,388,793	837,966
Annual vehicle kilometers	75,361	81,694	93,107
TOTAL OPERATIONAL COST	**£7,652,000**	**£2,723,000**	**£6,349,000**

The estimated operating costs for a CAM shuttle service using the ZF vehicle configuration are significantly higher than operating bus and slightly higher than operating an LRT light rail vehicles at lower frequency, even when the costs of self-driving operations are accounted for. This is primarily due to the cost of fleet depreciation, fuel and maintenance associated with managing a significantly larger fleet of vehicles, as shown in the breakdown overleaf. Whilst the cost of drivers for the CAM shuttles is removed, there is requirement for a significant number of control centre operatives and maintenance staff, as well as an allowance for revenue protection. A best estimate of these costs is identified in Table 7.5.

Table 7.5: Estimated Office and Depot Staff Costs for CAM Shuttle per annum

Staff Role	No. Staff per shift	Hours per shift	Shifts per day	Days per week	Hourly rate [4]	Total [5]
Revenue protection / station customer service	5	8	2	7	£13.15	£459,514
Control centre operatives[3]	-	-	-	-	£14.06	£1,353,486
Management team	3	8	1	5	£25.63	£191,918
Total Staff Costs						**£2,004,917**

Notes:
1. Vehicle costs included within OPEX in terms of annual depreciation of fleet value. It is currently assumed that vehicles would be purchased by an operator, but leasing or rental options could also be possible depending on the split of responsibilities between the manufacturer and operating company. This should be explored further within the Management Case of any subsequent business case work
2. Annual fleet kilometer calculations consider reduced operations at off peak times.
3. Based on 1 member of control centre staff per 6 vehicles (86 vehicles total). Hours calculated considering reduced staffing requirements at off peak times.
4. Based on Annual Survey for Hours and Earnings (ASHE) 2022 Survey
5. Total includes on costs at 20%

7. Operations

How much will it cost to operate a CAM solution and how does it compare

7.8 Operational Costs

A breakdown of operating costs by category is presented in Table 7.6, based on operating hours for all modes of 05:00 to 00:00, 7 days a week. Whilst bus and LRT costs have been estimated as a comparison with the CAM mode option, these are high-level costs based on assumptions and should be treated as such.

Table 7.6: Estimated Annual OpEx by category and public transport mode

	ZF CAM	DD Bus	LRT
Office and Depot	£2,005,000*	£162,000	£588,000
Fleet	£2,677,000	£508,000	£2,375,000
Drivers	£0	£1,615,000	£1,849,000
Fuel	£712,000	£302,000	£457,000
Maintenance	£2,258,000	£136,000	£1,080,000
TOTAL COST	**£7,652,000**	**£2,723,000**	**£6,349,000**

Further detail on what is included within each cost category in Table 7.6 is included overleaf with key assumptions made for each of the 3 modes considered.

It is noted that the ZF CAM costs have been developed based on a consistent frequency of service being provisioned, as expected of a typical public transport service. The size of the shuttle allows, potentially, a better match of service frequency with demand along the corridor, with the potential for some savings in the next iteration of these costs. Equally, costs for automated operations of a larger vehicle (such as a standard sized bus, as operated on the CAVForth project) could be considered which would require a lower service frequency thus saving cost.

Alternative operating models and circular economy considerations could help reduce costs associated with fleet financing and depreciation.

Finally, costs associated with remote vehicle operations, included within CAM office and depot costs (marked *), are linked to the complexity of the route, number of shuttles and level of segregation. Associated costs could be significantly reduced as time goes by if safety is proven and operational efficiency is improved. As the CAM industry develops, economies of scale and lessons learnt may also reduce maintenance and fleet costs.

Chart 7.1: Annual operating costs comparison with other public transport modes

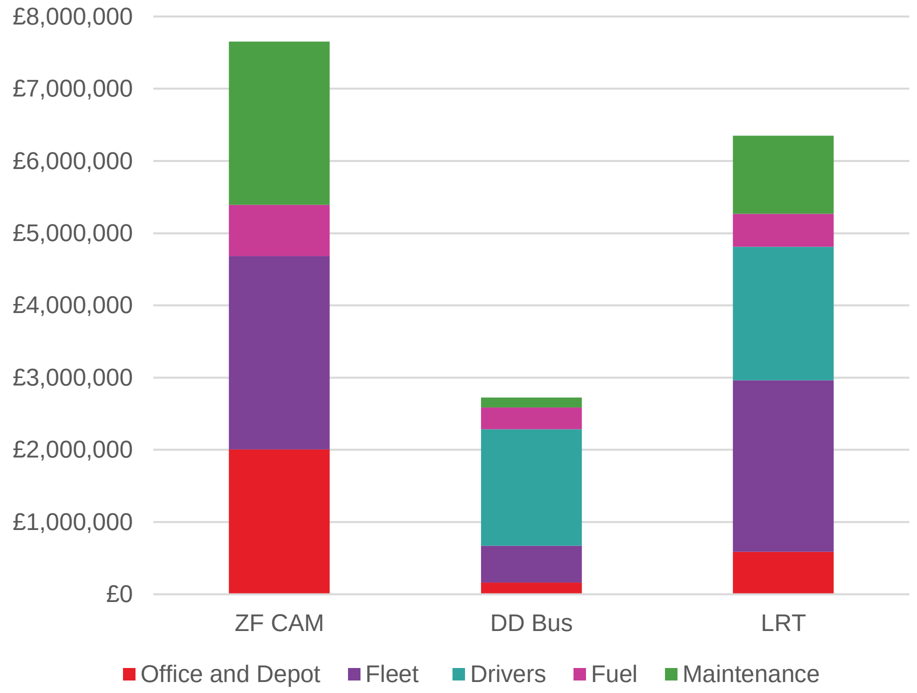


Table 7.7: Breakdown of annual operating costs and key assumptions, 2023 prices

	ZF CAM	DD Bus	LRT
Office and Depot	£2,005,000*	£162,000	£588,000
Costs associated with revenue protection, management and remote operation staff (where relevant).	Staff costs only for: • Revenue protection/ station customer service • Control centre operatives (accounting for reduced services at off-peak times)* • Management team	10% of driver costs	Staff costs only for: • Revenue protection/station customer service • Management team
Fleet	£2,677,00	£508,000	£2,375,000
Costs associated with financing, taxing, insurance, servicing and depreciation of vehicle fleet. Includes insurance, tax, MOT & service, as well as finance and depreciation calculated according to a straight-line depreciation of the vehicle fleet.	MOT & Service, Insurance and Tax: £3,965 per vehicle, for 91 vehicles Number of vehicles 86 (inc. 8 as spares) Purchase cost per vehicle: £350,000 Salvage value: £27,487.79 Life span: 12 years	MOT & Service, Insurance and Tax: £4150 per vehicle for 17 vehicles Number of vehicles 17 (inc. 2 as spares) Purchase cost per vehicle: £400,000 Salvage value: £14,073.75 Life span: 15 years	MOT & Service, Insurance and Tax: £6500 per vehicle for 9 vehicles Number of vehicles 9 (inc. 1 spare) Purchase cost per vehicle: £4,000,000 Salvage value: £140,737.49 Life span: 15 years
Drivers	£0	£1,615,000	£1,849,000
Driver salary	N/A	£14/hour 20% Sunday Supplement 20% on-costs	£30/hour 20% Sunday Supplement 20% on-costs
Fuel	£712,000	£302,000	£457,000
Fuel costs assuming all vehicles are electric, based on energy consumption and annual distance driven.	Energy consumption: 0.656 kWh/km Annual distance driven: 6,481,032 km Energy costs: 0.167 £/kWh	Energy consumption: 1.3 kWh/km Annual distance driven: 1,388,793 km Energy costs: 0.167 £/kWh	Energy consumption: 3.26 kWh/km Annual distance driven: 837,966 km Energy costs: 0.167 £/kWh
Maintenance	£2,258,000	£136,000	£1,080,000
Costs associated with vehicle maintenance and cleaning. Includes staff costs and an allowance for replacement parts.	Annual service costs: 7.5% of vehicle fleet price	Annual service costs: 2% of vehicle fleet price	Annual service costs: 3% of vehicle fleet price
TOTAL COST	**£7,652,000***	**£2,723,000**	**£6,349,000**

*These costs could be reduced if fewer, higher capacity vehicles are used instead of the current ZF shuttles.

7. Operations

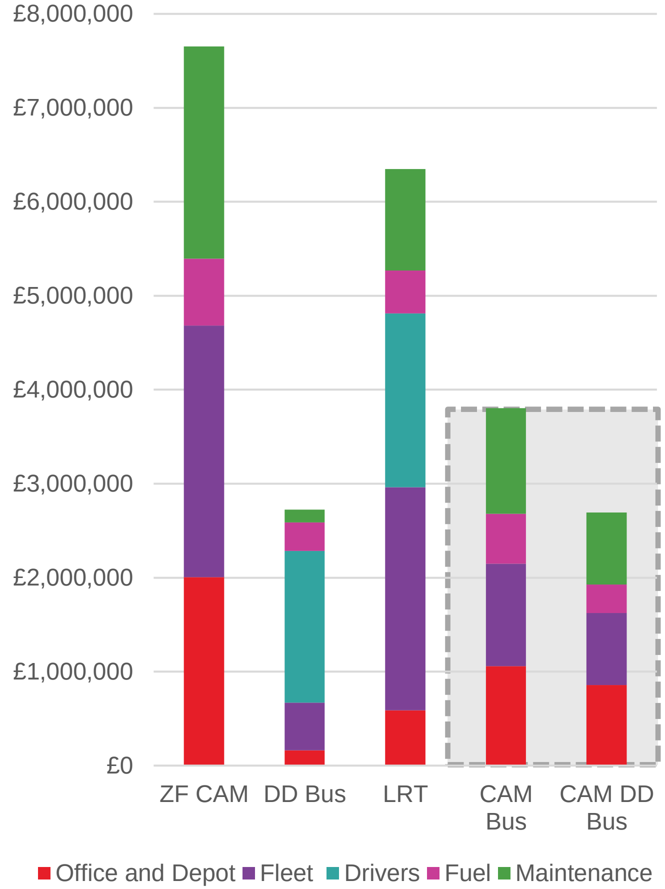
How much will it cost to operate a CAM solution and how does it compare

7.8 Operational Costs

Based on an assumption that CAM technology could be applied to public transport vehicles of different sizes, additional operating cost scenarios have been included for comparison purposes. The following key points are noted:

- High level estimates of vehicle costs etc, no specialist input from vehicle manufacturer - less confidence in these numbers versus the ZF shuttle.
- Based on provision of 600 seated capacity across all modes.
- CAM Bus – single deck vehicle similar to CAVForth (assumed £500k per vehicle, 4 min headway, 40 seats per vehicle).
- CAM DD Bus – not understood to exist currently but added to show a like-for-like comparison in terms of passenger capacity with DD bus option. This could be double deck or articulated (£600k per vehicle assumption, 7 min headway, 70 seats per vehicle).
- Drivers do more on public transport than just drive the vehicles (e.g. revenue protection / ticketing, passenger service, passive security etc). It is to be noted that there is a diminishing return of saving driver costs as the vehicle capacity is bigger.
- Additional staff costs (included in 'Office and Depot') associated with monitoring and maintenance of vehicles, added costs of revenue protection, and additional cost of vehicles largely offsets savings in driver costs.
- Estimated OPEX is roughly equivalent on a like-for-like comparison of vehicle sizes (conventional double decker vs CAM double decker). CAM OPEX (vehicles, maintenance and number of remote operators) may decrease significantly as time goes by and operational efficiency is improved, however any potential savings should be weighed up against additional risks of introducing CAM technology
- Lower frequency of higher capacity vehicles would negatively impact demand (and the overall economic case), when compared with high frequency ZF shuttle – not estimated as part of this study.
- Bus based modes (including CAM-based) would likely have a lower ride quality (defined in 5.4) than an LRT, or potentially ZF's smaller CAM solution (not considered as part of this study). This would also negatively impact demand and BCR.

Chart 7.2: Annual operating costs (additional scenarios)



7. Operations

A summary of the sections in this chapter

7.9 Summary

7.1 High-Level Operational Concept

A high-level operational concept has been developed which outlines the following areas:

- Hours of Operation
- Route & Stops
- Route Infrastructure
- Performance Capability
- Service Levels
- Assets and Facilities
- User Interfaces
- Accessibility

There are also some service notes that include suggestions for more detailed work in further studies

7.2 Operational Case Study: Rivium

The Rivium case study demonstrates an existing ZF service where six shuttles are ablet o carry up to 3,000 people a day. The route is 1.8km between the Kralingse Zoom metro station in Rotterdam to the Rivium Business Park, operates between 06:00 and 21:00 with a 2.5-minute headway.

The service first opened in 1999 and currently operates the 3rd generation shuttle with up to two members of staff to monitor the service. this includes supervising the interior and the environment around the shuttle, along with 2-way communication to the public at the stops along the service. maintenance, cleaning and charging are taken care of by a ZF depot, who are also on hand to provide technical support.

7.3 Human Machine Interface (HMI)

On traditional transport solutions, several functions are performed by human staff to allow interaction between customers and the service. A list of touch points have been identified that will need to be taken into consideration with the potential removal of staff. These are:

1. Fare Collection
2. Boarding
3. Incident / Accident processes
4. Accessibility (Wheelchair user / Partially sighted, etc)
5. Remote Supervision
6. On-board advice / interaction

In addition to the above functions, it has been identified that staff on public transport act as an authority figure to deter on-board anti-social behaviour. For this service, floating members of staff would be employed to these functions and deter anti-social behaviour.

7.4 Safety

The hazard analysis of the route was completed by combining multiple methods. A review of the orginal architectural drawings did not include sufficient detail so this was augmented by the use of Google Maps in satellite view and street view. This was combined with video capture of the route that was driven where possible. These techniques allowed for assessment of:

- Condition of the current road,
- Risks identification, and
- Required infrastructure changes assessment.

In addition to this, Syselek undertook a review of the Hazard analysis completed by ZF. This review found the work done by ZF was comprehensive although some additional recommendations were provided. From this work, a set of agnostic considerations were developed that should be kept in mind when discussing hazard analysis with a CAM OEM.

7. Operations

A summary of the sections in this chapter

7.9 Summary

7.5 Operational Technology Constraints

As with any technology, CAM solutions will have constraints in relation to the environment they operate in. This has been distilled in to three areas that outline these constraints and how the CAM vehicle will be expected to cope with them. These areas are:

- Scenery – Drivable Areas
- Dynamic Elements – Traffic
- Environmental Conditions Weather & Particulates

7.6 Regulatory Compliance

The regulatory compliance has two components. Firstly, the regulations that are in place and are being developed. Secondly, the considerations for insurance underwriters.

The first piece of legislation around automated vehicles was the Automated and Electric Vehicles Act 2018 which defined 'legally automated vehicles' and, in Part 1, creates the liability scheme for insurers. This was followed by the adoption of the UNECE ALKS regulation. Furthermore, the Law Commission released a report with the recommendation for a new legal framework for self-driving vehicles by 2025. In addition, the UK government has:

- Launched the Connected and Automated Vehicle Process for Assuring Safety and Security (CAVPASS).
- Updated the Highway Code
- Issued new codes of practice on testing automated vehicles

A January 2022, a review by the Law Commission of England and Wales and the Scottish Law Commission published a joint report with 75 recommendations for a legal framework for automated vehicles. These include:

- Introduce a new Automated Vehicles Act
- Vehicle Approval & Oversight
- A new system of legal accountability

7.7 Regulatory Compliance: Under-writers Considerations

As part of the consideration for underwriters, there are several points around the assessing risk, safety cases and roles and responsibilities. In addition, specialist insurance brokers will be needed to guide an operator to the correct insurance product or products. Engage with CCAV and the OEMs to ensure quality feedback is provided with stakeholders. Also, understand the prototype vehicle capabilities and short comings which will not have completed full type approval. The insurer would also work with the OEMs to define the methods to access vehicle along with the frequency of provision and how to share the data if needed.

7.8 Operational Costs

The cost of operating a CAM service along the corridor has been estimated and compared to operational costs for traditional transport solutions. In this case, the comparison is with a double decker bus and a tram. The calculations for these costs are based on a peak demand of 600 pphpd in a service window of 05:00 to 00:00, 7 days a week.

With the CAM shuttle having the significantly smaller carrying capacity, more vehicles are required leading to higher operating costs. However, a service using a CAM vehicle with higher carrying capacity would save cost as fewer vehicles would be needed. It is also noted that with a smaller vehicle size allows for the service frequency to be optimised, reducing cost while providing improved service. A detailed breakdown of the comparison costs are given in Table 7.7.

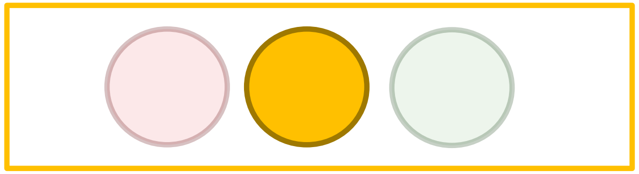
7. Operations

Performance against the Feasibility Questions

7.9 Summary

Feasibility Question 9

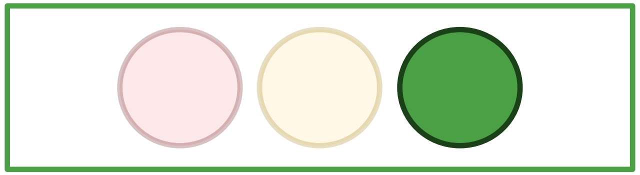
Could a CAM solution be delivered at a lower OPEX when compared to LRT?



This study used ZF's 15-seater vehicle platform as the primary CAM option, resulting in 78 shuttles being required to service the route. On this basis, when compared against LRT, calculations indicate that at this stage in technology development any reductions in costs associated with drivers are replaced by the greater cost and quantity of vehicles, the need for remote monitoring, and supporting technological infrastructure, demonstrating marginally higher OPEX. When comparing fewer, higher capacity CAM vehicles against LRT the CAM OPEX reduces significantly. Against BRT, equivalent capacity CAM OPEX is marginally lower. CAM technology costs could however be expected to drop over time, thus further improving operational savings against BRT.

Feasibility Question 10

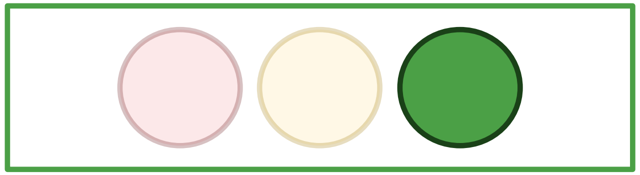
Can the required level of system reliability be delivered?



Current operating parameters of 'best in class' technology developers indicate that systems should be able to continue operating within the majority of environmental scenarios. This is demonstrated by the service delivery reliability at the Rivium automated system in Rotterdam. Capability in this area is projected to continue to improve as the sector continues to develop.

Feasibility Question 11

Can the route be delivered with acceptable safety?



Significant time has been spent understanding the nature of the route, cataloguing potential hazards and identifying high-level mitigations. Alongside manufacturer assessment, an independent hazards analysis has been carried out to provide a deeper level of assurance of deliverability. There is a high level of confidence that, within the agreed Solution Requirements, this route can be delivered with acceptable safety.

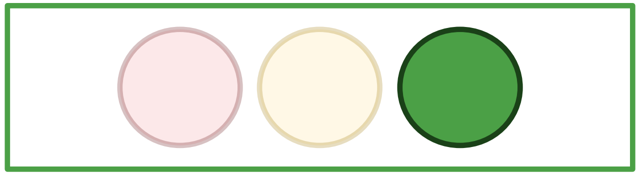
7. Operations

Performance against the Feasibility Questions

7.9 Summary

Feasibility Question 12

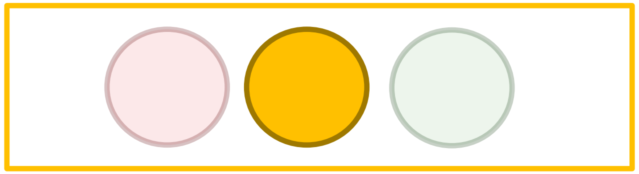
Can fares be protected, on-board riders be safe, and accessible transport all be provided pragmatically?



The Rivium case study illustrates how automated services can be successfully integrated into public transport networks, delivering a safe rider experience where fares are protected. That said, this case study is not on the same scale as the EBNS route, and as such further work to identify solutions at scale is recommended.

Feasibility Question 13

Will an automated solution be legislated for and insurable?



Evidence indicates that the UK is highly supportive of developing the required legislation to see automated systems made legal, however the precise legislation is still in formation and as such caution must still be exercised. Development of legislation will be a critical part of commercialisation of the technology.

8. Cost-Benefit Appraisal

FQ14 Would a CAM solution be expected to provide value for money?

8. Cost-Benefit Appraisal

We will provide analysis of the core costs and benefits for the system

8.0 Introduction

8

Chapter 8 assesses ridership demand for the route and subsequently compares the expected benefits delivered by the system as described, to the total identified costs to reach an early indicative Benefit Cost Ratio.

8. Cost-Benefit Appraisal

A comparison of the high-level costs and benefits of the scheme

8.1 Appraisal Methodology

This feasibility study of the proposed EBNS CAM shuttle is underpinned by an economic assessment model that calculates demand impacts, cost implications and economic benefits in accordance with DfT's Transport Appraisal Guidance (TAG) and best practice in economic evaluation.

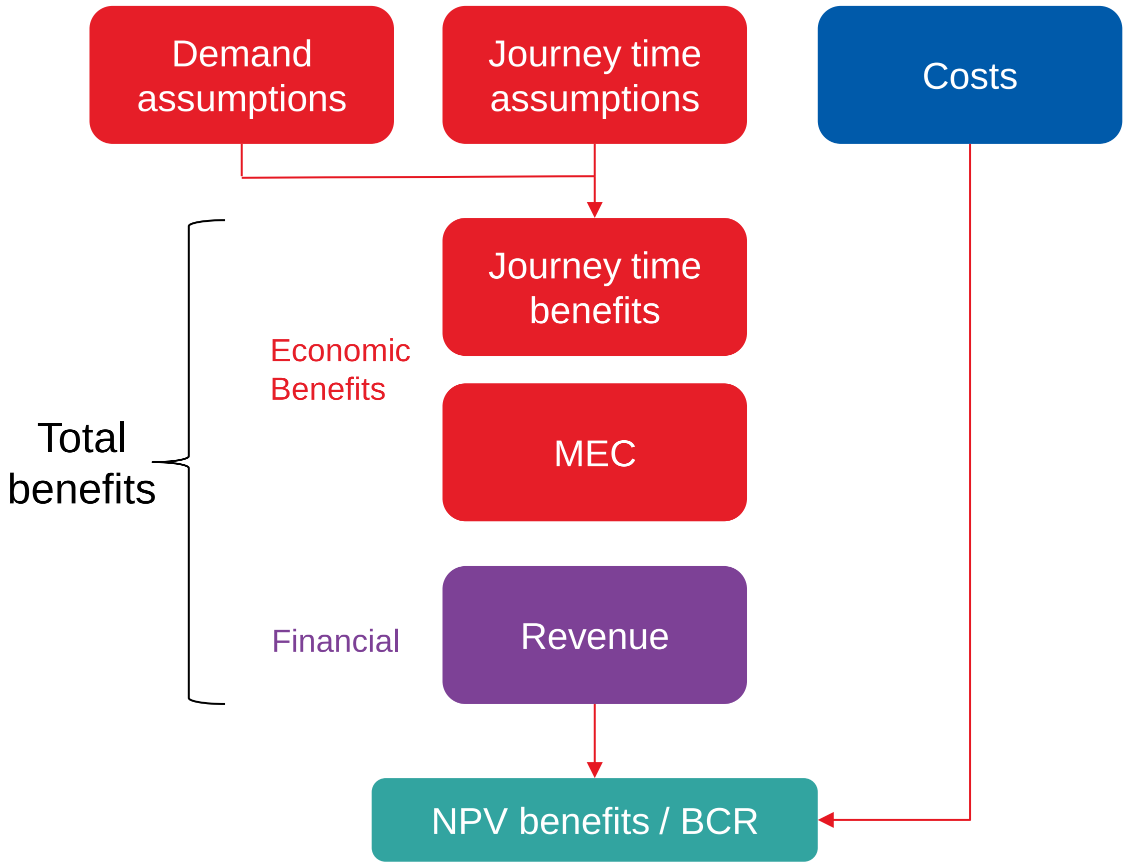
A key guiding principle for demand modelling and economic assessment is proportionality, which refers to striking a balance between the level of detail and the cost of the modelling, taking into account factors such as the required functionality, data availability, and robustness and resource and time constraints.

The economic assessment includes estimates of **operating costs** and **capital expenditure.**

Benefits calculated include **user benefits** – those that are experienced by passengers. **Non-user benefits** in the form of Marginal External Costs (MECs) are experienced by wider society, and include the impacts of reduced emissions, accidents and congestion.

A **60-year appraisal term** has been considered, to make an assessment of infrastructure costs over their lifespan. Scenarios with and without opening of HS2 have been considered, although only the former is presented in this report for clarity.

Figure 8.1: Economic Appraisal Methodology Overview



8. Cost-Benefit Appraisal

A comparison of the high-level costs and benefits of the scheme

8.2 Costs and Benefits Appraisal

Costs and Benefits

The economic assessment includes estimates of capital expenditure (outlined in section 6.1) and operating costs (outlined in section 7.8). For the purposes of the appraisal, the costs have over the 60-year appraisal period have been discounted to 2010 costs, as per TAG guidance.

In addition to the operating costs, an infrastructure maintenance allowance of 1.5% per annum has been made to account for ongoing infrastructure maintenance costs. Vehicle renewal costs are included within operating costs, with an assumption that the fleet is renewed every 12 years.

Optimism bias of 46% is included for capital costs, based on TAG for Stage 1 road schemes (see TAG Unit A1.2 Table 8) and 10% for operating costs to account for uncertainty around the vehicle technology and regulations.

Monetised benefits associated with Marginal External Costs (MECs) and journey time savings are calculated according to standard TAG methodology.

Revenue

The demand modelling (5.2) provides a means to illustrate the potential passenger numbers, which can be used to estimate the impact on revenues. Detailed modelling of fares has not been undertaken at this early feasibility study stage. For the purposes of the appraisal, an average fare income yield of £3 per customer journey is assumed for the CAM shuttle, versus an average of £2 for bus and LRT services, on the expectation that the proposed service would provide a significant frequency enhancement, and a premium quality, innovative service.

Value for Money

The scheme BCR presented implies a low value for money against the standard TAG VfM categories.

It should be noted that BCRs should not be the sole determinant of whether or not a proposal goes ahead. BCRs are part of the economic case, which in turn is one of the five cases that form a business case. Even with a low BCR, further study of the corridor represents an opportunity for further investigation and refinement of this innovative transport solution. A proposal with a low BCR can have significant non-quantified benefits and help achieve strategic objectives (such as meeting environmental or social goals); in these cases the strength of the strategic case could suggest that a proposal ought to proceed despite a low BCR.

Exclusions

The following are excluded from the economic appraisal:

- Analysis of fares;
- Assessment of Wider Economic Impacts;
- Disbenefits to traffic resulting from the proposals – further design work would be required to quantify this; and
- Costs and benefits associated with active travel infrastructure along the corridor.

Table 8.1: Results Summary, £000s (2010 prices)

MEC	
Congestion	£24,422
Infrastructure	£104
Accident	£2,578
Local Air Quality	£179
Noise	£195
Greenhouse Gases	£1,459
Indirect Taxation	£466
Total (60-year appraisal period)	**£29,402**
GJT Savings	
Business	£61,272
Commuting	£228,687
Leisure	£144,391
Total (60-year appraisal period)	**£434,350**
Costs	
Capital Cost	£360,537
Operating Costs	£184,201
Total (60-year appraisal period)	£544,738
Revenue	
Additional Revenue	£160,056
Summary	
Present Value of Costs (PVC)	£384,682
Present Value of Benefits (PVB)	£463,752
Net Present Value (NPV)	£79,070
Benefit-Cost Ratio (BCR)	1.21

8. Cost-Benefit Appraisal

A comparison of the high-level costs and benefits of the scheme

8.3 Funding

The West Midland Combined Authority (WMCA) has been the recipient of funding from UK government in the form of the City Region Sustainable Transport Settlement (CRSTS) funds. CRSTS1 was allocated to WMCA for a funding period of April 2022 to March 2027 at a value of £1.05B. CRSTS2 was allocated for the funding period of April 2027 to March 2032at a value of £2.648B.

For CRSTS1, a project along the East Birmingham – Solihull (EBS) corridor has been planned and will begin in June 2024 and run until March 2027 with the goal of introducing short to medium term enhancements such as priority bus measures, improved access to employment sites and improved active travel infrastructure.

The scheme in this this documents could be developed as a part of an extension of the existing work and part of CRSTS2.

It should be noted that before this scheme can be considered, it would need approval from the TfWM board which is outstanding currently.

8.4 Alignment with EBNS Corridor Options Assessment Study

Throughout this project, the consortium has been in contact with a separate EBNS corridor study investigating traditional transport solutions being run by TfWM Rail Executive. Regular meetings and information has been exchanged between both project teams. Both study reports should be considered together to get a full picture of the options for the route.

The route used for the Traditional Transport EBNS Study initially followed the orginal proposal. This has been modified to match the revised route used in this study to take account of the APM, between HS2 Interchange station and Birmingham International Rail Station, and to link into the current metro extension plans to High Street Deritend.

However, due to the higher level of detail the Traditional Transport EBNS Study is going to, there will be a full connectivity plan created. This will include how a transport solution along this corridor will link to the existing rail, bus and active travel offerings. Additionally, the route may be modified further to improve the service to customers. Currently the Traditional Transport EBNS Study is approximately five months behind this study with their report being available in early to mid 2024. This report will be provided to them for inclusion.

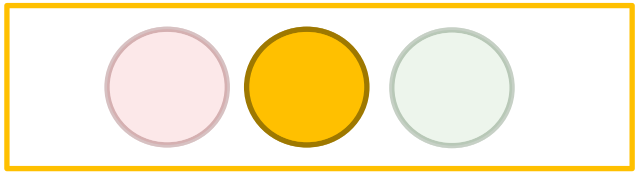
8. Cost Benefit

Performance against the Feasibility Questions

8.5 Summary

Feasibility Question 14

Would a CAM solution be expected to provide value for money?



The results of the early-stage economic appraisal indicate that a CAM public transport corridor would result in a benefit-to-cost ratio of more than 1. Whilst further work is required to update the demand modelling (to account for changes to the HS2 route, account for development along the corridor, and the impacts of the COVID-19 pandemic etc) it is noted that the potential for a higher frequency CAM solution (and minimal waiting time) could result in significantly higher demand for the corridor, and potentially a higher willingness to pay, versus a traditional, higher capacity and lower frequency service. A key constraint of the economic appraisal undertaken is that it does not account for potential negative impacts on general traffic, which should be a key consideration in any future transport modelling.

9. Risk Appraisal

FQ15	Is automated transport a secure technology? (Physical & Digital)
FQ16	Will an automated solution that can technically serve this route be ready within stated target timeframes?
FQ17	Are transport operators open to exploring delivering CAM services?
FQ18	Will there be system / vehicle manufacturers ready to deliver the scale of system, with sufficient demonstrable evidence of delivery and funding to secure public / commercial contracts?
FQ19	Can we Compulsory Purchase Order (CPO) for CAM solutions; is it politically palatable?
FQ20	Do we want to be first? Is there any advantage to being first? What are the disadvantages of being first?
FQ21	Will a CAM solution be socially accepted? Will it be abused / a target for abuse that makes it unreliable / unusable?

9. Risk Appraisal

Our approach – A macro focus

9.0 Introduction

9

This chapter will discuss the potential risk to the installation of a CAM solution at a Macro (mode) level. Seven of the studies Feasibility Questions are addressed within this chapter as they are considered generic questions relating to the feasibility of an automated mass transit route and therefore beyond being 'route specific'.

To explore the seven identified risks, within the context of the studies feasibility question methodology, a mix of sector-wide 'best practise', international insight, consortium view and external published data / studies are utilised, arriving at a conclusion as to whether the risks can be considered fully, partially or insufficiently mitigated.

9. Risk Appraisal

Physical security depends on public acceptance

9.1 Security Risks – Is Automated Transport a Secure Technology?

Security threats consider malicious intent under two main areas: physical security, and digital security.

Physical security

Several physical security risks are unique to automated vehicles. These include any malicious intent, changes to road infrastructure, objects, or behaviour of other road users, etc. This is a large area and relatively unresearched for automated vehicle public deployment.

Interference

In San Francisco there are relatively large deployments of automated vehicles in the public urban environment (c.100 by Waymo and c.100 by Cruise). These have led to negative behaviour from some other road users who perceive automated vehicles to be unsafe for public deployment. These road users have identified weaknesses in automated vehicle perception systems, which can be exploited through simple actions, to leave individual automated vehicles incapacitated. Further forms of low-level interference concerning automated vehicle perception systems vulnerabilities in object detection, lane detection, etc., by manipulation of infrastructure.

It is important to clarify at this point however that California's regulations are different to the UK. In California AV deployments are based on self-certification. The UK's legislative approach aims to ensure safe and secure deployments with rigorous approval, authorisation and in-use monitoring process. In a world where UK CAM services are delivered under a high safety threshold, a main challenge for a future UK service could be to manage public perceptions, and ensure the public is aware of the safety and security of CAM services in a bid to mitigate hostile public behaviour. Public education of operational safety will be important to build public trust and mitigate the cause of such low-level interference.

Risk impact

The risk and impact of malicious physical damage to automated vehicles is potentially greater than to human driven vehicles. The high value of perception system sensors, and their prominent/exposed position on automated vehicles, raises the potential of malicious damage or theft. Any occurrence will likely result in much higher cost repairs than human driven vehicles would incur, raising insurance costs. The impact of incapacitated vehicles on a public passenger transport service, particularly users relying on the service, could be severe.

Risk deterrent and protection

Current automated vehicles have relatively low resilience to physical attack. Malicious behaviour towards human driven vehicles is deterred by the witness account that a human driver can provide investigating authorities. However, automated vehicles' perception systems are currently designed with a field of view to cover relevant infrastructure and the normal behaviour of other road users. It is not designed to track other suspicious actors. Once incapacitated through disruption of the perception system, an automated vehicle has no recourse.

High levels of segregation provide automated vehicles with increased protection from malicious behaviour of other road users, but this is not currently part of the proposed deployment.

Public engagement will be important to build a sense of public ownership and care. (See also 9.7 Public Acceptance.)

Further work is recommended to address this physical security threat, incorporating examination of existing mass transit solutions; CCTV footage of incidents; edge case testing; integration with police forces

9. Risk Appraisal

Digital security approaches exist

9.1 Security risks cont.

Security threats consider malicious intent under two main areas: physical security, and digital security.

Digital security

Current best practices in automated vehicle technology provide relatively high resilience to digital security threats since this is a well-researched area. Digital security can be described by the CIA triad illustrated in Figure 9.1.

CCAV funded cybersecurity research, such as ResiCAV, has determined the UK's digital security engineering approach to ensure digital resilience of automated vehicles through high level assessment and mitigation requirements (although without detailed prescription of specific cybersecurity solutions). A formal method to establish legal arguments that the digital vulnerabilities of an automated vehicle are reduced ALARP now exists.

Digital security includes an expectation to match or surpass the digital security of conventional human-driven vehicles, as defined by UNECE regulations (UNECE R155 and ISO/SAE 21434). Type approval expectations are also under review and are expected to be updated to allow continuous monitoring of emergent threats from in-life updates. This area will develop further over the coming years, but manufacturers, operators, and TfWM/ SMBC can already plan based on the CIA triad.

Confidentiality

This concerns the prevention of unauthorised data access. Malicious misappropriation and exploitation of sensitive information could compromise safe automated vehicle operation.

Integrity

This concerns the detection of unauthorised access and prevention of unsanctioned data modification to preserve data authenticity, accuracy, and consistency over the life cycle, critical to maintaining trustworthiness of data.

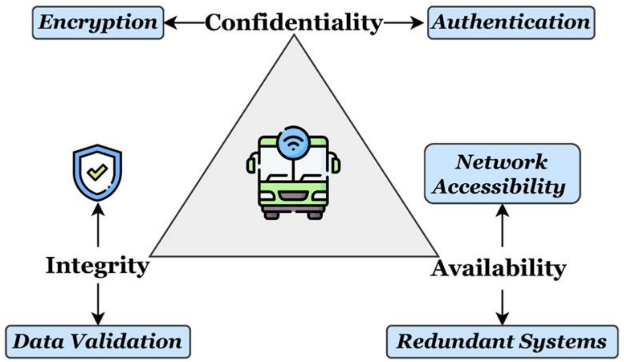
Availability

The automated vehicle's effective operation depends upon the consistent availability of necessary data, which if compromised could present safety implications.

In addition to the CIA triangle, digital security attributes include privacy, authenticity, accountability, non-repudiation, and reliability. Consideration of these characteristics are part of an integrated security framework to protect automated vehicles from possible threats.

Prior to any future deployment extensive consultation with CAM cyber security providers would be undertaken.

Figure 9.1: The Confidentiality-Integrity-Availability (CIA) Triad



9. Risk Appraisal

Technology / infrastructure system will be mature for trial and deployment

9.2 Technical readiness – When can a technical solution be expected to be ready?

The current maturity of automated vehicle technology is believed to suit operation in highly controlled TODs, with early deployments being proven in highly segregated domains closed to the public, such as manufacturing logistics or airport airside handling.

Further research and development will be necessary to establish what the evidence base will be to verify the safety of automated vehicles in the proposed TOD. The most important activity will around be comprehensive hazard identification, and definition of the corresponding validation activity. In particular, the physical security resilience is yet to be fully tested. Without evidence from other comparable deployments, the reliability of the proposed deployment cannot be anticipated, nor will the assurance framework be designed and tested ready for implementation.

It is not possible to determine when such an evidence base will be ready and therefore a solution ready to serve this route. Considering the recent evolution of CAM vehicles since the Urban version of the DARPA Grand Challenge (2007), it is reasonable to estimate that at least the remainder of this decade will be the minimum time requirement to generate such proof.

9.3 Operators' readiness

UK based operators have not yet declared intentions to deliver passenger transit services using automated vehicles. However, some operators are engaged in research activities (First (Milton Park) and Stagecoach (CAVForth)), which suggests a keenness to familiarise themselves with automated vehicle technology and improve knowledge about the technology's capabilities and maturity ahead of such a decision.

Several uncertainties will need to be resolved before the commercial risks will be low enough for operators to potentially deliver such a service. These uncertainties will also need to be understood by insurers, such that underwriters can quantify and value the risks involved. It is possible that services on routes with greater levels of segregation, or less requirement for segregation, will be the priority for operators.

There are strong motivating factors to encourage operators to deliver passenger transit services with automated vehicles. Anecdotally, current levels of driver recruitment are not sufficient to maintain existing passenger transit services. Automated vehicle operations present a potential solution to deliver such services with less labour resources. However, other costs may undermine the economic viability of delivering passenger transit services this way, which will need to be explored further.

9. Risk Appraisal

Stakeholder organisations are improving readiness

9.4 Manufacturers' readiness

Automated vehicles for passenger transit services are a popular field, with tens of new entrant OEMs in Europe, China, and North America developing automated shuttle bus products. Furthermore, many traditional OEMs are working inhouse or with automated driving system developers to also develop automated passenger transit bus products. Albeit many of these developments will not reach market due to technical or financial challenges, the current volume of development suggests there is sufficient activity that several suppliers will achieve the technical maturity, and be financially sustainable, to reach market. Some suppliers will also meet the further commitments expected by public sector procurement, although buyers may consider modifying these commitments to allow consideration of potentially superior product offerings from smaller suppliers.

Most European based manufacturers are performing their development in line with industry best practices, which should ensure products of sufficient maturity ready for trials in time for the proposed deployment.

However, it should be noted that all manufacturers are on a steep learning curve and will learn from evidence gathered during their first deployments. This learning relates to edge cases that are very rarely encountered, but which introduce hazards that threaten safety. The industry is very poor at sharing learning, as evidenced from high profile collisions and occasional fatalities in the US market. A cultural shift towards knowledge sharing will be required to foster sufficient learning across the industry and among all developers to maintain this steep learning curve. In addition, the UK Automated Vehicles Bills proposes a safety framework that would also ensure that learnings from on-road incidents are integrated into the safety approach.

In parallel to the timeframe for industry learning, regulatory bodies are also learning about possible assurance processes and frameworks that will suit automated vehicles. These will need to be developed and released for consultation before being formalised. It is unclear if a stable regulatory product assurance framework will be in place in time for the proposed deployment. This may still be in a provisional trial status.

Suppliers' ability to provide demonstratable evidence of capacity to deliver assured products, in time for the proposed deployment (target year 2029), will depend on this assurance framework being released imminently. This currently looks unlikely.

Alongside industry learning, public acceptance of automated vehicle operations in their neighbourhood will require extensive engagement and training, which would have to begin imminently in time for the proposed deployment.

Collaboration between developers, regulators, and operators, will be essential during the years ahead of the proposed deployment. TfWM's and SMBC's willingness to partner with these stakeholders and support their learning will accelerate the maturity of products and understanding of their deployment.

9. Risk Appraisal

Compulsory Purchase Orders

9.5 Compulsory Purchase Orders (CPO) – Will they be palatable for an innovative technology?

Legacy Compulsory Purchase Orders

The original IOBC for this route included a section on the impact of the route would have had on the residents and businesses. This was split into three categories, Landscape, Townscape and Heritage. Below is a synopsis of these categories.

Landscape

Outcome – Slight Adverse Impact

Comment – The proposed scheme followed an existing transport corridor in an urban setting and thus no impact on this area. The link between the end of Chelmsley Road and The Crescent in Birmingham Business Park required traversing a green space. The surrounding area is considered a green belt area hence the outcome. This would be minimised using green tracks.

Townscape

Outcome – Slight Adverse Impact

Comment – The scheme was planned to extend the already existing tram network which was already considered to be part of the existing infrastructure. However, approximatly 65 properties were identified for demolition as part of the development along Bordesley Green.

Heritage

Outcome – Moderate Adverse Impact

Comment – There is a lack of historic buildings east of Belchers Lane so expected to have a neutral effect on heritage. However, the Snooker Hall, a listed building, and the Fire Station are both notable building along the route and the segregation would have required land take or demolition of these buildings. This would have been locally sensitive, hence the outcome.

Looking at these comments through a modern lens, the assessment would be similar as the areas identified have not undergone drastic changes in the intervening years. A high-level review of satellite imagery of the route does not highlight any new developments that would be of concern.

One exception to this is the building of a new church at Kingston Road. When the IOBC was developed construction had not begun and was deemed a relatively simple land acquisition task. Since then, the church has been completed and would potentially make the land acquisition task more complex.

Mott MacDonald Corridor Study

The Mott MacDonald corridor study identified six roads where compulsory purchase would be required. These are:

- Kingston Rd
- Bordesley Green
- Bordesley Green E
- Chelmsley Road
- Solihull Parkway
- Bickenhill Parkway

Current Compulsory Purchase Order Processes

From discussions with TfWM teams on the current CPO process it is clear that, while it is possible, it should be a last resort. The advice is to acquire the land needed through negotiations with the landowner if possible. If it is not possible, it must be proven that the scheme cannot proceed without a CPO. It will then be brought to the Mayor for approval before it can be enacted.

During this process, the landowner can sell the land privately which would require the CPO process to begin again. This also assumes that the scheme has the approval of the Local Authority Cabinets involved.

9. Risk Appraisal

Does benefit outweigh risk with being amongst the first to introduce a new technology?

9.6 Early Deployment - Is there risk to being first?

Although not the fist this deployment would be one of the earliest in the UK for a CAM service. This raises the question if an early deployment is an advantage or if it would be better to wait until the technology matures.

The Harvard Business Review article The Half-Truth of First-Mover Advantage gives a framework that can be used to make this judgement. This article investigated multiple examples to understand where first mover advantage existed and where it did not. From the research done, the authors offer the following quote

Specifically, we identified two factors that powerfully influence a first mover's fate: the pace at which the technology of the product in question is evolving and the pace at which the market for that product is expanding.

This sentiment is refined on to a matrix (Figure 9.2) based on the conditions identified which influences the first mover advantage and are defined as:

- Calm Waters – A gradual evolution of both the market and technology giving a first mover the best chance of market dominance
- The Market Leads – Rapid market growth which gives the advantage to organisations with more marketing resource
- The Technology Leads – Rapid development of the technology gives advantage to organisations with more R&D resources
- Rough Waters – The market and technology rapidly develop giving advantage to agile organisations

Figure 9.2: The Combined Effects Of Market And Technological Change

		Pace of Market Evolution	
		Slow	Fast
Pace of Technological Evolution	Slow	Calm Waters	The Market Leads
	Fast	The Technology Leads	Rough Waters

In the context of this feasibility study, it is reasonable to classify CAM solutions as being in the *The Technology Leads* category of this matrix. The article explains that an organisation would require deep pockets to enter this type of market as years of flat sales would be expected or for early products to be rendered obsolete.

However, these are the exact conditions where government investment would produce the highest benefit. The article is written with profit as the core motive. For a government backed scheme, the core motive is social benefit while being value for money. This negates the risk that a would be present if a private company attempted to deploy a CAM solution independently.

In addition, the deployment of a CAM system would spur on the requirement for trained professionals to operate the system at all levels and for support from the supply chain. This will require further investment into skills and innovation to sustain and enhance any CAM deployment.

9. Risk Appraisal

Public perception of the role of CAM as part of public transport

9.7 Public Acceptance and Perception

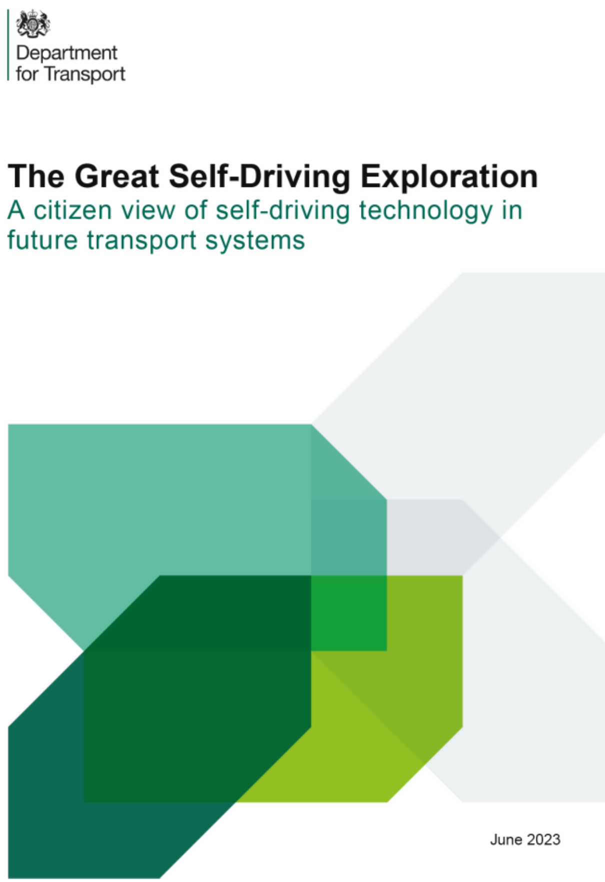
Public Acceptance and Perceptions of CAM solutions

The report The Great Self-Driving Exploration published in June 2023 is an in-depth study into the public's view of CAM technology. The insights highlight the existing view of CAM services and the potential for CAM vehicle's role in local transport systems.

Existing View Of CAM Services

The summary of the publics existing view of CAM is:

- There is a strong correlation between positive attitudes towards technology and positivity towards SDVs. Those most likely to be positive include men, younger people, those with higher incomes, those with higher education levels, and those living in urban areas.
- While awareness of SDVs is high and almost two thirds of the national control sample report having talked to others about SDVs in the past, there is low accuracy of understanding of user responsibilities when travelling in SDVs and what vehicles can currently legally do on UK roads.
- Comfort with using or sharing the road with SDVs is low, with the proportion giving the lowest comfort ratings consistently and significantly outweighing the proportion giving the highest comfort ratings in the national control survey.
- However, the low, medium, and high exposure audiences in this research were consistently more comfortable with the prospect of SDVs than the national control sample, indicating higher starting positivity among research participants compared to the wider UK public.
- People are most willing to use a private SDV with shared responsibility for the driving task compared to other types of SDVs.
- Views were mixed in the national control survey about whether SDVs would make the local transport system better, worse or no different, as well as whether there were more advantages or disadvantages to their use.
- By contrast, the medium and high exposure audiences were significantly more positive about the potential impact of SDVs, and while many were still unsure or wanted more information, there was limited outright negativity.



9. Risk Appraisal

Public perception of the role of CAM as part of public transport

9.7 Public Acceptance and Perception

Potential role of CAM in local transport

The summary of this section from The Great Self-Driving Exploration report is:

- **Initial thoughts**
  - Initial views tend to be neutral to positive among study participants
  - There are multiple assumptions that study participants brought to the study
  - Safety is a key area of interest, both of the system and to road use
- **Opportunities**
  - Benefits identified as study participants learnt more
  - Town and rural participants identified a range of use cases
  - CAM Vehicles could improve public transport services
  - Urban participants see CAM services ‘plugging gaps’ in the transport network and for longer journeys
  - Expectation for CAM to be used in public transport first
- **Drawbacks**
  - Participants raised concerns over the safety of the vehicle over a human controlled vehicle
  - Risks around personal safety (physical abuse) and data (hacking/data breach)
  - Poor real world intergration and functionality, especially early on
  - Concerns of job losses in local communities
  - High cost of implementation and lack of funding available in local government
  - Dehumanisation of services leading to higher levels of isolation
  - Inequality due to potential high cost, physical accessibility and digital literacy
- **Expectations**
  - Majority of study participants expect a gradual roll out of CAM systems based on safety and convenience of users
  - CAM services will be in addition to and not replace existing transport networks in the short to medium term
  - Safety and security assurances with redundancy systems and potentially a human presence for shared vehicles
  - Large scale communications campaign to educate the public on CAM vehicles, along with updates to driving tests on CAM interactions

The report includes many recommendations to drive behaviour change on the public during the adoption of CAM systems. This report demonstrated that while there is hesitancy and questions in the publics collective mind around CAM deployments, there is significant optimism and potential acceptance in their use.

It should also be noted that The Great Self-Driving Explorations and similar study has focused on the public acceptance of *potential customers* and not on *local residents* or *other road users*. As evidenced by news reports on the Cruise and Waymo deployments in San Francisco, there are more negative feeling towards CAM systems when sharing the environment with them but not making use of them. Further specific studies will be needed to understand the acceptance of CAM solutions by other road users and residents who may not directly experience the benefits of such a system.

9. Risk Appraisal

Public perception of the role of CAM as part of public transport

9.7 Public Acceptance and Perception

Local Perception of CAM

There have been two local studies that have asked residents of Birmingham and Solihull on their perceptions of CAM solutions. These are Solihull Low Carbon Future Mobility Travel Behaviour Change (Oct 2023) and Self-Driving Buses. Keep WM Moving! Online Community Topic (Feb 2023)

Both studies show that residents in these areas are curious to use CAM solutions but have reservations on the deployment of the solutions. Additionally, it was noted that while residents express that they would switch to automated vehicles for some journeys, they would not replace all journeys.

Chart 9.1 shows the reasons for resident's opinions on CAM solutions, which were based on the launch of the CAVForth project.

Figure 9.3 Shows the comments made by Solihull residents on why they would not use CAM options.

In both outputs the concerns generally surround the safety of the vehicles which may stem from a lack of understanding of the level of technology development. This is in line with the national survey, and the key to overcoming these concerns is communication and experience.

Figure 9.3: Comments made by respondents related to why they won't use automated vehicles

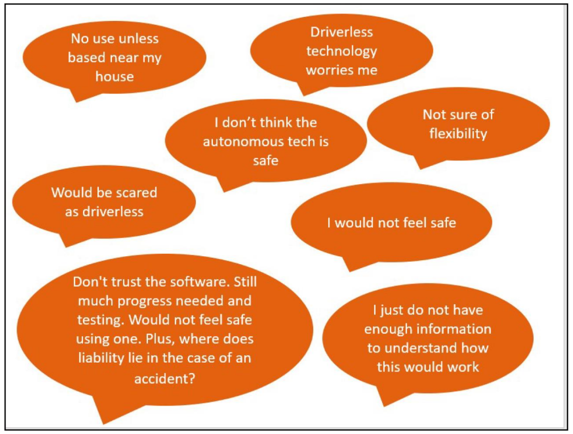
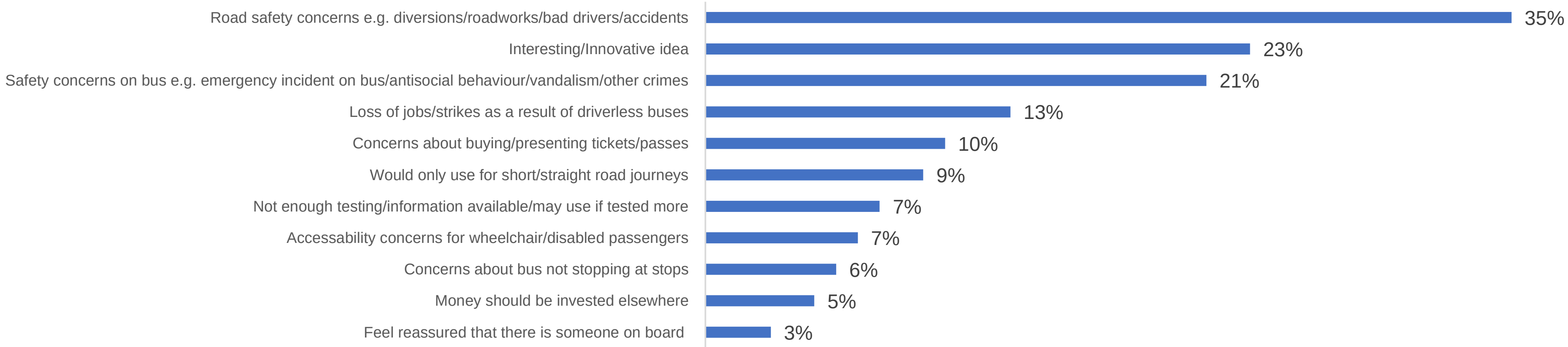


Chart 9.1: Reasons for opinions on CAM solutions Self-Driving Buses



9. Risk Appraisal

Public perception of the role of CAM as part of public transport

9.7 Public Acceptance and Perception

Local Perception of CAM

Despite the understandable reservations shown locally, research also indicates that a CAM system holds the most potential to replace car journeys.

Solihull MBC have deployed their Aurrigo CAM shuttle at the NEC, Birmingham Airport and Birmingham Business Park over the past two years (2021 – 2023) as part of a GBSLEP funded project. The post-ride surveys illustrate a high satisfaction with the ride experience, and a significant reduction in concern / cynicism post-ride. 94.6% of riders stated they enjoyed their experience; 98.2% of riders stated they felt safe at all times; 87.9% of riders felt they could become accustomed to riding without any safety operator on board; finally, 96.5% of riders stated they would readily ride on an automated vehicle again.

Observations of the deployed vehicle were that very few times did passersby / other road users act maliciously or dangerously, indicating a general default position of behaving cautiously around the technology.

9. Risk Appraisal

Statistics of the crimes that would be a concern to a CAM solution

9.7 Public Acceptance and Perception

Crime Statistics

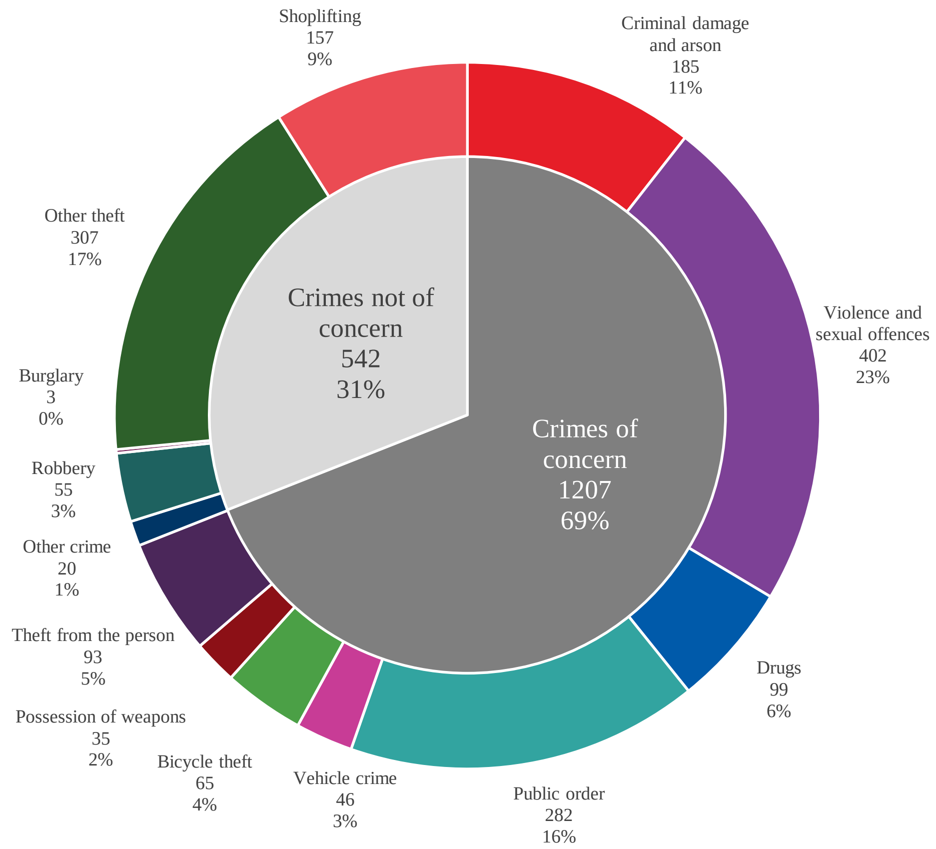
Personal safety of passengers will be protected for mass adoption a public transport CAM solution. The report The Great Self-Driving Exploration noted the following as part of the perceived drawbacks of CAM systems

Dangers onboard: *There were concerns that passenger safety and security while travelling would decrease due to the absence of staff on shared and public transport, removing a 'neutral' third party in the event of disputes or antisocial behaviour. Particularly among urban participants, it was felt that the use of SDVs could lead to an increase in anti-social behaviour on public transport. The removal of staff was also seen as potentially providing opportunity for criminals (e.g. for drug dealing, theft). These perceived drawbacks and risks were raised particularly often by women and people who tended to travel at night.*

Chart 9.2, opposite, shows the crime statistics reported by British Transport Police for the period August 2022 to August 2023. These crimes occurred either in Birmingham or Solihull. The chart shows Crime Types in the outer ring while the centre shows which crime types, should be considered of concern to a CAM solution.

Some crime types would not be a concern due to the different infrastructure, however, more than ⅔ of the crimes committed in the period would be a concern to a CAM solution. These crimes relate to potential actions against other passengers, allowing for criminal activity to be carried out or damage to the vehicle itself. It is reasonable to assume an increase in these crimes without the presence of an authority figure in the form of a driver or attendant. If these crimes were to go unchecked, public perception and acceptance of a CAM solution may be irreparably damaged.

Chart 9.2: British Transport Police Crime Statistics August 2022 to August 2023 for Birmingham and Solihull LSOAs Source: https://data.police.uk/



9. Risk Appraisal

Public perception of the role of CAM as part of public transport

9.7 Public Acceptance and Perception

Learnings

From the research discussed in this section there are several elements that would be applied to a real-life service. A key part of the research is to ensure all aspects of a CAM service are communicated with the public. This would be done as part of the launch campaign and encompass potential customers, other road users and residents.

As part of the service, a customer feedback system and regular surveys would be performed to identify shortcomings of the services and potential growth areas. This would continue for the life of the service and should form the basis for a total quality management approach to system and process improvements of the service.

As mentioned, further studies will be needed to ensure the safety of passengers and vehicles from anti-social behaviour. These studies would identify techniques and methods to reduce, or ideally eliminate, anti-social behaviour towards passengers and vehicles.

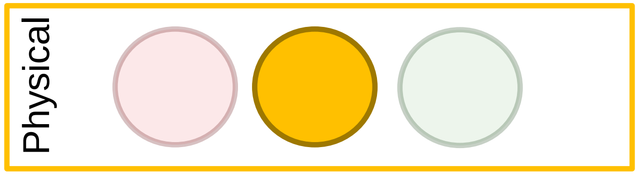
9. Risk Appraisal

Performance against the Feasibility Questions

9.8 Summary

Feasibility Question 15

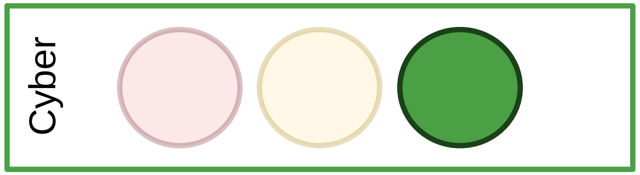
Is automated transport a secure technology?



There are multiple risks to CAM solutions as demonstrated by the public's reaction to early deployments in locations such as San Francisco. The physical safety of vehicles therefore requires further exploration.

Feasibility Question 15

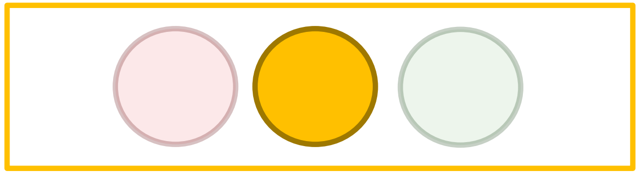
Is automated transport a secure technology?



There is currently high resilience to cyber security threats as this area has been extensively researched. CCAV have already funded and created a framework develop mitigation requirements and a method to for legal arguments to reduce digital vulnerabilities. Additionally, the expectation is that digital security will meet or exceed those for non-CAM vehicles as defined by the UNECE and will be included in Type approval process.

Feasibility Question 16

Will an automated solution that can technically serve this route be ready within stated target timeframes?



CAM solutions have been proven to be highly effective in controlled and semi-controlled environments. For complex urban deployments a CAM solution requires infrastructure to maintain a safe level of segregation, as identified within this study. Further study into the capability readiness is required.

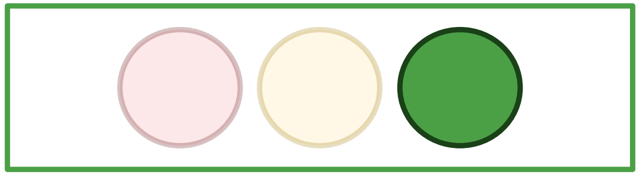
9. Risk Appraisal

Performance against the Feasibility Questions

9.8 Summary

Feasibility Question 17

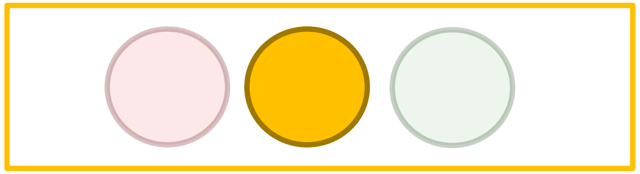
Are transport operators open to exploring delivering CAM services?



UK based operators have not yet declared intentions to deliver passenger transit services using automated vehicles. However, some operators are engaged in research activities, which suggests a keenness to familiarise themselves with automated vehicle technology. There are strong motivating factors to encourage operators to deliver passenger transit services with automated vehicles.

Feasibility Question 18

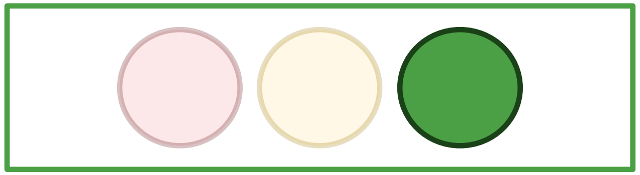
Will there be system / vehicle manufacturers ready to deliver the scale of system, with sufficient demonstrable evidence of delivery and funding to secure public / commercial contracts?



OEMs are in the process of developing CAM solutions and while progress is being made there will be a steep learning curve during the initial deployments. Regulatory bodies will need to issue assurance frameworks in the very near future to allow the supply chain to develop systems that comply. There is currently no developed specification for public authorities to tender for such systems, and demonstration of delivery at scale is not readily available for any suppliers in the sector.

Feasibility Question 19

Can we Compulsory Purchase Order for CAM solutions; is it politically palatable?



While CPO is a last resort it is not impossible, and the land acquisition outlined in the previous IOBC suggested that the impact would be minimal along the corridor

The original IOBC and more detailed corridor study identified several areas where compulsory purchases would need to be made for a tram deployment. Following a desktop review of these locations it is evident that these locations will still need to undergo a more detailed review for their purchase to allow for a segregated corridor.`

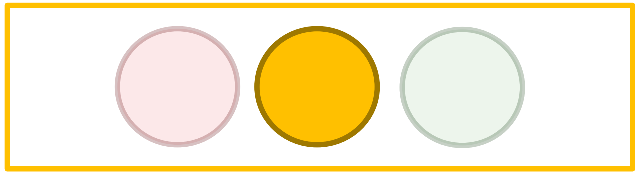
9. Risk Appraisal

Performance against the Feasibility Questions

9.8 Summary

Feasibility Question 20

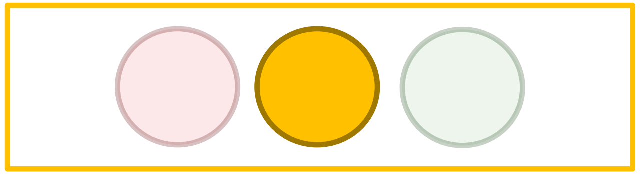
Do we want to be first? Is there any advantage to being first? What are the disadvantages of being first?



While this would not be the very first deployment, being first (/ amongst the first) could be expected to benefit from government involvement due to the high initial cost, long payback period and nature of innovation. This type of deployment would allow for innovation to grow in the region with reduced risk to commercial entities, however, lessons learned could be significant.

Feasibility Question 21

Will a CAM solution be socially accepted? Will it be abused / a target for abuse that makes it unreliable / unusable?



While potential customers are keen on the concept of CAM, security and safety solutions must be put in place and significant engagement with the public will be needed. Further studies into the acceptance from other road users and residents will also be needed. Any deployment will need a detailed plan on how to protect passengers and the vehicles while in operation.

10. Outline Implementation Programme

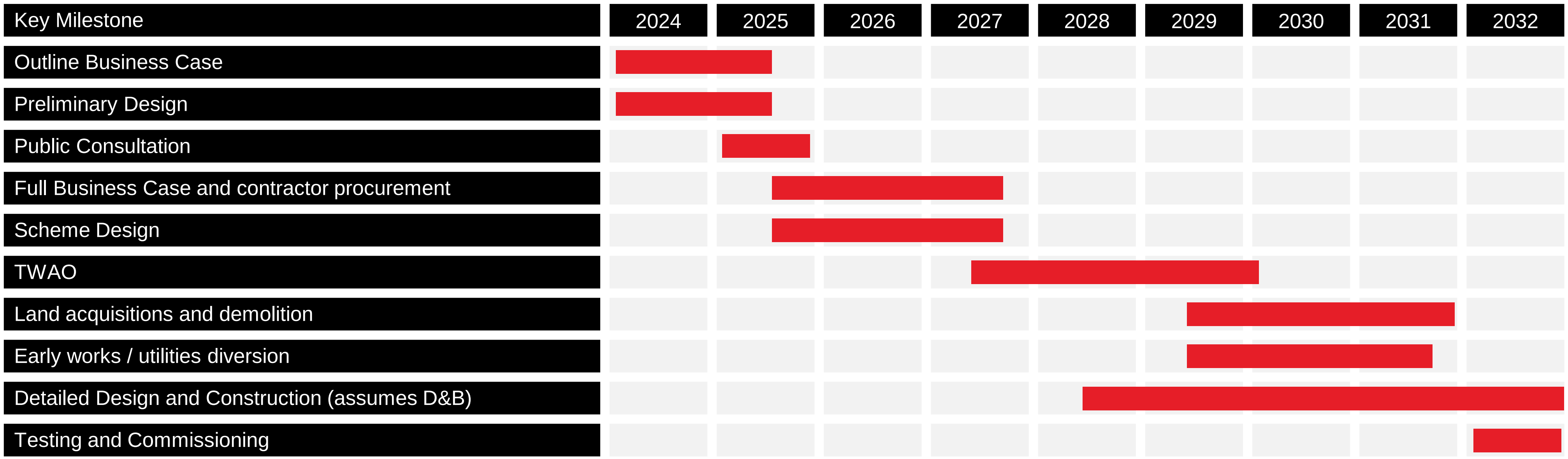
10. Outline Implementation Programme

Implementation would be expected to take eight years

10.1 Programme

For this scheme, an initial high-level schedule is given below. The following key items are highlighted for further analysis and detailed consideration on programme at subsequent stages of the study:

- Programme assumes design and build contract, although alternatives would need to be considered in full within the Management case of the OBC;
- The Transport and Works Act Orders (TWAO) process will be a key item informing the programme and will require careful management/ consultation and a robust business case.
- This programme is considered pragmatic at this early stage of the project. There may be opportunities to optimise based more in-depth knowledge of specific risks of the corridor. Key considerations will be the potential for objections to TWAO processes, complexity of utilities, diversions and demolition of existing assets, ground and environmental conditions (e.g. archaeological, contaminated land, environmental/ecological impacts such as the relocation of sensitive habitats/vegetation) and the complexity of traffic management required.
- The route could be delivered in phases, i.e. those sections not requiring significant land acquisition, without complex utilities diversions or without objections to TWAO or favourable ground conditions which can be considered further as the project develops through ground investigation and no complex utilities diversions
- This programme should be kept under review and developed further during subsequent project stages.



11. Study Recommendations

Study Recommendations

To progress to Outline Business Case, further work is recommended

11.1 Recommendations and Next Steps

Qu	Feasibility Question	Chapter	Traffic Light	Recommendation
FQ1	Do previous studies support the potential for CAM for public or mass transit?	Previous Studies		Best practice / lessons-learned visits to CAM deployments Engagement with leading academic institutions to model corridor
FQ2	Is this route supported by local, regional and national strategy and policy?	EBNS Strategic Context		Incorporate learning from parallel WMCA EBNS corridor study currently underway – expected to conclude Q1 2024.
FQ3	Do future plans on this route support its viability?	EBNS Strategic Context		Incorporate learning from parallel WMCA EBNS corridor study currently underway – expected to conclude Q1 2024.
FQ4	Is a new service along this route needed?	Constraints and Opportunities		Incorporate learning from parallel WMCA EBNS corridor study currently underway – expected to conclude Q1 2024.
FQ5	Is an automated solution (SAE Level 4) the optimal technology for this route?	Route Feasibility		Incorporate learning from parallel WMCA EBNS corridor study currently underway – expected to conclude Q1 2024. Undertake a detailed assessment of emerging technologies applicability to the route
FQ6	Based on the agreed assumptions, can a CAM solution deliver target outcomes within this urban context?	Route Feasibility		Review best practice output from Project Fuse and connectivity plan from parallel EBNS study Research the potential congestion effects of different headway scenarios to meet demand Develop optimised traffic signal timing for junctions along the route Research the potential to optimise service reliability with V2X implementation
FQ7	Can appropriate levels of segregation be provided along the route?	Route Feasibility		Detailed analysis of full route to identify optimal level of segregation at each stage
FQ8	Could a CAM solution be delivered at a lower CAPEX when compared to LRT?	Capital Costs		Further design work to better define infrastructure works required along the route, stops design and depot / control centre / roadside infrastructure
FQ9	Could a CAM solution be delivered at a lower OPEX when compared to LRT?	Operations		Calculate the impact of different vehicle sizes (passenger capacity) on operational costs and better understand maintenance requirements. Consider the impact a 24/7 service would have on benefits and operational costs. Carry out sensitivity analysis in relation to headway and its impact on ridership demand. Understand the extent to which technology development / maturity is likely to reduce future system costs.
FQ10	Can the required level of system reliability be delivered?	Operations		Fully develop the ODD for the route
FQ11	Can the route be delivered with acceptable safety?	Operations		Full safety case. Support the CAM sector to develop commonly agreed and used goal orientation as a foundation for standardising safety cases.

Study Recommendations

To progress to Outline Business Case, further work is recommended

11.1 Recommendations and Next Steps

Qu	Feasibility Question	Chapter	Traffic Light	Recommendation
FQ12	Can we protect fares? Can we safeguard on-board riders? Can we provide accessible transport?	Operations		Conduct human factors research into behaviours relating to fare evasion; late night behaviours; perceptions of minority groups
FQ13	Will an automated solution be legislated for and insurable?	Operations		Continue to engage with the relevant public bodies to develop appropriate primary and secondary legislation to allow for future deployment of CAM systems
FQ14	Would a CAM solution be expected to provide value for money?	Cost Benefit Appraisal		Appraise larger vehicle capacities running at increased headways, When vehicle confirmed - investigate ride quality and the impact on benefits. Further transport modelling to identify demand post-COVID and post-HS2 northern leg decision, as well as potential negative impact on traffic congestion / delay
FQ15	Is automated transport a secure technology? (Physical & Digital)	Risk Appraisal		There is significant lack of understanding of Physical Security. Important research is needed to raise the understanding of Physical Security to a par with understanding of Digital Security.
FQ16	Will an automated solution that can technically serve this route be ready within stated target timeframes?	Risk Appraisal		Detailed design of route and assessment against projected CAM capability
FQ17	Are transport operators open to exploring delivering CAM services?	Risk Appraisal		Market engagement with traditional operators to explore co-ordinated development of CAM-based solution
FQ18	Will there be system / vehicle manufacturers ready to deliver the scale of system, with sufficient demonstrable evidence of delivery and funding to secure public / commercial contracts?	Risk Appraisal		Manufacturers must meet the product and service specifications used in public procurement. However, since vehicle product development can take up to 5 years. A universally agreed specification for UK public transport CAM is needed to guide manufacturers' development activities.
FQ19	Can we CPO for driverless solutions; is it politically palatable?	Risk Appraisal		Complete a detailed CPO review at OBC stage
FQ20	Do we want to be first? Is there any advantage to being first? What are the disadvantages of being first?	Risk Appraisal		Engage regional and national bodies to understand support on offer for delivery of route
FQ21	Will a CAM solution be socially accepted? Will it be abused / a target for abuse that makes it unreliable / unusable?	Risk Appraisal		Research and develop mitigations to protect passengers from anti-social behaviour Research and develop mitigation to protect the vehicle from anti-social behaviour Research the acceptance of CAM by non-CAM customers (residents, other road users, etc.) Develop public communications framework to support deployment of CAM service

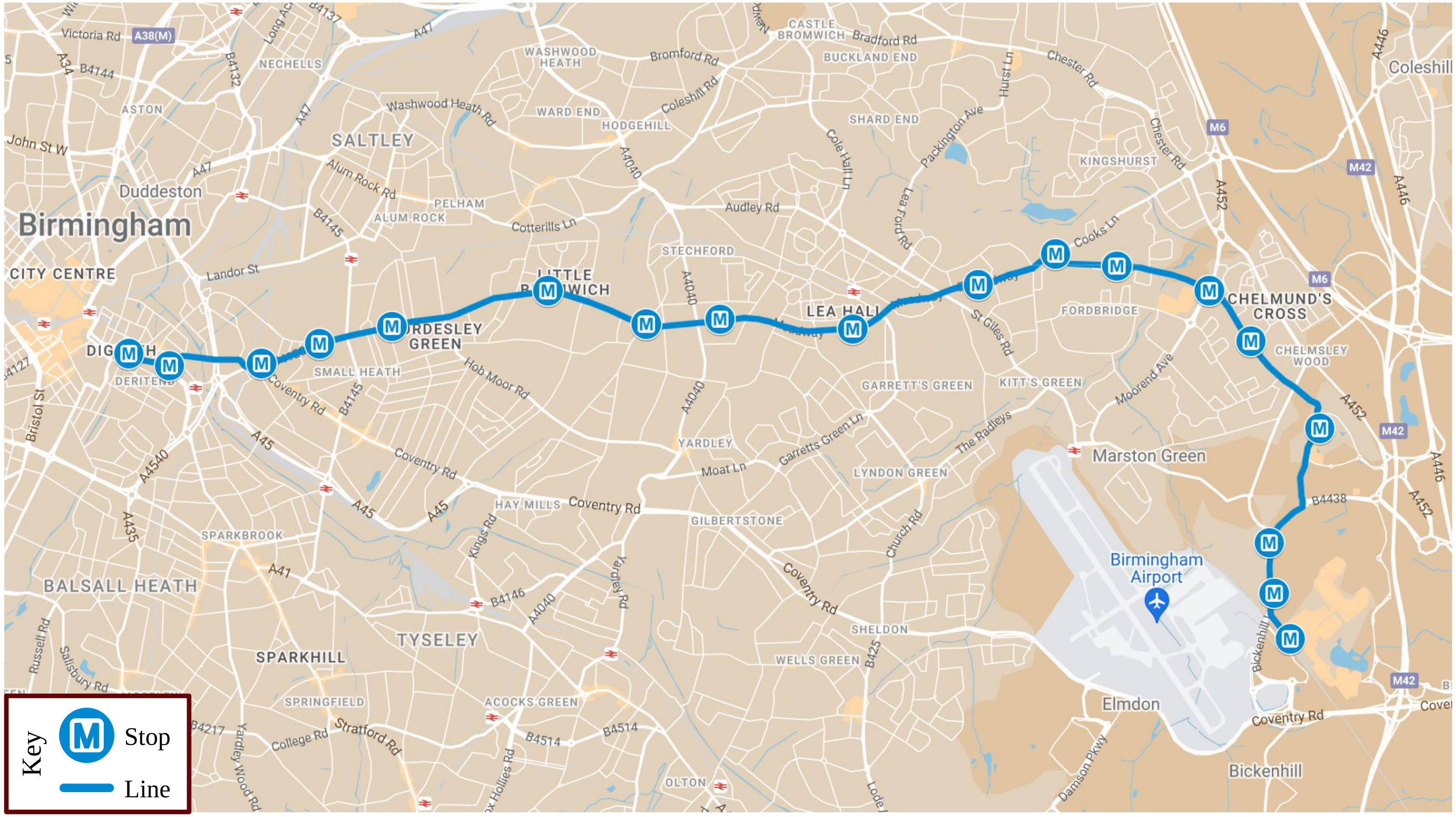
Appendices

Appendix - Chapter 1

1.2 Study Route Appendix

Appendix Chapter 1

1.2 Study Route Appendix



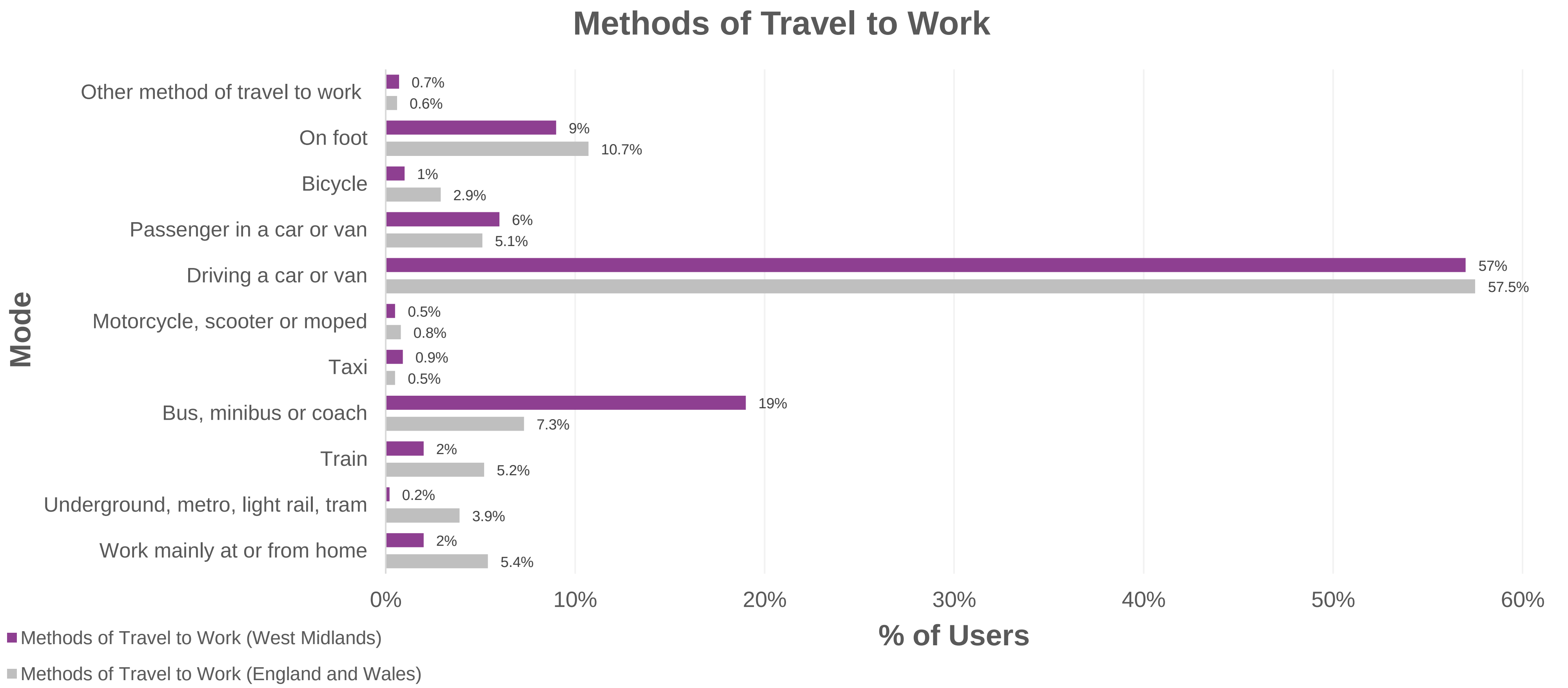
Appendix - Chapter 4

4.1 Mode Split Appendix
4.6 Road Appendix
4.7 Environmental Considerations – Appendix
4.8 Future Transport Proposals - Appendix

Appendix Chapter 4

4.1 Mode Split Appendix

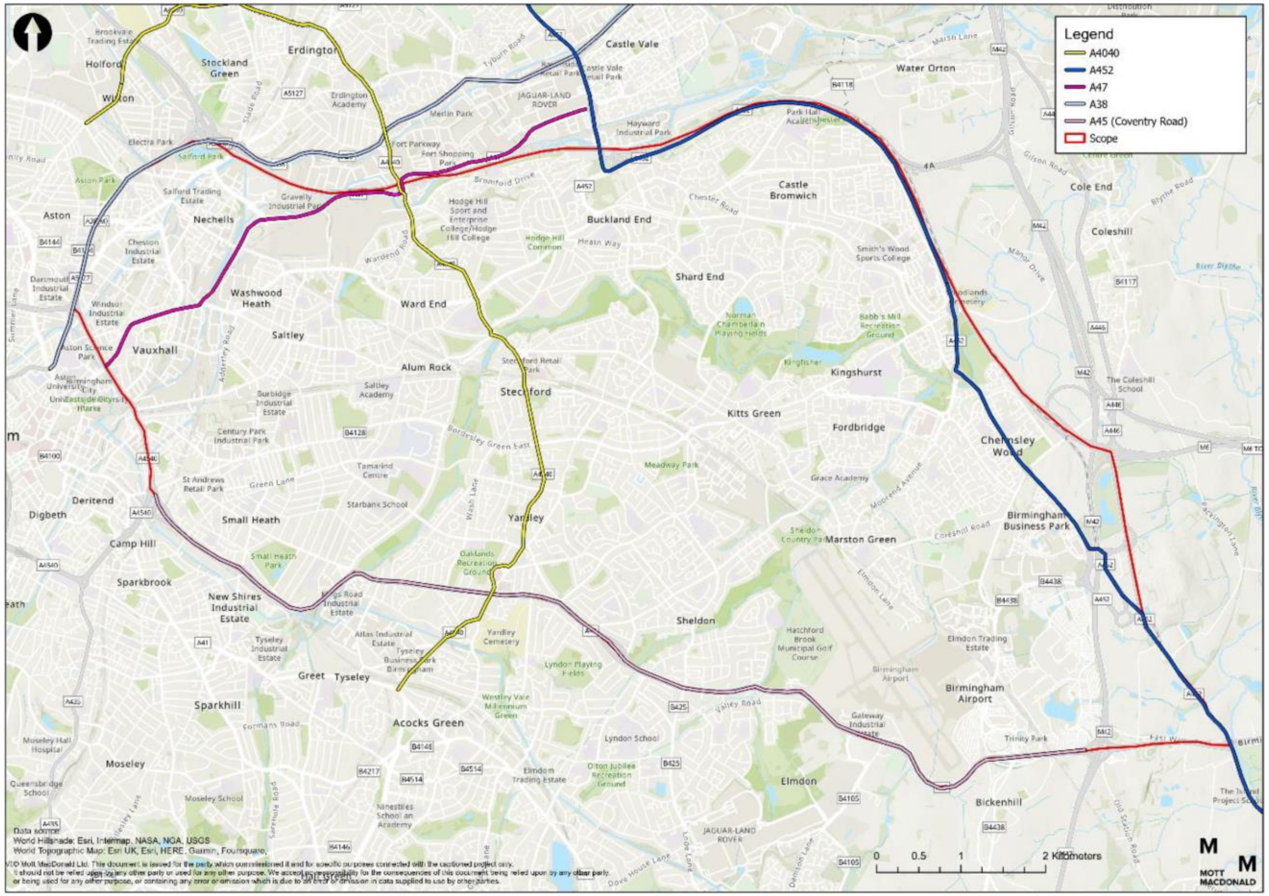
Chart 4.1: Methods of Travel to Work throughout the study area. Source : Census 2011 data



Appendix Chapter 4

4.6 Road Appendix

Major Road Network in and around Birmingham



Primary Road Network

A45 (Coventry Road)

The A45 is the primary A-road passing through the area of scope forming the southern boundary of the study area. It runs from Birmingham City Centre via Birmingham International Airport to the M42, before continuing to Coventry where forms an onward route bypassing the city before eventually meeting the M45 motorway which continues west towards the M1.

Locally the road links the A4540 Ring Road, where it bypasses Small Health and the historical Coventry Road route forming a purpose-built road corridor. It meets the A4040 at a grade-separated junction, and the B425 in Sheldon. The subsequent section east of Solihull to Coventry forms a continuous highly trafficked dual carriageway route.

Appendix Chapter 4

4.6 Road Appendix

A38

While the A38 is a key national route providing access to Birmingham City Centre and the western end of the study area. Regionally the A38 route links Birmingham with regional destinations including Worcester, Bromsgrove, Birmingham City Centre, Sutton Coldfield and Lichfield.

Locally the route links South Birmingham and the suburbs of Longbridge, Northfield, Bournville, Selly Oak and Edgbaston through to Birmingham City Centre. North of the city centre the route becomes the Aston Express A38(M) Motorway linking the city centre and to northern suburbs including Erdington, Castle Vale and Minworth and providing interchange with the M6 motorway.

A47

The A47 is part of a longer route that runs from Birmingham to Lowestoft via Hinckley, Leicester, Uppingham, Peterborough, Wisbech, King’s Lynn, Dereham, Norwich and Great Yarmouth.

Locally the road starts at a junction with the A4540 east of Birmingham City Centre, near to the HS2 Curzon Street Station site. It leaves Birmingham continuing east through Castle Bromwich, The Fort and Water Orton.

A452

The A452 runs between Brownhills, just north of Birmingham, to Royal Leamington Spa and Warwick (where it meets with the M40 via Sutton Coldfield, Castle Bromwich, Chelmsley Wood, Birmingham Airport and Kenilworth.

The road passes through Erdington before running through Castle Bromwich and The Fort and Chelmsley Wood and meeting with the airport before continuing south near to Hampton-in-Arden and Balsall Common.

A4040

The A4040 functions as a suburban informal Outer Ring Road for Birmingham, and passes through our area, providing connections to the northern and southern parts of the city without traveling via central areas. The route links areas including Aston, Handsworth, Bearwood, Harborne, Selly Oak, Kings Heath, Hall Green, Acocks Green, Yardley, Stechford and Erdington.

Within our area of scope, it also joins the A45 to the M6 and Alum Rock Road, a local road. It acts as the main north-south route within our area of scope.

Key local routes

B4128 Bordesley Green Road/Meadway

The B4128 runs between the junction with the B4100 at Bordesley to a junction with the A4040 south of Stechford station. The road then continues eastwards as ‘Meadway’, without a B-road classification. The route frequently changes names before meeting with the B4114 and A452 at Chelmsley Wood and Coleshill Interchange.

The road is a primary east-west connector within the study area and has featured as the primary movement corridor in a number of previous proposals for mass transit solutions through the study area.

The nature of the road changes considerably from the West to the East with its start on the Coventry Road being a wide single carriageway with two lanes in each direction between the B4100 and A4540 in Bordesley.

Appendix Chapter 4

4.6 Road Appendix

The B4128 then continues to travel along the Coventry Road before turning onto the narrower Cattell Road through an area of late 20th century housing. Further east, the B4128 joins the narrower, more enclosed Bordesley Green which is comprised of a mixture of two and three lane sections for turning. Land use includes a mixture of late 19th century terraced housing, industrial and commercial businesses. There are two signalised junctions at Bordesley Green Road and at the access to the South and City College Birmingham with the provision of formalised parking between them.

The B4128 Bordesley Green gradually widens out, to the east of South and City College Birmingham, to two lanes in each direction but with informal parking. As the Road heads east, it becomes more residential in nature until it reaches the roundabout junction with Belchers Lane.

To the east of Belchers Lane, the B4128 opens into the dual carriageway boulevard that is Bordesley Green East where it passes through progressively more modern 20th century residential areas. The road itself is comprised of a mixture of two-lane dual carriageway with bus lanes in each direction and single carriage way with service roads. This standard of road is maintained past Birmingham Heartlands Hospital, across the A4040 to Meadway, through Lea Hall until it reaches Tile Cross.

At Tile Cross the road narrows to a two-lane single carriageway road with a lane in each direction, no service roads, and immediate building frontages. This is mostly maintained with the exception of the signalised junction with Gressel Lane and Tile Cross Road where the road widens out to provide turning lanes in each direction.

From the Cooks Lane roundabout junction with Chelmsley Road the route continues eastwards along a single carriageway, two-lane road with cycle lane provision and immediate residential frontages until it reaches the B4114 Chester Road and A452.

B4114 Washwood Heath Road/Coleshill Road/Chester Road

The B4114 runs between the junction with the A47 at Saltley Viaduct all the way across the north of the study area and continues to Leicester. The route frequently changes names before meeting with the B4128 and A452 at Chelmsley Wood and Coleshill Interchange.

The road is a primary east-west connector across the north of the study area but also provides an alternative and connector route for the A47 and A452.

From west to east, the B4114 Washwood Heath Road is generally a wide single-carriageway enclosed by late 19th century housing and interspersed commercial properties with marked on-street parking provision. However, there are exceptions at the roundabout with Alum Rock Road, the signalised junction with Ashton Church Road where turning lanes are provided, and the section of dual carriageway to the west of the A4040 Bromford Lane/B4114 junction.

East of the A4040 Bromford Lane, the B4114 widens out into Coleshill Road; a single carriageway road lined by grass verges, wide pavements and larger 20th century residences before crossing Hodge Hill Common and continuing in a similar nature to Castle Bromwich.

At Castle Bromwich, the B4114 becomes Bradford Road and opens up further into a wide single carriageway road with service roads to interwar and post war housing, interspersed by commercial properties at key junctions. This nature of the road continues along Chester Road to the A452, with the exception of Castle Bromwich centre where the housing is broken by shops and surface level car parking.

Appendix Chapter 4

4.6 Road Appendix

Alum Rock Road/Cotterills Lane

Alum Rock Road and Cotterills Lane run between the B4114 Washwood Heath Road in the west to A4040 in the east. The route is all unclassified.

The roads form a secondary east-west connector across the west of the study area; linking Alum Rock, Pelham and Stechford.

From west to east Alum Rock Road starts as the very tightly lined commercial centre street for Alum Rock. Alum Rock Road is the principal local centre serving Saltley and Washwood Heath. Linear in form, it comprises mainly traditional terraced shops with some more recent infill including a number of community uses. The road itself is a two-way single carriageway with a lane in each direction, lined by formalised parking spaces to serve businesses. There are numerous junctions with tightly packed 19th century terraced residential streets all along the course of the road until Pelham.

The Alum Rock Road itself maintains its tightly enclosed nature with formalised parking but becomes more residential to the east of Tarry Road mini-roundabout.

The road widens at Pelham where the housing becomes less 19th century terraced and more early 20th century/interwar with front gardens and more green space.

Turning into Cotterills Lane, the route becomes much more residential in nature with a narrower road width and informally parked cars that create pinch points for through traffic between Alum Rock Road and Belchers Lane. Cotterills Lane maintains these characteristics up to the A4040 although with more road width to allow for passing vehicles.

Coventry Road

Coventry Road runs from the B4100 in the west, sharing a section with the B4128, to the A45 Heybarnes Circus in the east. The road is unclassified but used to be the main road between Birmingham and Coventry before the A45 Small Heath Highway was constructed.

The road forms a secondary east-west connector and central shopping area for Small Heath, tying into the north-south B4145 connector road. It is a key place in the study area for shopping and community amenities.

The Coventry Road centre is a traditional linear inner city local centre, straddling Coventry Road and stretching from Cattell Road to Small Heath Park, a distance of roughly 1.6 km (1 mile).

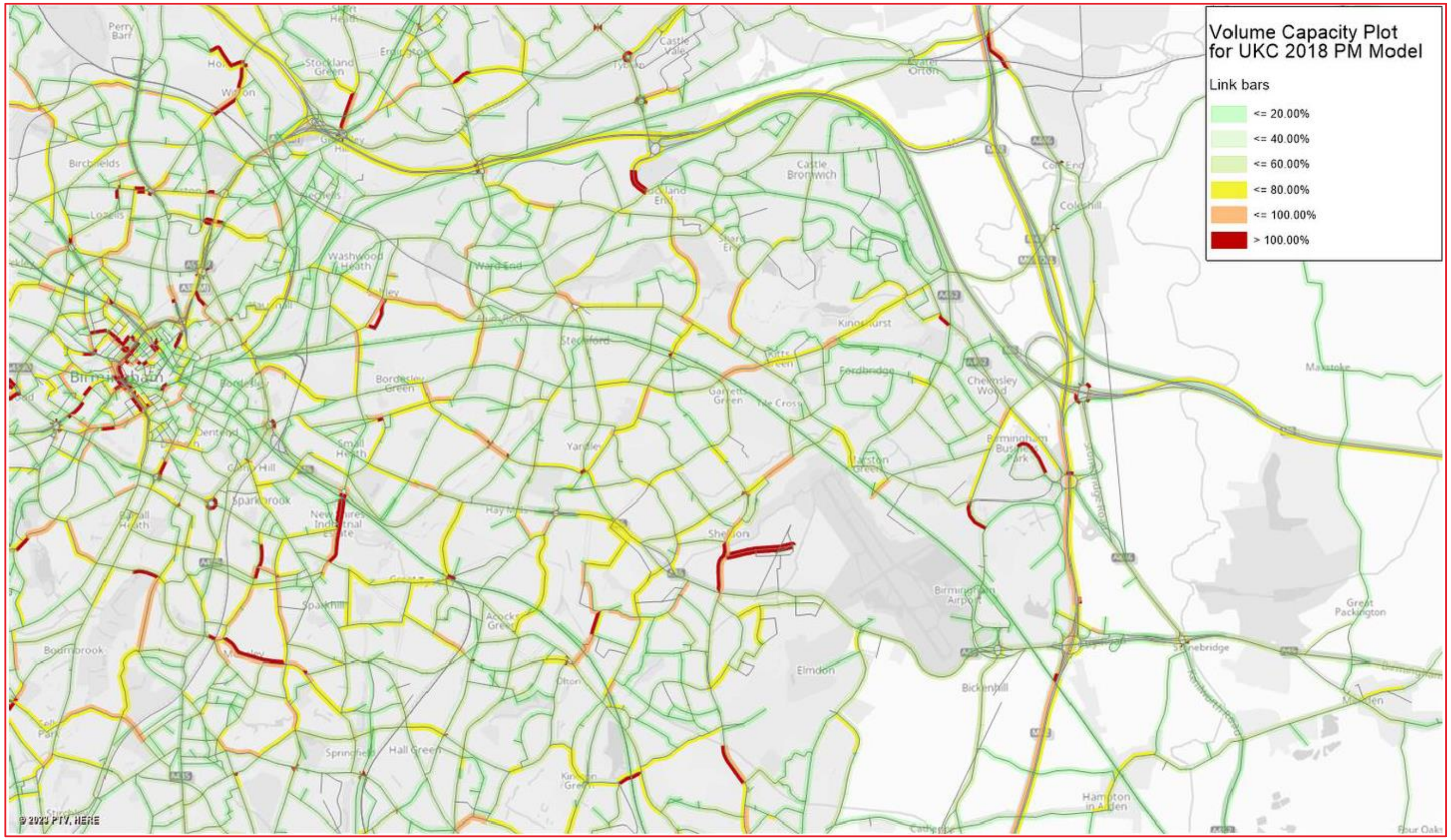
From west to east Coventry Road is mostly the commercial centre street for Small Heath. The road itself is a relatively wide two-way single carriageway with a lane in each direction, lined by formalised parking spaces and wide pavements to serve businesses. There are numerous junctions with tightly packed 19th century terraced residential streets all along the course of the road. These roads are relatively well used as they provide through routes and ‘rat-runs’ to the rest of Small Heath and areas further afield such as Sparkbrook and Bordesley Green.

The Coventry Road itself maintains its tightly enclosed nature with formalised parking but becomes more residential to the east of Small Heath Park, which lies to the south.

Appendix Chapter 4

4.7 Environmental Considerations - Appendix

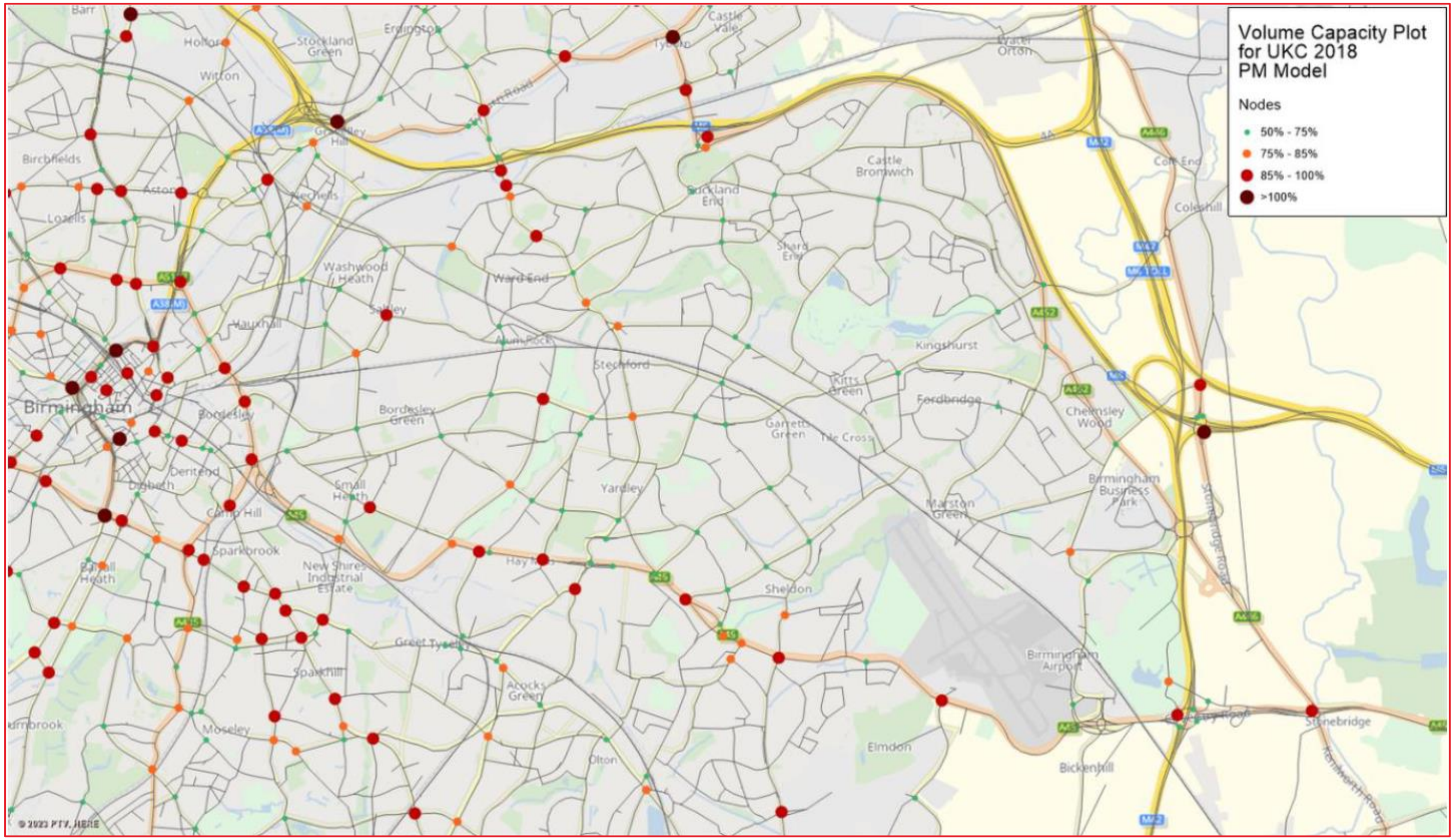
Figure 4.1: PRISM Model Link Volume/Capacity across the EBNS Study Area



Appendix Chapter 4

4.7 Environmental Considerations - Appendix

Figure 4.2: PRISM Model Node V/C across the EBNS Study Area



Appendix Chapter 4

4.7 Environmental Considerations - Appendix

Figure 4.3: Journey Times for the A452 Birmingham Airport to Brownhill

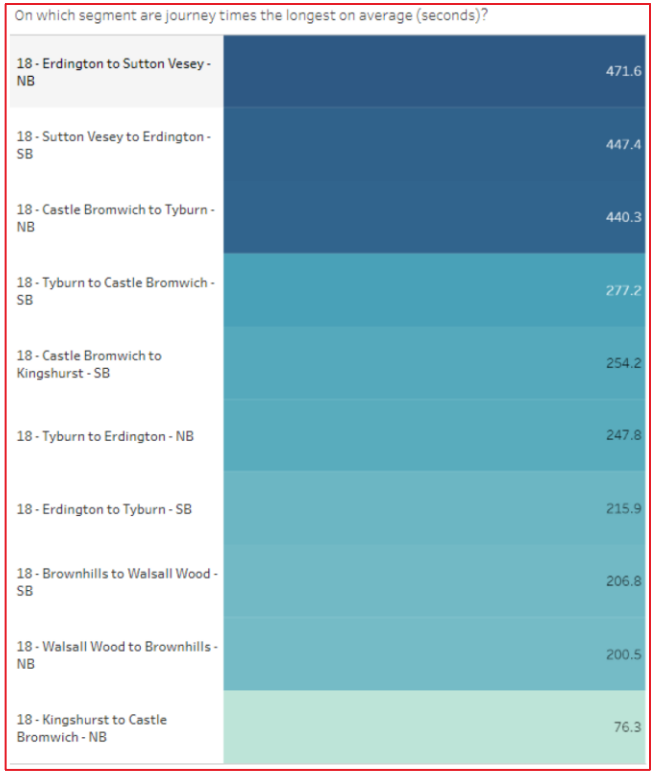


Figure 4.4: Journey Times for the A47 Heartlands Parkway

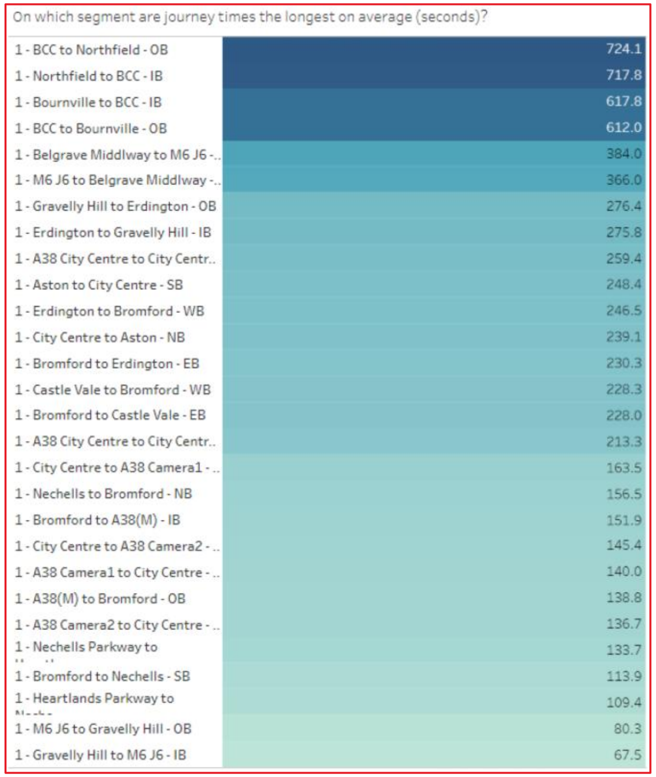
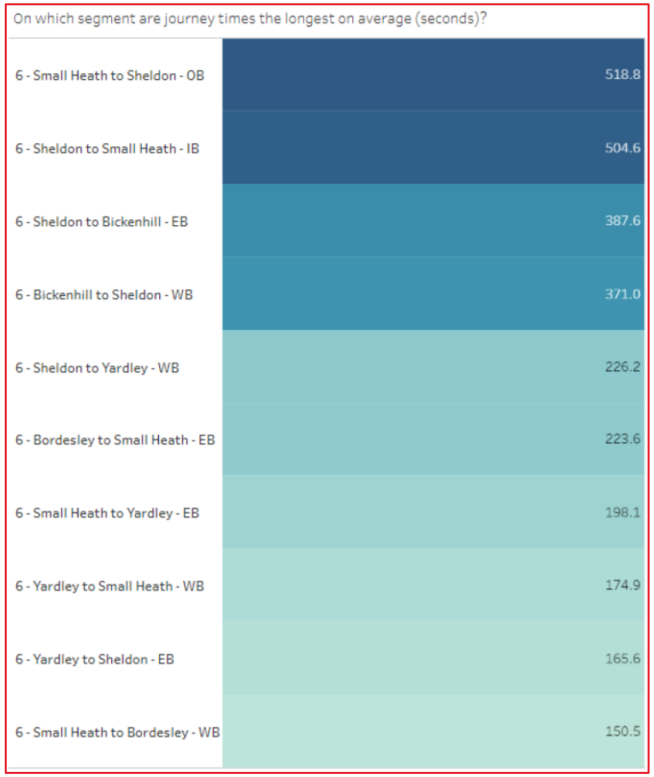


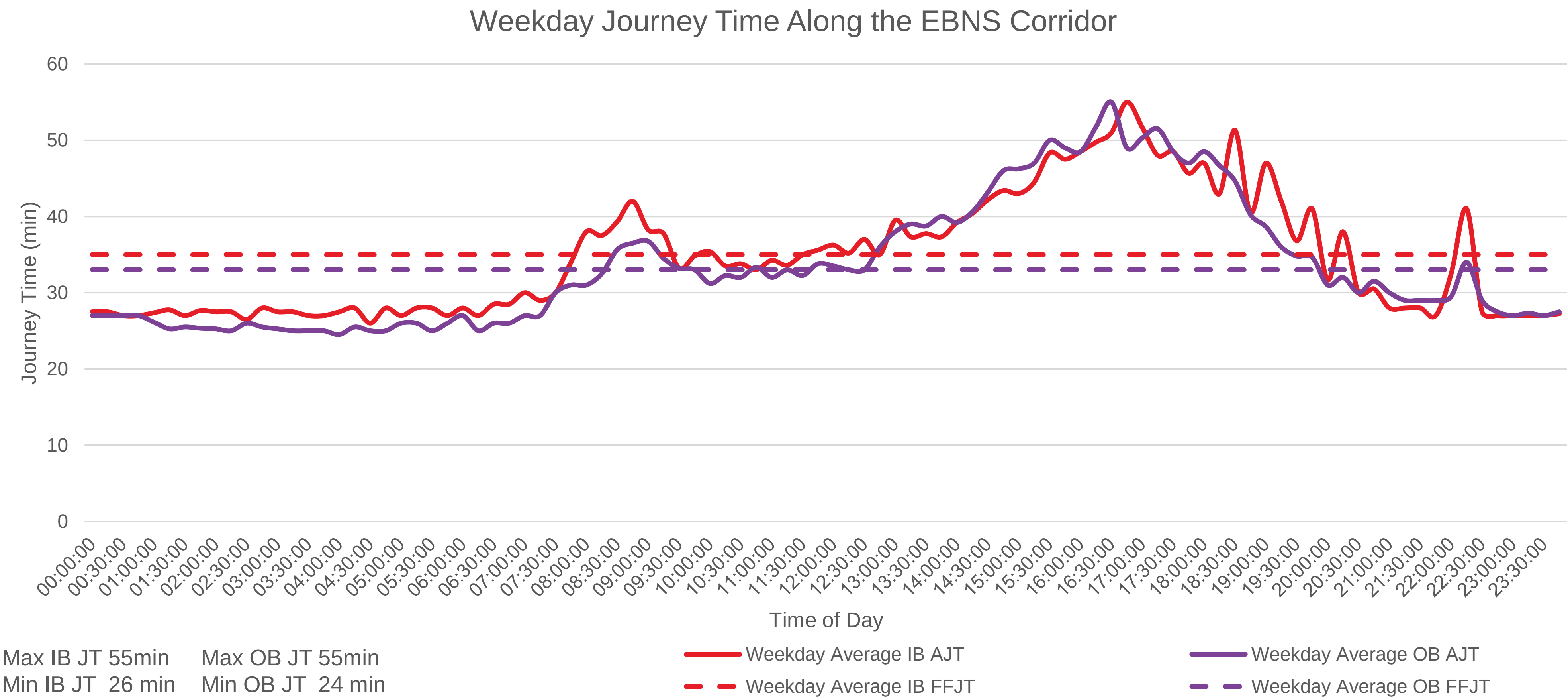
Figure 4.5: Journey Times for the A45 Coventry to Birmingham



Appendix Chapter 4

4.7 Environmental Considerations - Appendix

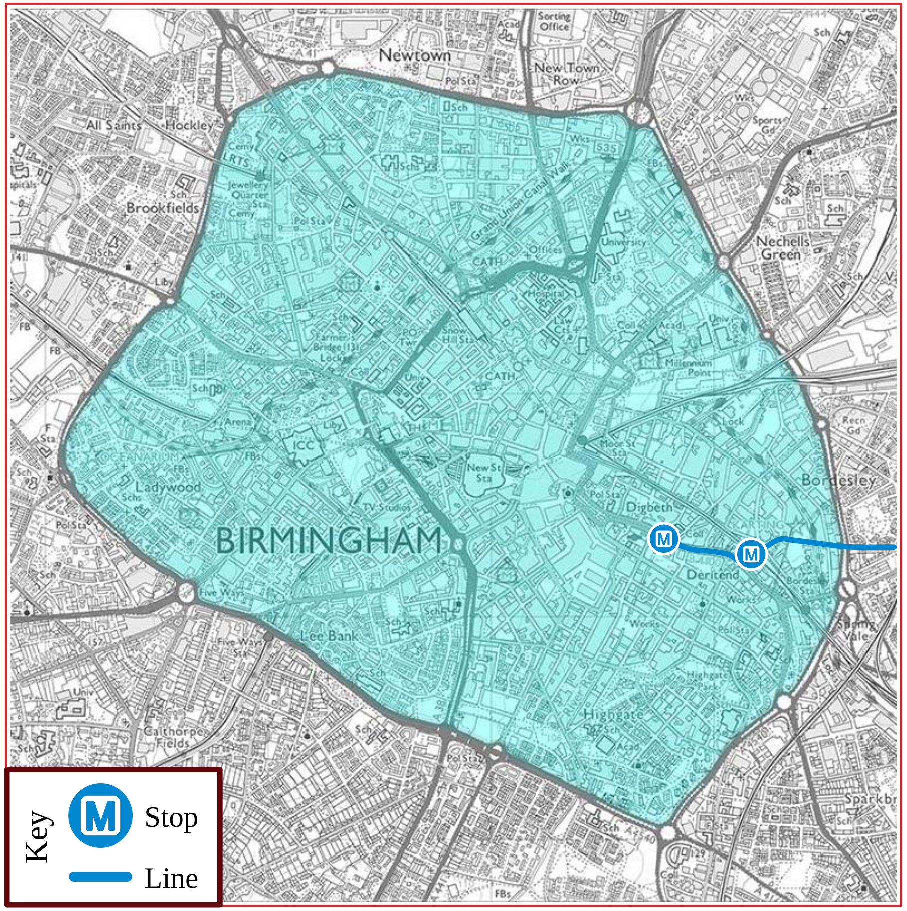
Chart 4.2: Weekday average journey times along the EBNS Corridor



Appendix Chapter 4

4.7 Environmental Considerations - Appendix

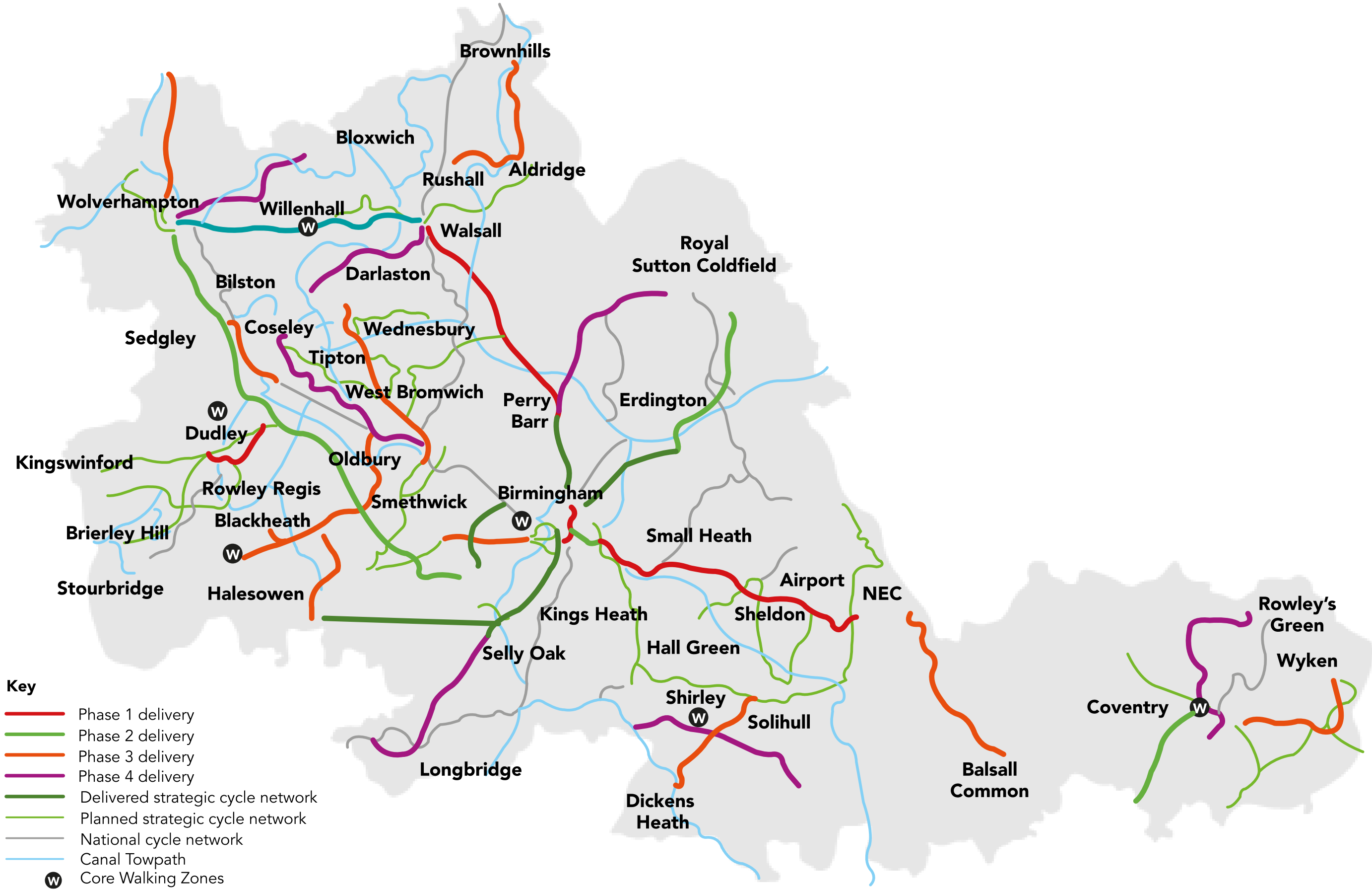
Figure 4.6: Map of the Birmingham Clean Air Zone (CAZ)



Appendix Chapter 4

4.8 Future Transport Proposals - Appendix

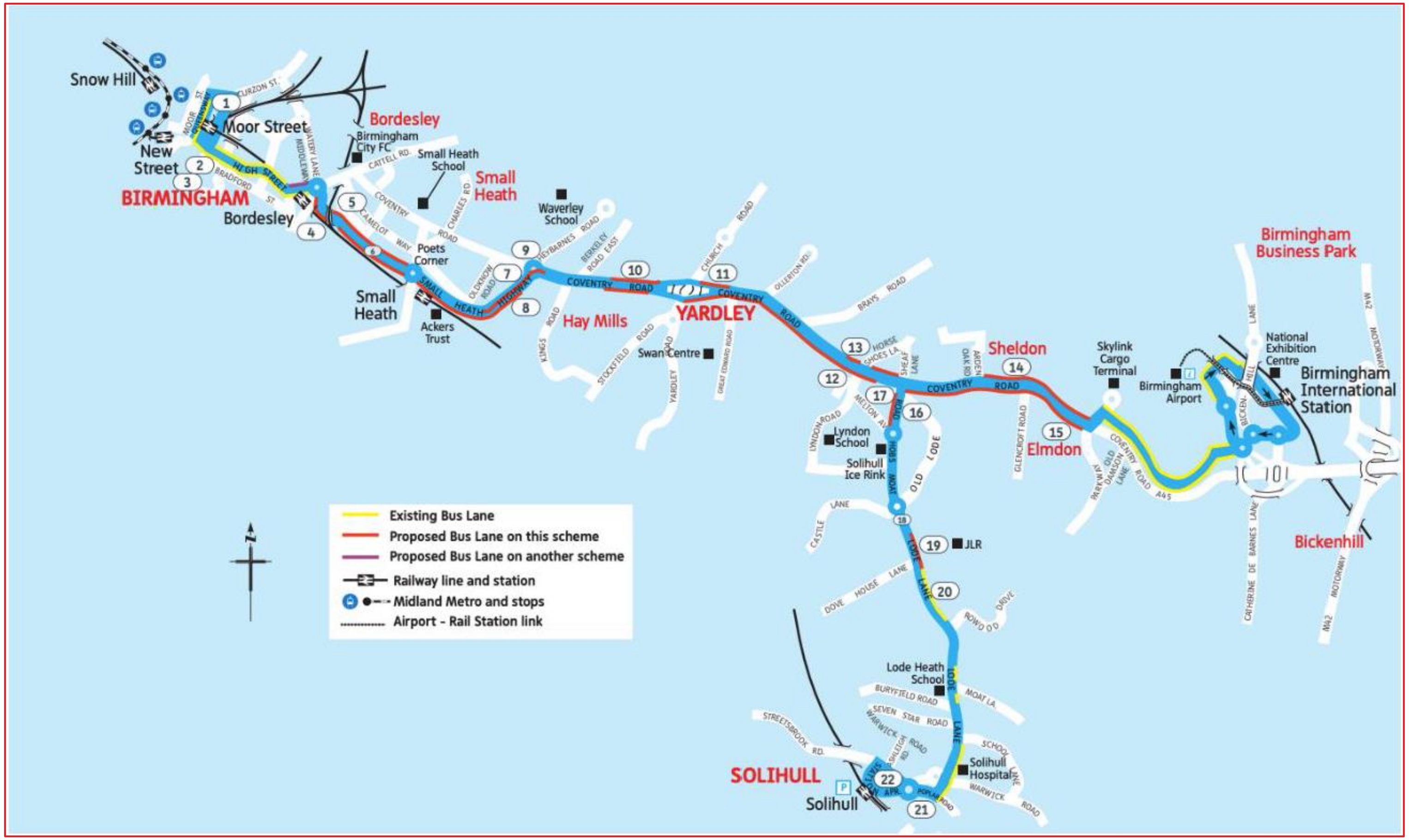
Figure 4.7: Proposed Priority Cycle Corridors and Routes. Source: West Midlands Combined Authority, LCWIP 2019



Appendix Chapter 4

4.8 Future Transport Proposals - Appendix

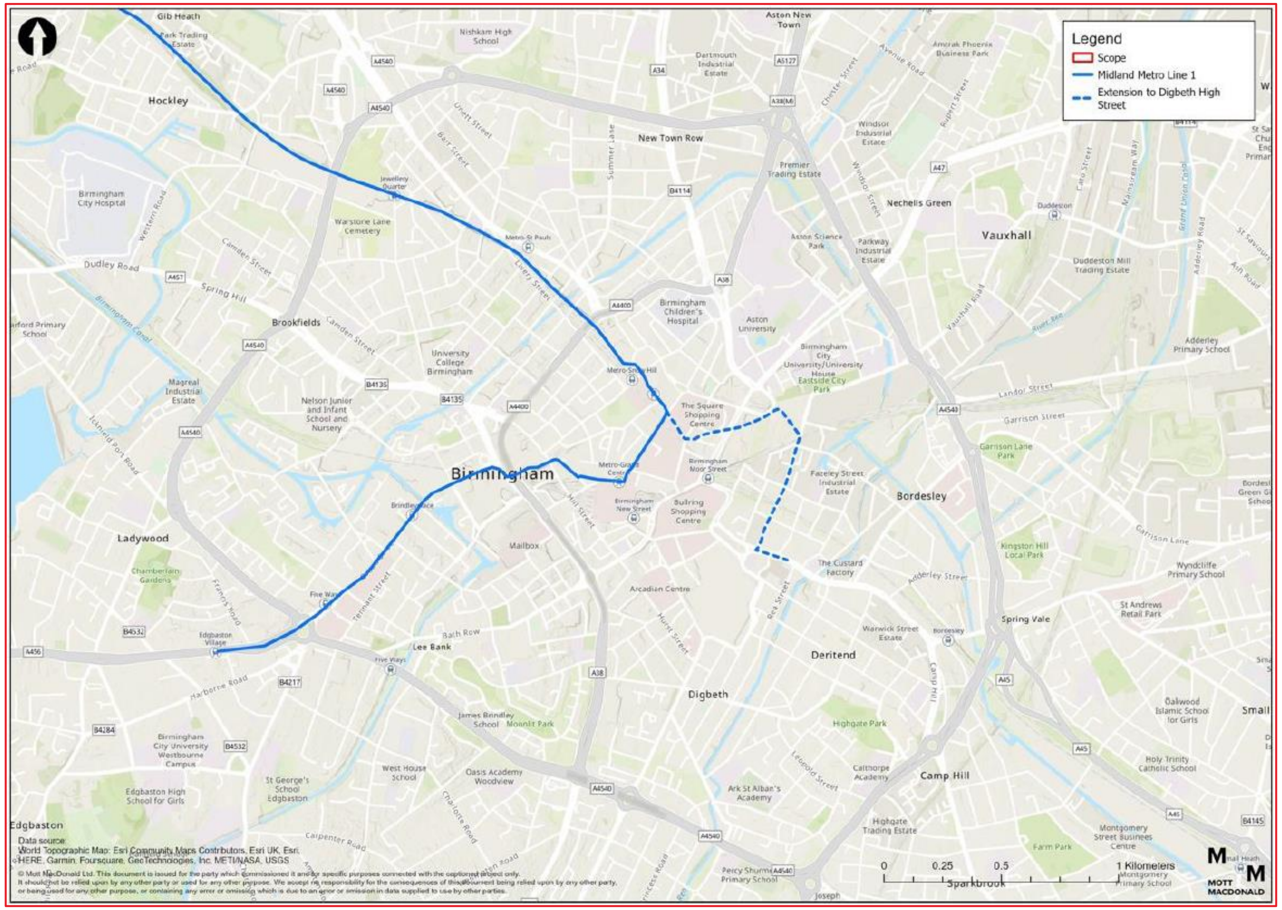
Figure 4.8: Sprint Phase Two map. Source: Sprint public transport routes consultation - Transport for West Midlands



Appendix Chapter 4

4.8 Future Transport Proposals - Appendix

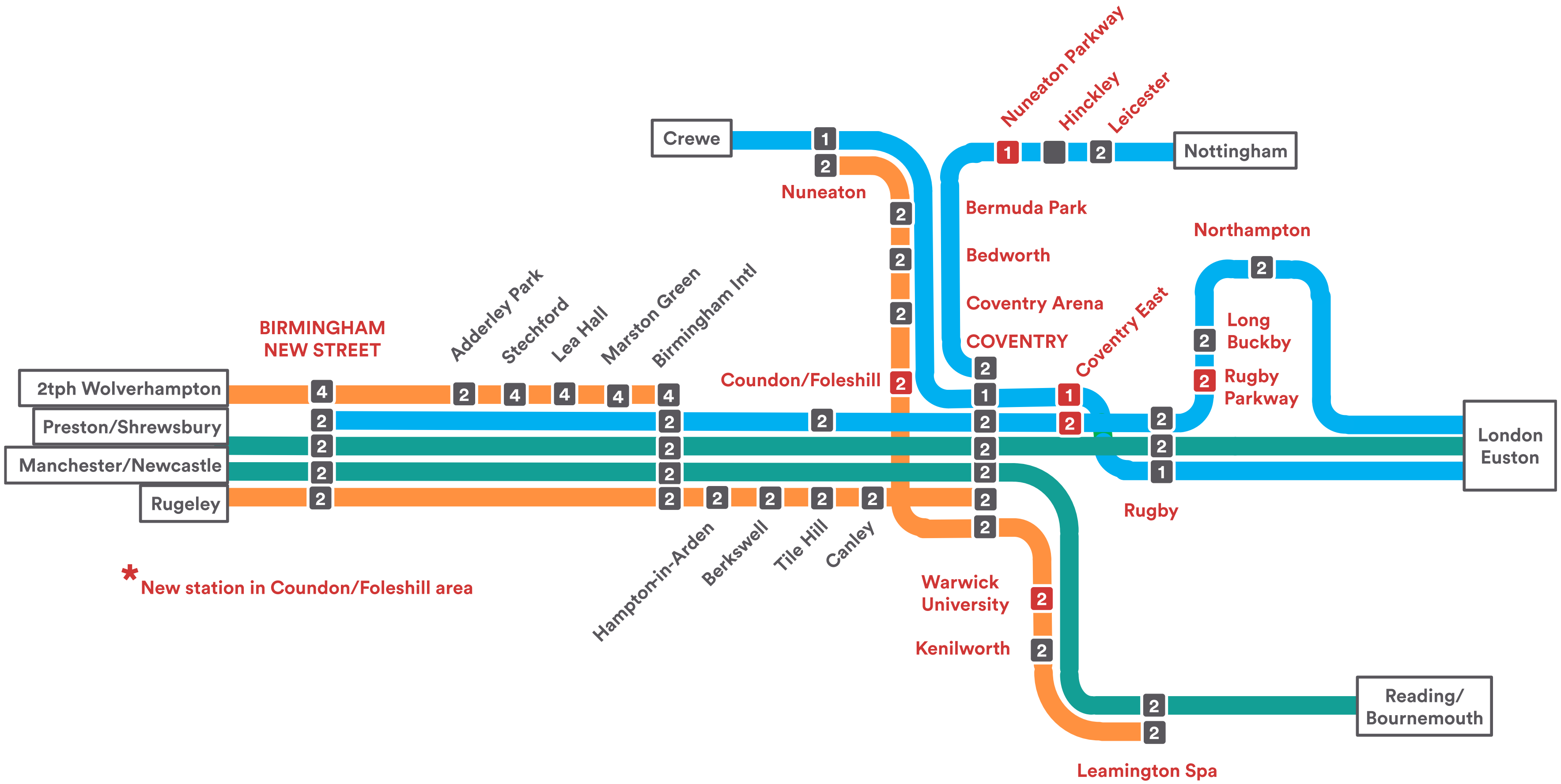
Figure 4.9: West Midlands Metro extension to Digbeth High Street. Source: Mott MacDonald, based on Midland Metro Alliance and TfWM data



Appendix Chapter 4

4.8 Future Transport Proposals - Appendix

Figure 4.10: 2040 Indicative Rail Service Pattern Source: West Midlands Rail Executive



Appendix Chapter 4

4.8 Future Transport Proposals - Appendix

Figure 4.11: HS2 Phase 1 Route Source: OpenStreetMap contributors, CC0, via Wikimedia Commons

Appendix Chapter 4

4.8 Future Transport Proposals - Appendix

Figure 4.12: West Midlands Rail Investment Strategy Network Map Source: West Midlands Rail Investment Strategy

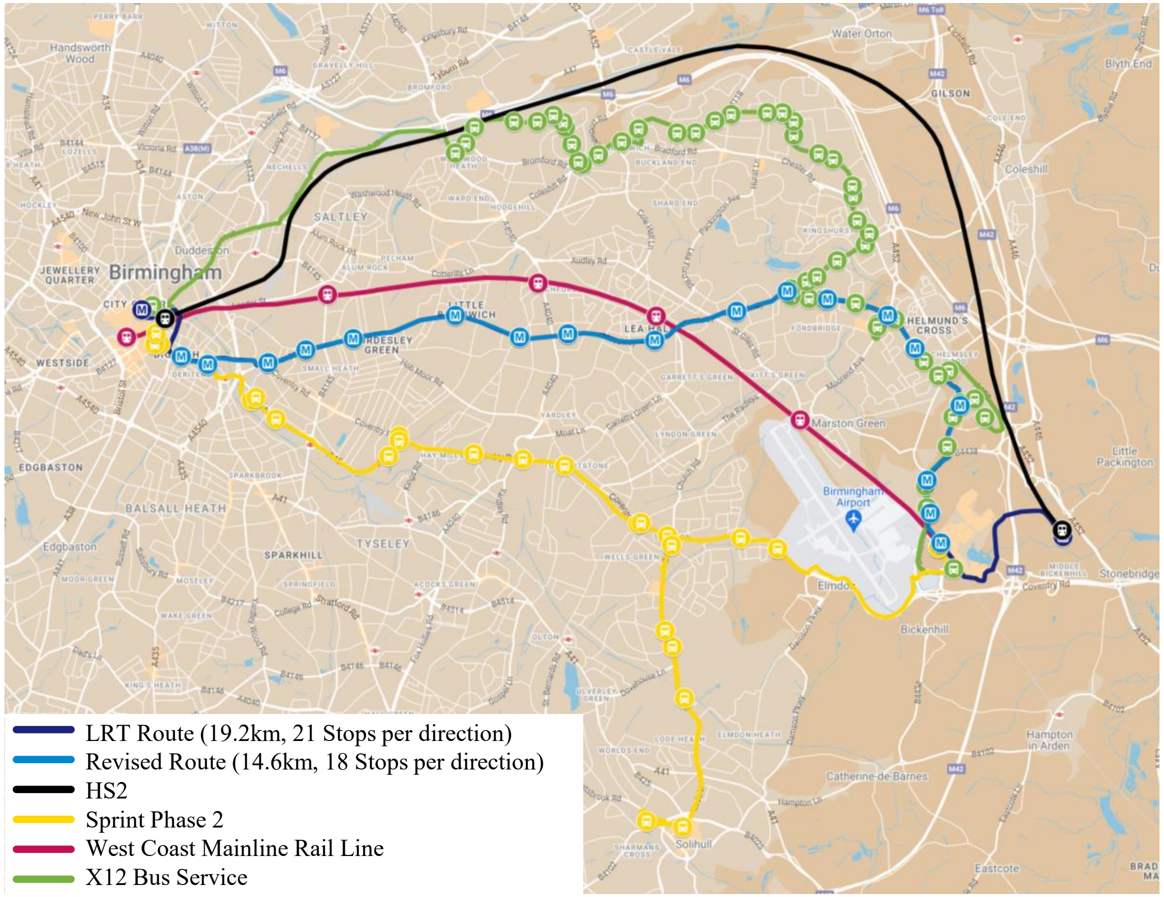
Appendix - Chapter 5

5.1 Route Option Precedents Appendix
5.3 Automated Technology Overview Appendix
5.4 Segregation solution Appendix
5.6 CAM Route Assessment Appendix

Appendix Chapter 5

5.1 Route Option Precedents Appendix

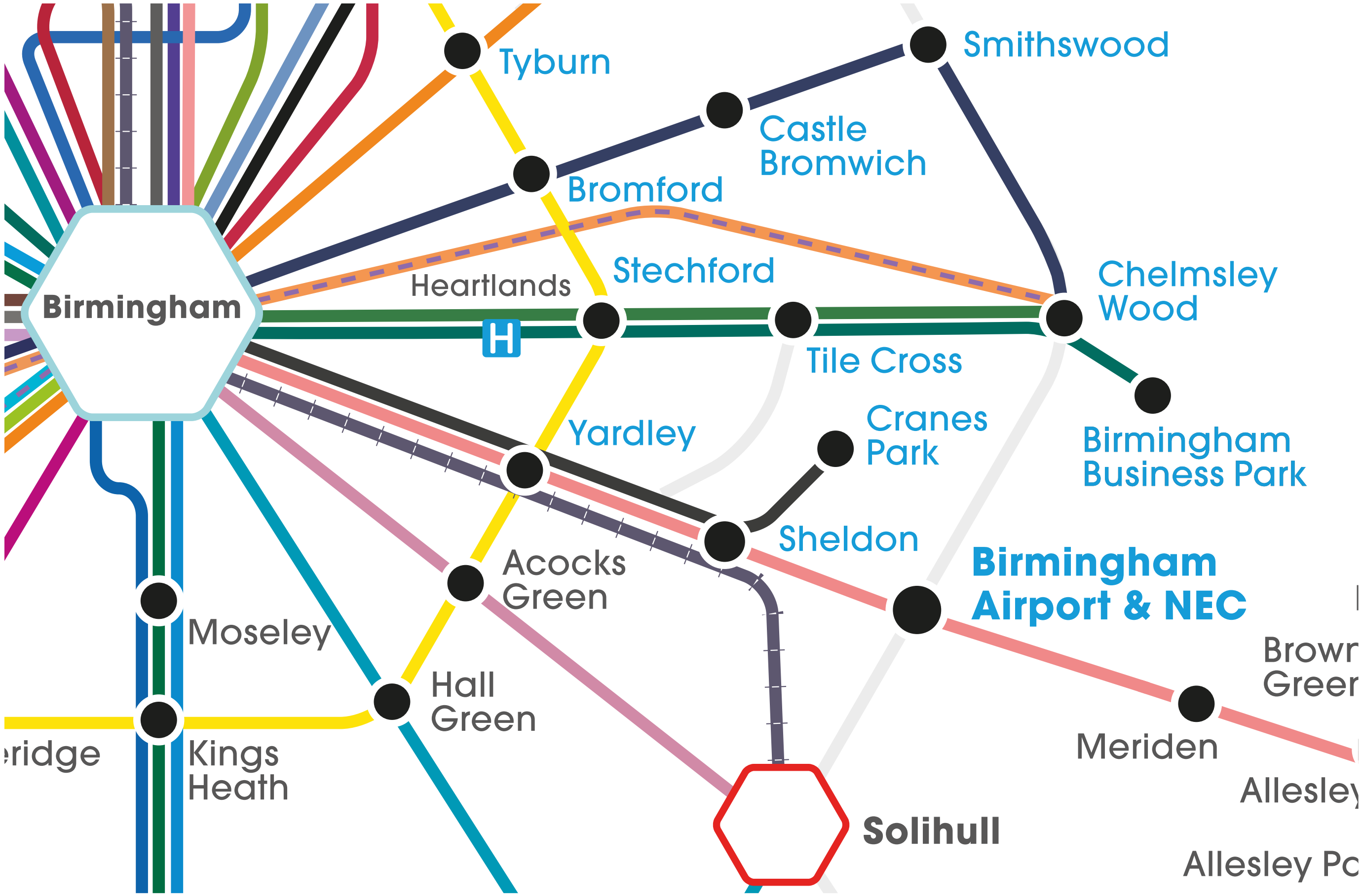
Figure 5.1: Comparison of the originally proposed metro extension route and the revised route considered in this study



Appendix Chapter 5

5.1 Route Option Precedents Appendix

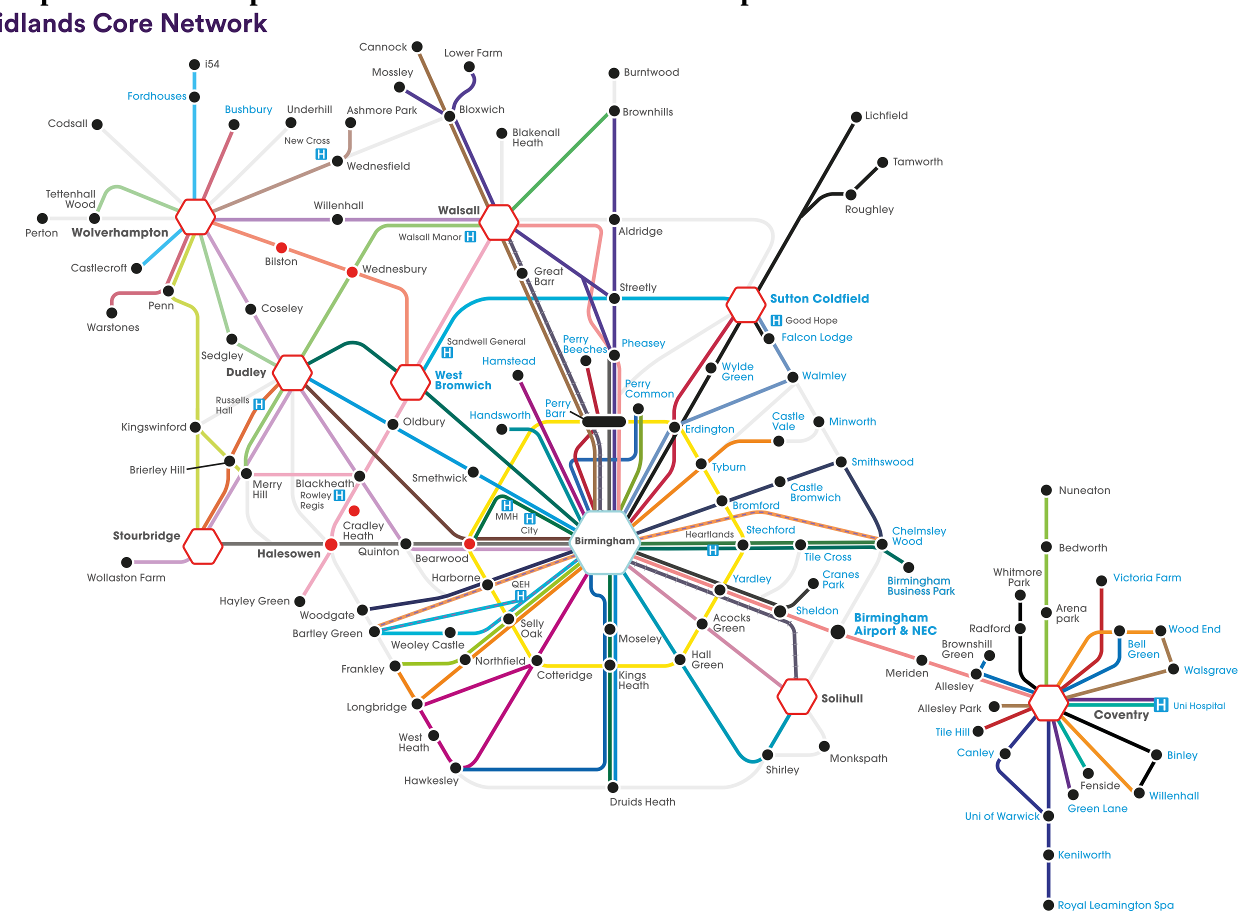
Figure 5.2: Study area network map



Appendix Chapter 5

5.1 Route Option Precedents Appendix

Figure 5.2b: Bus Priority Network Map. Source: Transport for West Midlands Bus Service Improvement Plan 2021



Appendix Chapter 5

5.3 Automated Technology Overview Appendix

Personal Rapid Transit (PRT)

Group Rapid Transit (GRT)

Appendix Chapter 5

5.3 Automated Technology Overview Appendix

Very Light Rail (VLR)

Connected Automated Mobility (CAM)

Appendix Chapter 5

5.3 Automated Technology Overview Appendix

Automated People Mover (APM)

Autonomous Rail Transit (ART / "Trackless Trams")

Appendix Chapter 5

5.3 Alternative Technology Overview Appendix

Automated Light Metro (ALM)

Appendix Chapter 5

5.4 Segregation solution Appendix

Figure 5.4a: EBNS Route Section 1 Satellite Image

Appendix Chapter 5

5.4 Segregation solution Appendix

Figure 5.4b: EBNS Route Section 2 Satellite Image and Street Level View

Appendix Chapter 5

5.4 Segregation solution Appendix

Figure 5.4c: EBNS Route Section 4 Satellite Image and Street Level View

Appendix Chapter 5

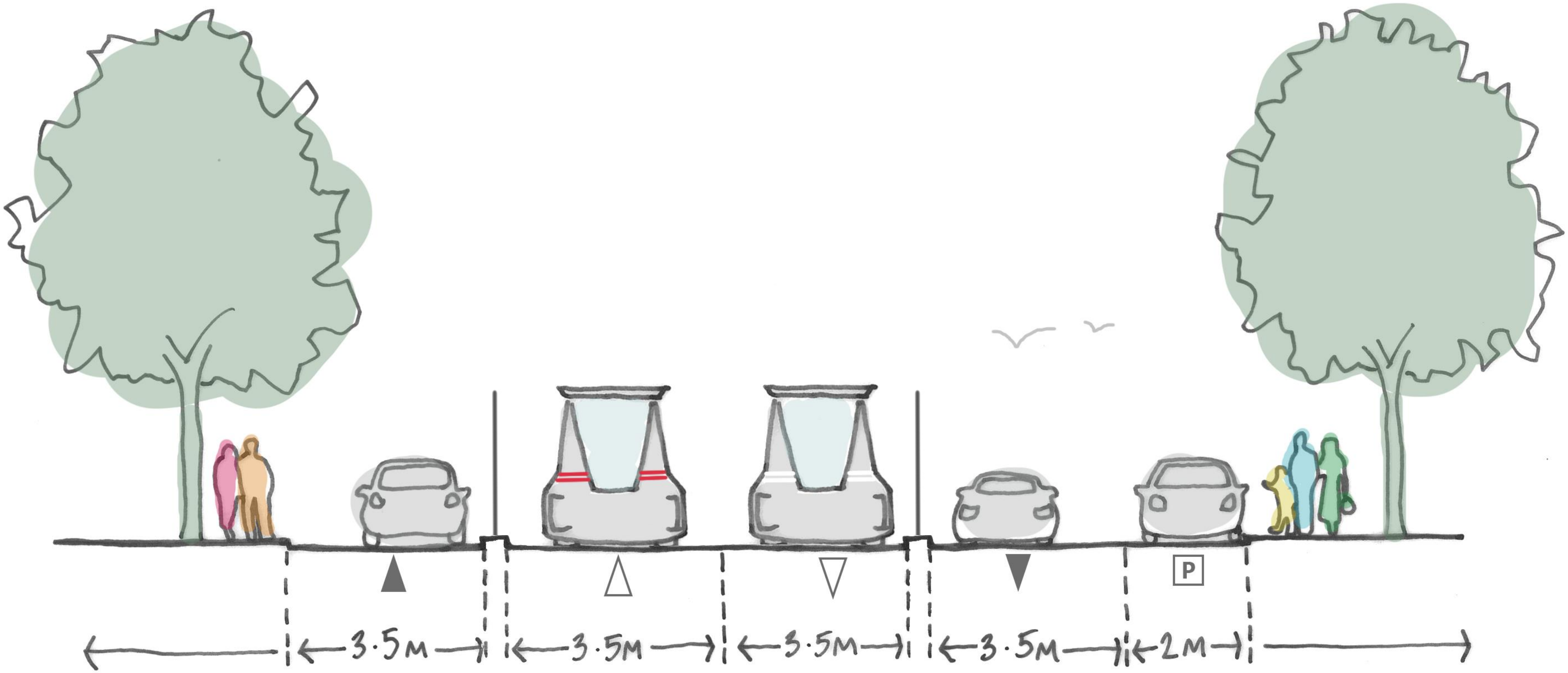
5.4 Segregation solution Appendix

Figure 5.4d: EBNS Route Section 14 Satellite Image and Street Level View

Appendix Chapter 5

5.4 Segregation solution Appendix

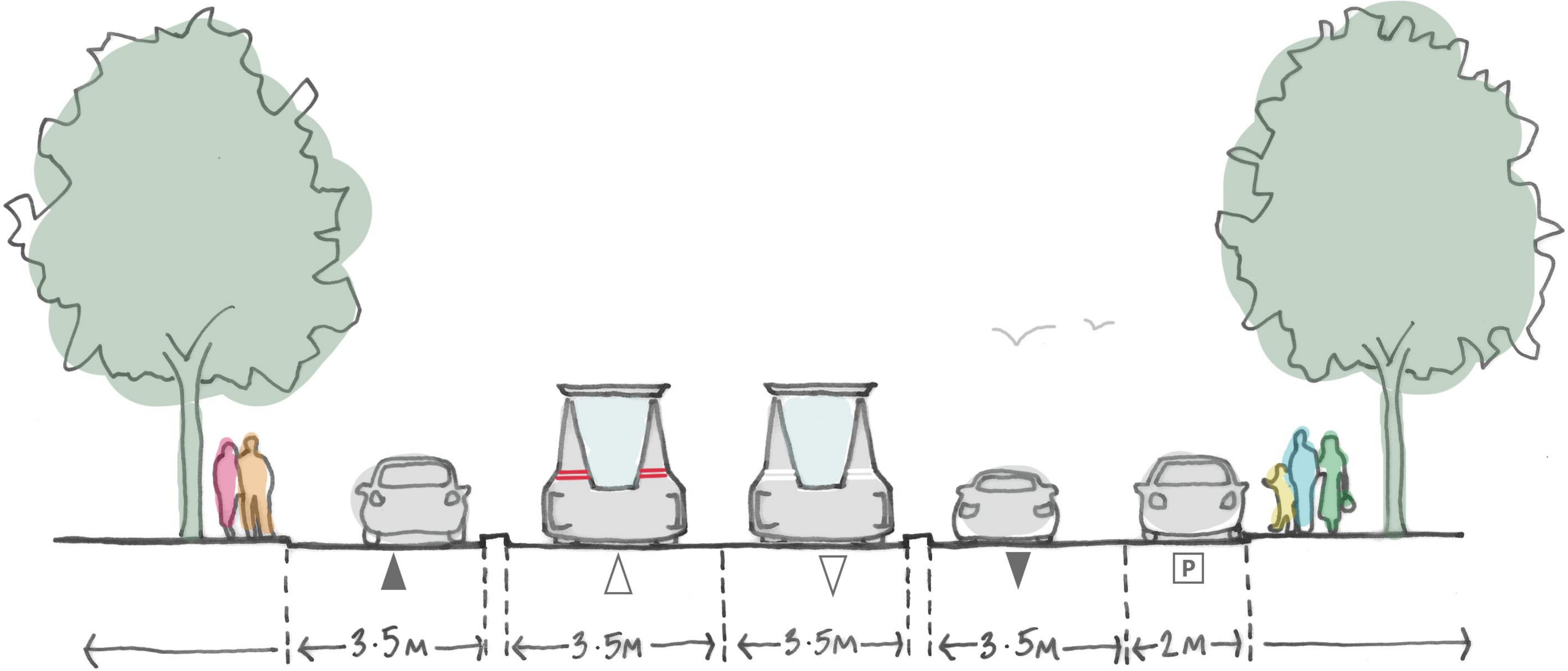
Figure 5.5a: CAM Shuttle Corridor Cross Section



Appendix Chapter 5

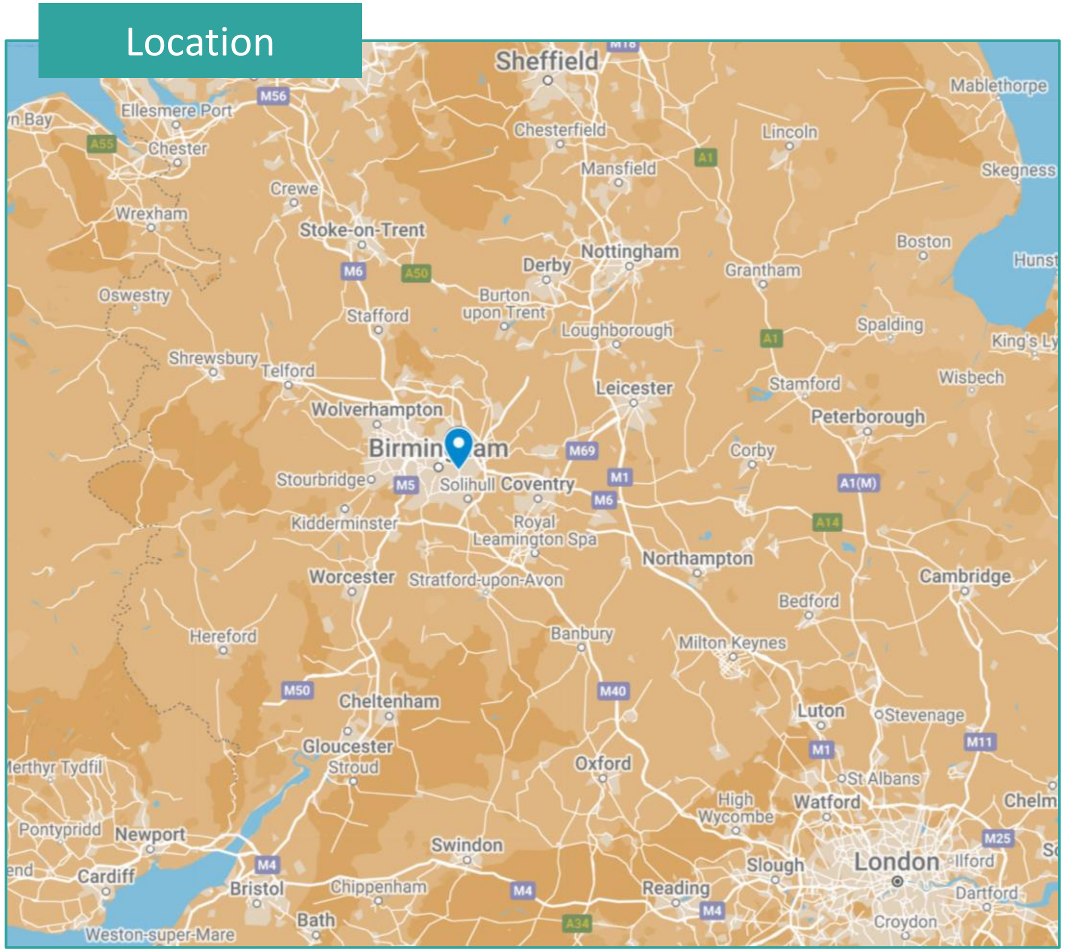
5.4 Segregation solution Appendix

Figure 5.5b: CAM Shuttle Corridor Cross Section



Appendix Chapter 5

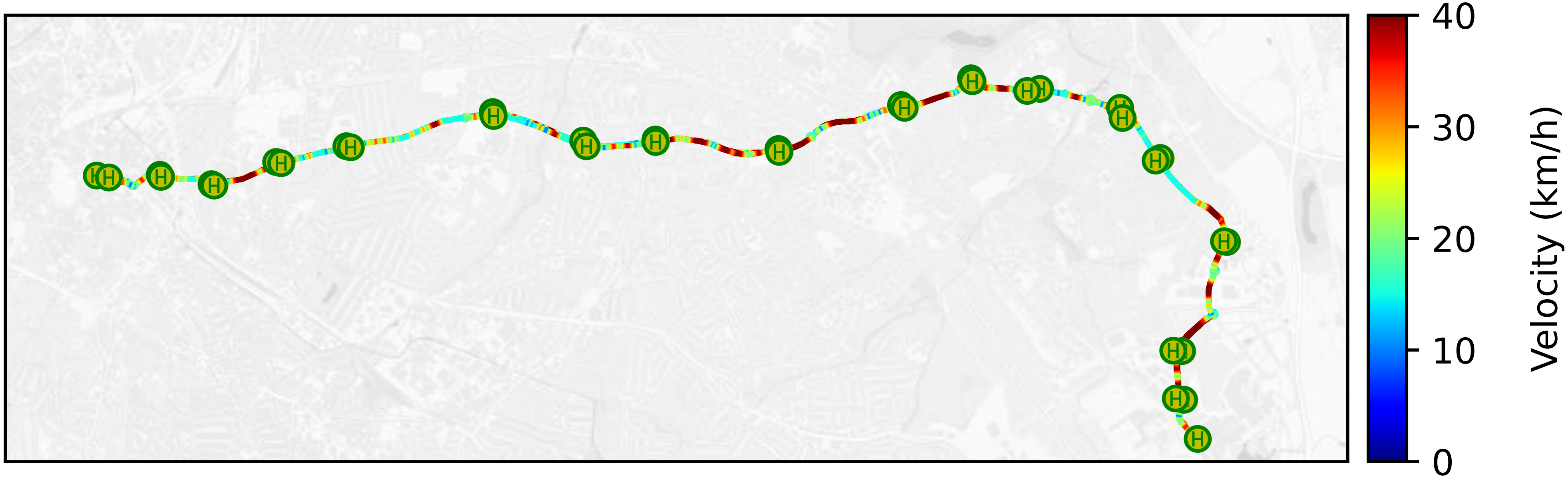
5.6 CAM Route Assessment Appendix



Appendix Chapter 5

5.6 CAM Route Assessment – Velocity Profile Appendix

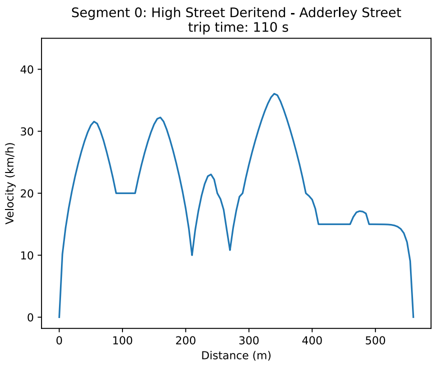
Velocity profile

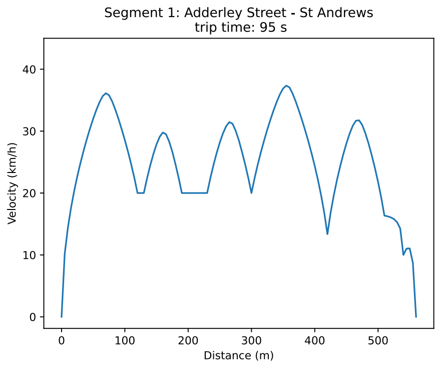


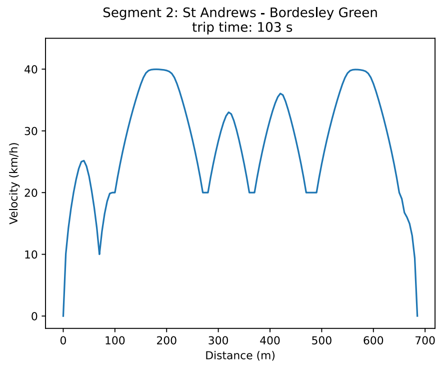
Appendix Chapter 5

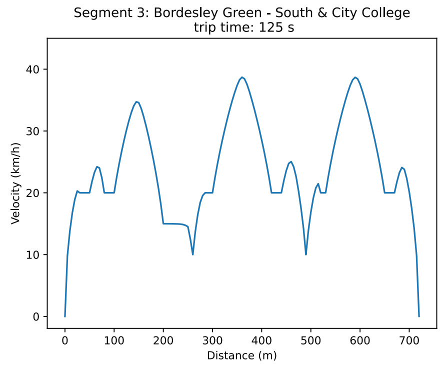
5.6 CAM Route Assessment – Velocity Profile Appendix

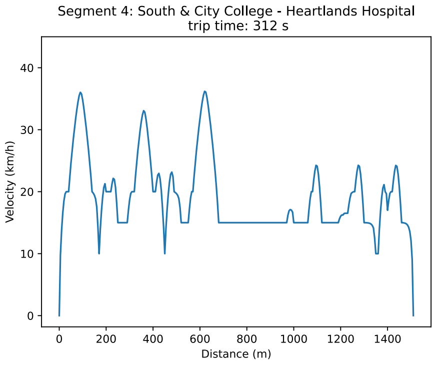
The following charts show the velocity profiles for each segment of the route

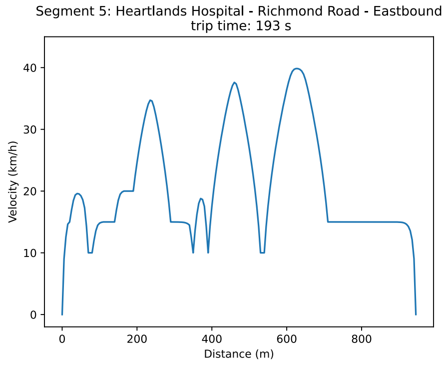


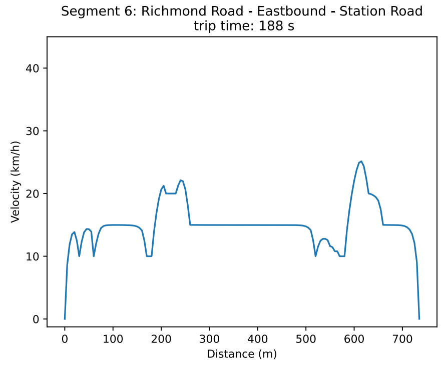


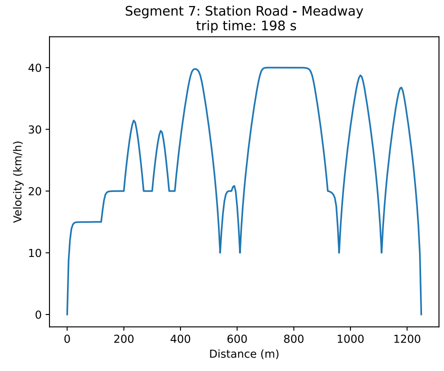








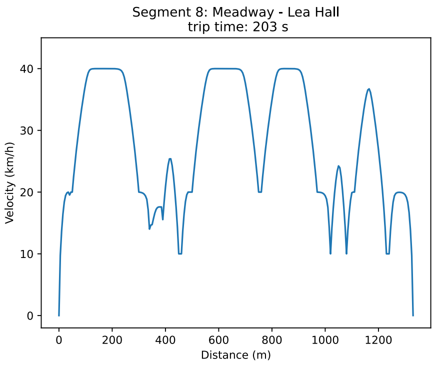


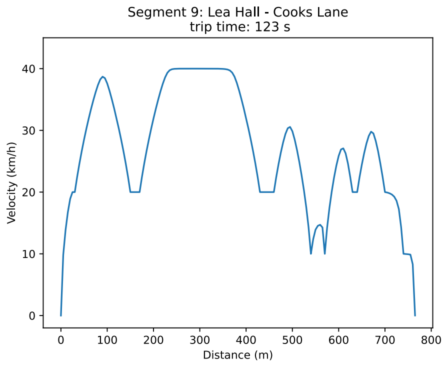


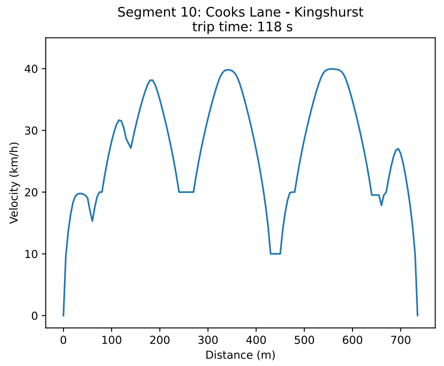
Appendix Chapter 5

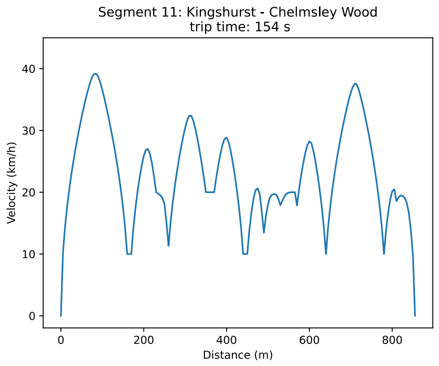
5.6 CAM Route Assessment – Velocity Profile Appendix

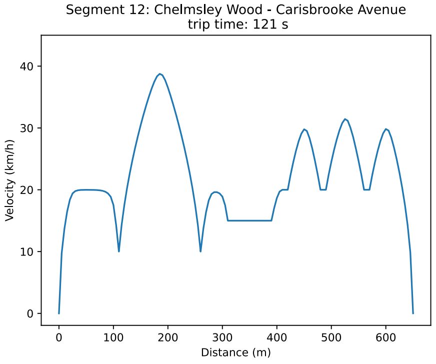
The following charts show the velocity profiles for each segment of the route

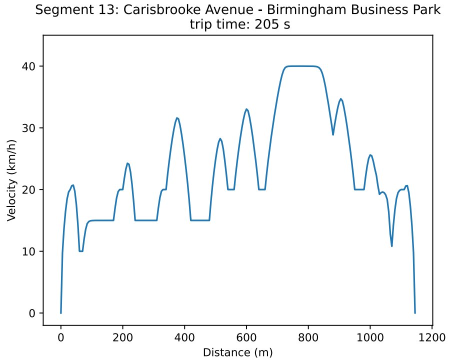


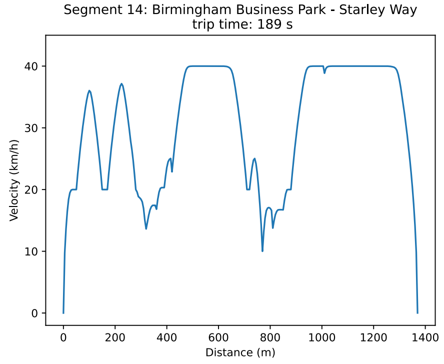


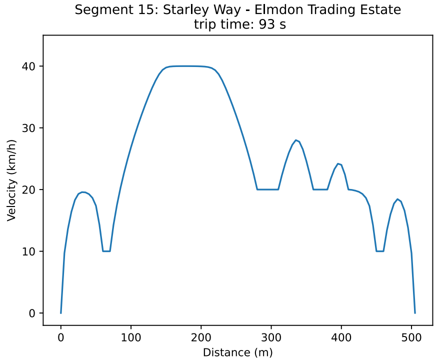








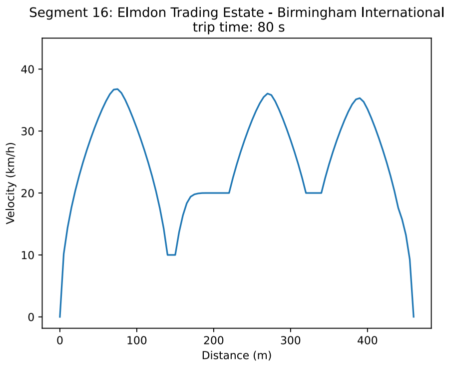


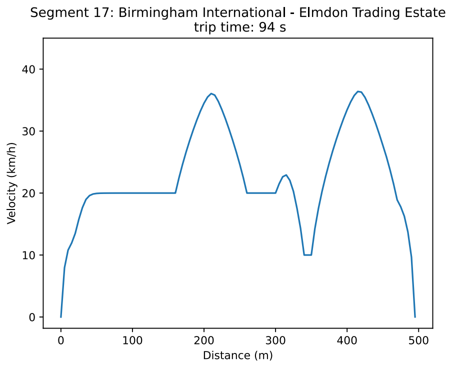


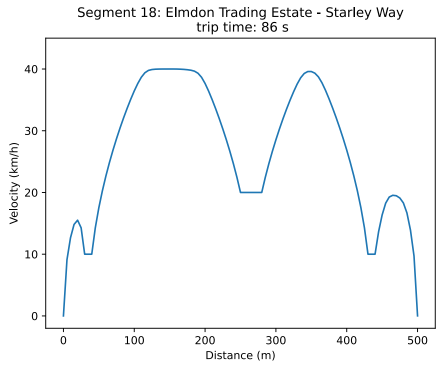
Appendix Chapter 5

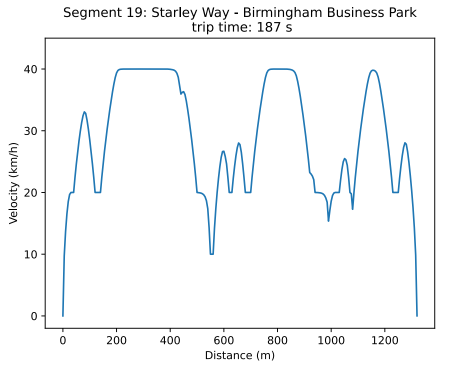
5.6 CAM Route Assessment – Velocity Profile Appendix

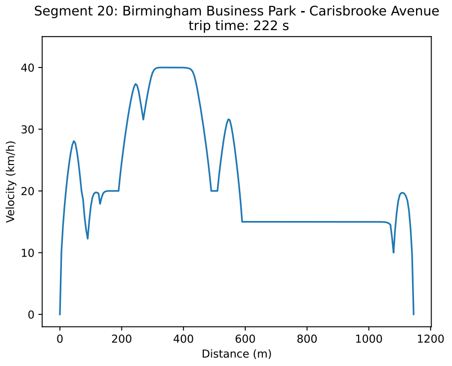
The following charts show the velocity profiles for each segment of the route

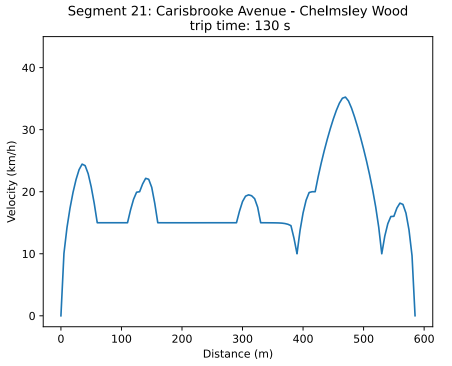


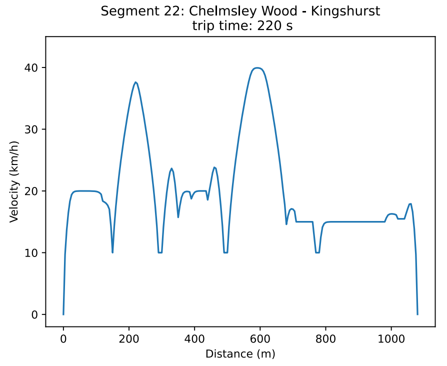


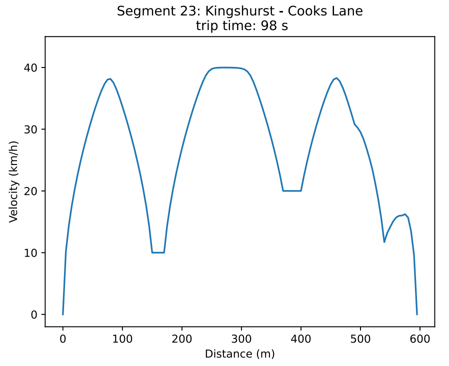








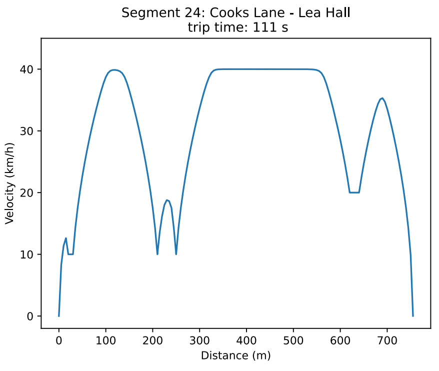


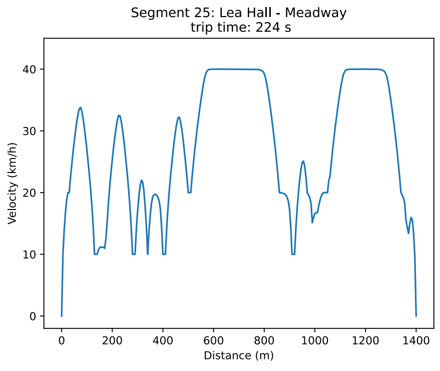


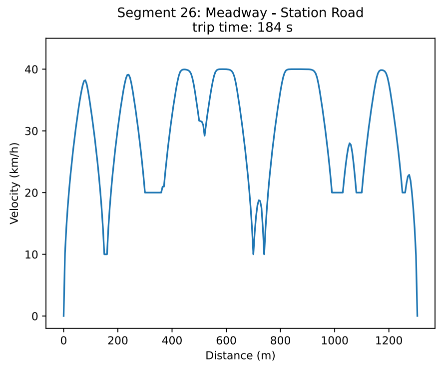
Appendix Chapter 5

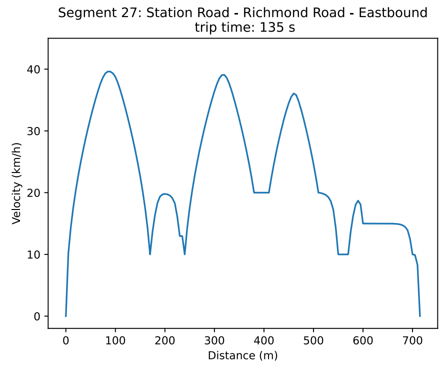
5.6 CAM Route Assessment – Velocity Profile Appendix

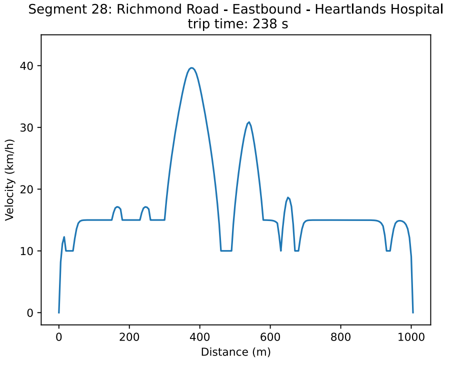
The following charts show the velocity profiles for each segment of the route

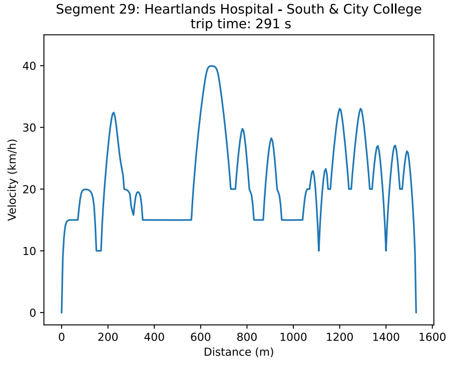


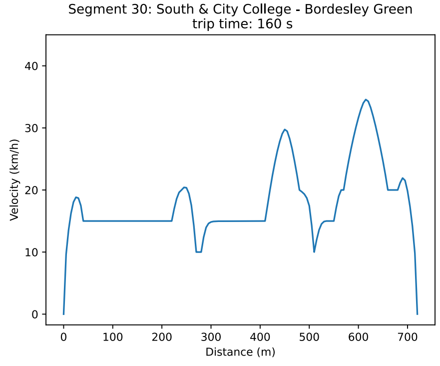


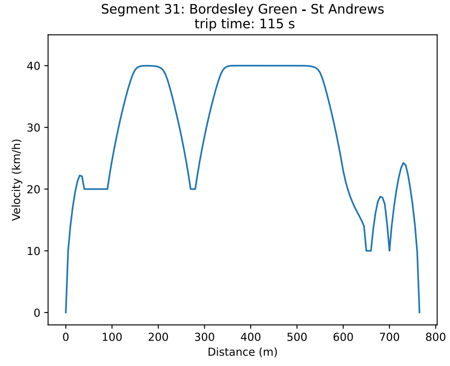








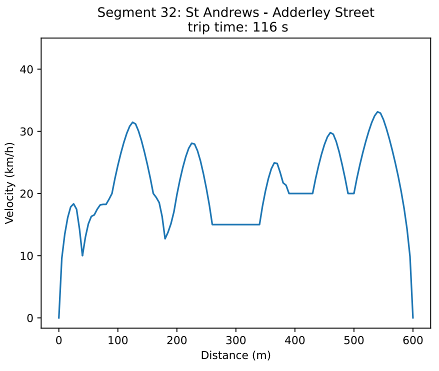


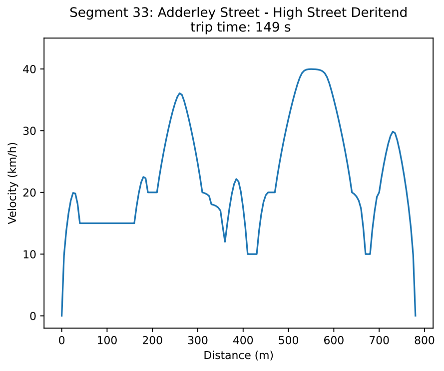


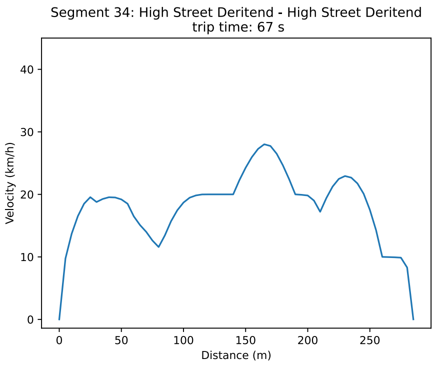
Appendix Chapter 5

5.6 CAM Route Assessment – Velocity Profile Appendix

The following charts show the velocity profiles for each segment of the route







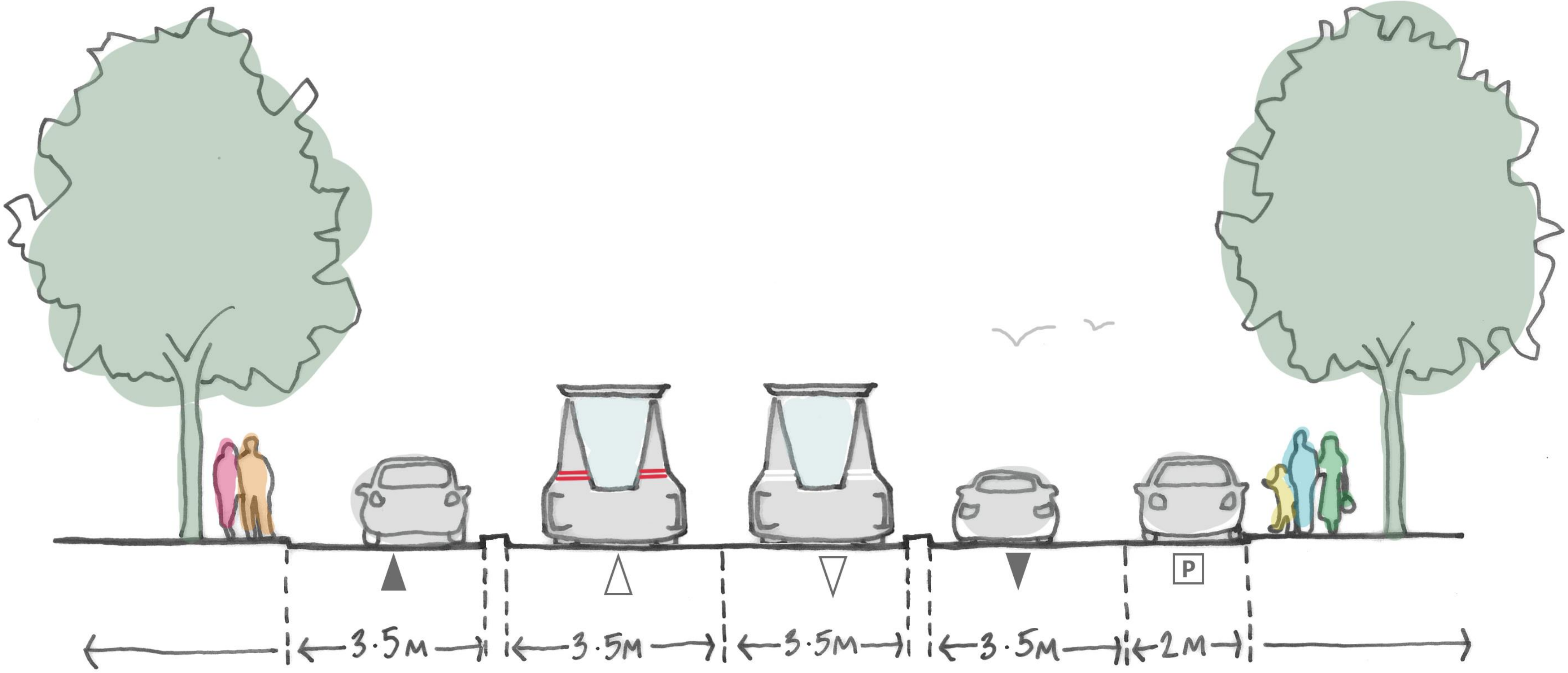
Appendix - Chapter 6

6.1 Route Description and Cost Appraisal Appendix

Appendix Chapter 6

6.1 Route Description and Cost Appraisal Appendix

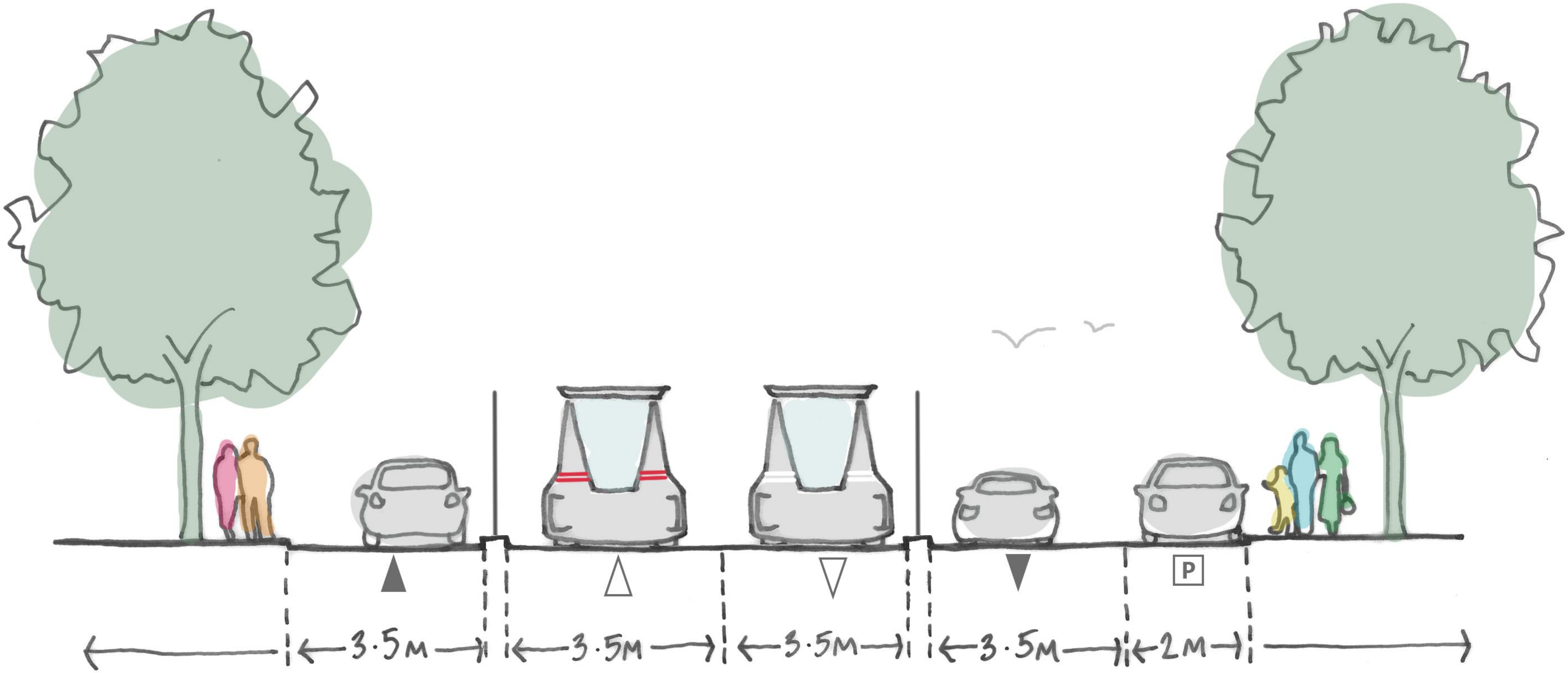
Figure 6.1a: Typical CAM Shuttle Corridor Cross Section



Appendix Chapter 6

6.1 Route Description and Cost Appraisal Appendix

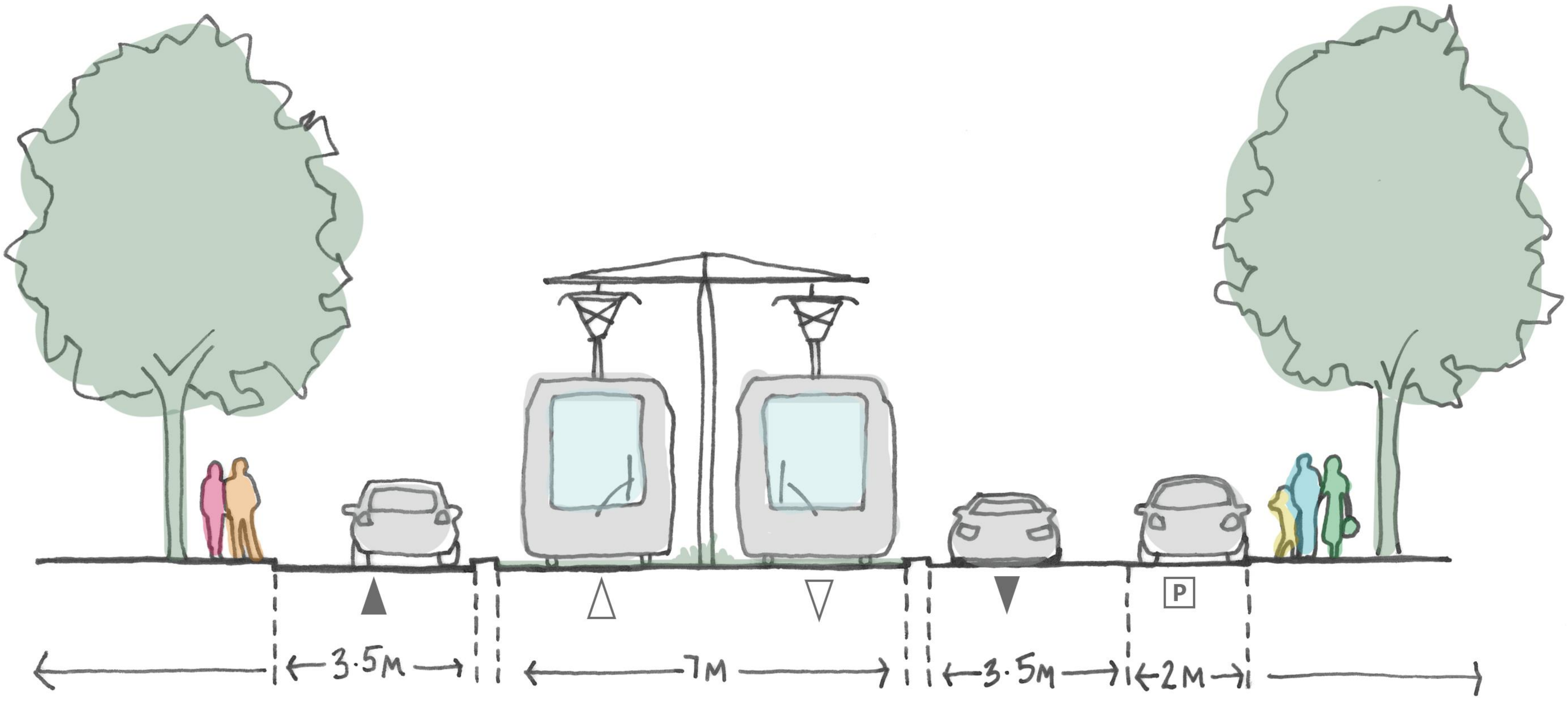
Figure 6.1b: Typical CAM Shuttle Corridor Cross Section – Full segregation



Appendix Chapter 6

6.1 Route Description and Cost Appraisal Appendix

Figure 6.1c: LRT proposals



Appendix - Chapter 9

9.7 Public Acceptance and Perception Public Acceptance and Perception

Appendix Chapter 9

9.7 Public Acceptance and Perception

Figure 9.3: Comments made by respondents related to why they won't use automated vehicles

Appendix Chapter 9

9.7 Public Acceptance and Perception

Chart 9.1: Reasons for opinions on CAM solutions Self-Driving Buses