The potential introduction of trams to Bath

Initial evidence-based study

October 2017

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Bath Tram Study

Use the buttons at the top to navigate through this evidence-based study into the potential introduction of trams to Bath.

This document provides:

- An introduction (section 1) which explains the rationale for this scoping study, including the policy context and supportive evidence from campaign groups;
- The strategic evidence (section 2) for introducing a tram system to Bath, including data on traffic demand in order to understand and identify the key corridors within Bath that may provide the greatest benefits from the introduction of a tram;
- The technological aspects (section 3) of trams that need to be taken into consideration, including power systems, minimum road space requirements, minimum turning radii at junctions, maximum gradients, maximum loadings and structural support requirements, track construction, depot requirements, supplier market, safety implications;
- Corridor assessments (section 4) of the key corridors identified from the strategic evidence section. Assessments take into account highway widths, current public transport services/routes, gradient, identification of key growth sites, and consideration of environmental factors; and
- A summary (section 5) which presents the findings of this initial study, and sets out potential next steps in progressing the investigation into a tram for Bath.

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1. Introduction

The West of England Joint Transport Study has identified a Transport Vision that would transform travel behaviour in the city region. This includes an ambitious programme of measures in Bath and North East Somerset, including proposals for mass transit connecting Bristol with Bath.

Building on this, Bath and North East Somerset (BANES) Council wishes to consider the feasibility of introducing trams into Bath. Trams in Bath were not explicitly identified in the recommendations from the Joint Transport Study, but the Council requires consultancy support in assessing whether trams could play a role in helping to meet the future transport needs of the city.

This document takes an evidence-based approach to assessing the key issues in Bath regarding public transport accessibility and demand, to provide an initial overview of how a tram system may assist in improving the city's public transport.

The evidence gathered looks at the need for intervention for a tram in Bath, in relation to travel volumes, demand and purpose for travel into and around Bath. The assessment for a tram in Bath takes into account current car and bus usage in Bath, with a view to complementing walking, cycling and Park & Ride schemes.

A summary of the briefing note from Bath Tram Re-Introduction Group has also been reviewed.

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1.1 Policy context

Bath Transport Strategy

Encouraging sustainable transport and the objective to “reduce the impact of vehicle movements” are key in the strategy, and trams assist in these ambitions – although there is not specific reference to trams.

Joint Local Transport Plan

The section on ‘Future Plan Ideas’ references tram and light rail, however there is no real detail regarding locations, timeline or steps going forward to make this a reality. There is also mention of delivering sustainable transport improvements.

BANES Core Strategy

The Strategy says that “rebalancing the movement and transport systems in favour of pedestrians, cyclists and public transport users” is important, as well as “enabling sustainable transport choices”. It is also cited that congestion is an issue in the city centre and a barrier to public transport use. However, there is not specific reference to trams.

West of England Joint Transport Study

The final report from the Joint Transport Study cites an “ambition for light rail/metro where potential is greatest for high passenger flows”. The strategy proposes other light rail schemes in the region; therefore, any future study might consider the potential integration with a Bath Tram.

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1.2 Supporting documents

Bath Tram Re-Introduction Group Briefing Note to BANES Council, 2015:
A briefing note was prepared by the Bath Tram Re-Introduction Group (BTRG) in 2015 for BANES. It suggests that a consortium could be formed, led by the BTRG, and consisting of First Group, a European Tram Company and BANES. The BTRG suggest that capital costs and set up charges could be taken away from the council, but BANES could still be in charge of issuing the licence to operate.

In the briefing note, the BRTG outlines the key benefits that it considers could be achieved through trams in Bath. These include:

- Fewer cars on the road meaning a reduction in congestion, pollution and noise. Experience from other places shows that drivers are more willing to switch to trams that buses.
- Trams will result in easier and faster movement in and around the city.
- Trams have not been a barrier in other places with World Heritage Site status, in fact trams are tourist attractions in themselves.

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2. Strategic Evidence

This section presents evidence relating to the strategic case for a Bath tram. This includes:

Census Travel to Work data, focusing on car and bus commuting movements into Bath.

Bus accessibility data, analysed and presented using TRACC software, which assesses the connection of areas to Bath city centre in terms of travel times by public transport. The route map for buses connecting to Bath city centre is also included for reference.

Journey purpose data, which has been summarised from Road Side Interview surveys from October 2014. The data was filtered to focus on those journeys with destinations in the centre of Bath.

Traffic volume data, which has been summarised from Highways England count data for 2016.

As a result of the investigation into the strategic evidence for a Bath tram, key corridors which could benefit most from a tram in Bath have been identified. These outline the key origins of demand based on the data reviewed and their broad corridors of travel into Bath. Key routes are then outlined, suggesting the roads within Bath that could be used for a tram system.

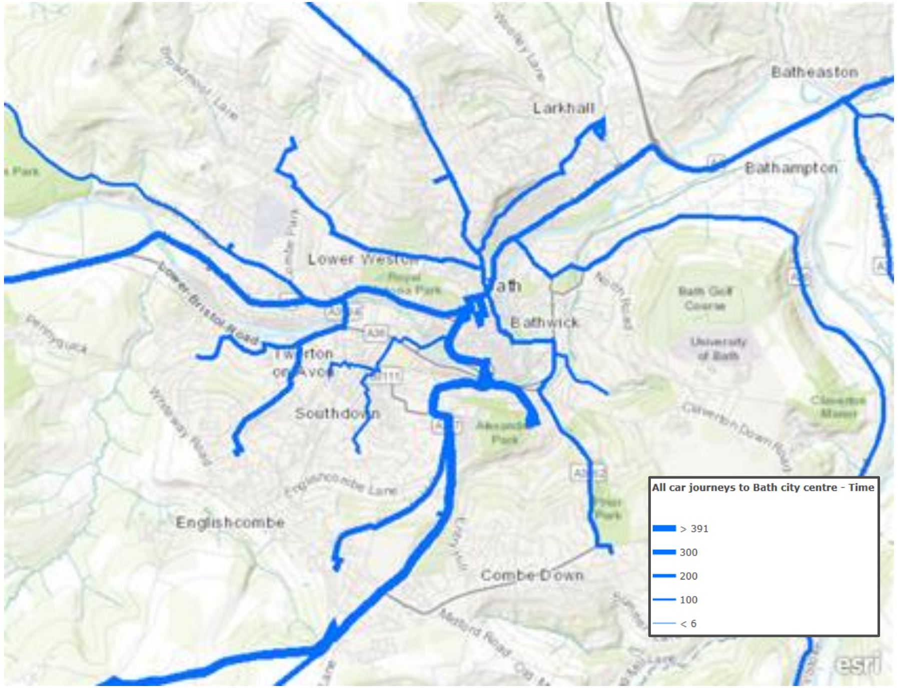
2.1 Commuting into Bath by car

The map shows journeys to work into Bath city centre by car, based on Census 2011 travel to work data. It indicates that the A367 corridor from the south is used most frequently for journeys into Bath for work by car. Other corridors with high levels of car commuting include the A4 both east and west into the city.

It is important to note that these are the optimal corridors for commuters travelling into Bath for work only and does not include those people who travel for other purposes, or through/near Bath for longer distance journeys, which would be expected on the main road network near Bath (e.g. A4, A36, A46).

This map indicates that, during the peak periods, there are significant volumes of car traffic into Bath city centre from origins both inside and outside the city. The car trips from within Bath tend to be from the outer edges of the city, where it is more difficult to walk, cycle or use the bus to reach the city centre.

The car trips from outside Bath are, in many cases, from more rural areas without access to the rail network and with high dependence on travelling by car.



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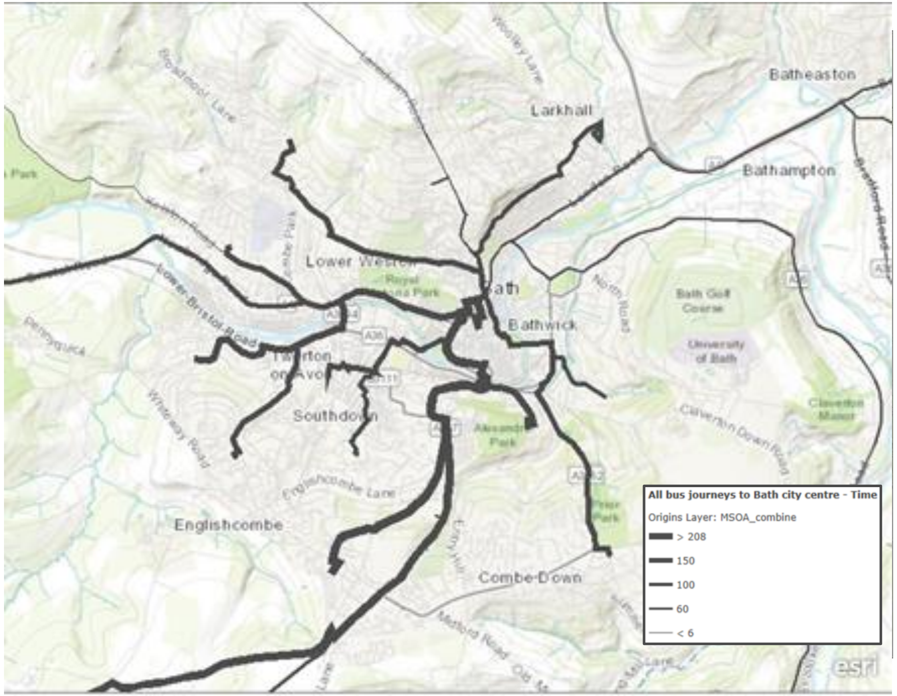
2.2 Commuting into Bath by bus

The map shows the journeys to work into Bath by bus. It indicates that the key corridors used to enter Bath city centre by bus are from the south and west. In particular there is strong bus use on the A367 which connects Bath to towns and villages to the south, including Radstock and Midsomer Norton. There is also strong bus use from the west on the A4, A431 and Weston Road.

It is important to note that these are the optimal corridors for commuters travelling into Bath for work only, and does not include those people who travel for other purposes.

This map indicates that, during the peak periods, people travel by bus from origins both inside and outside the city. Bus trips from within Bath tend to be from the outer parts of the city, where it is more difficult to walk or cycle to reach the city centre.

The bus trips from outside Bath are focused on key corridors with more frequent services. There are relatively small numbers of people commuting by bus from the east. The relatively poor public transport choices from the east appear to be one of the causes of the high traffic flows on the A4 London Road into the city.



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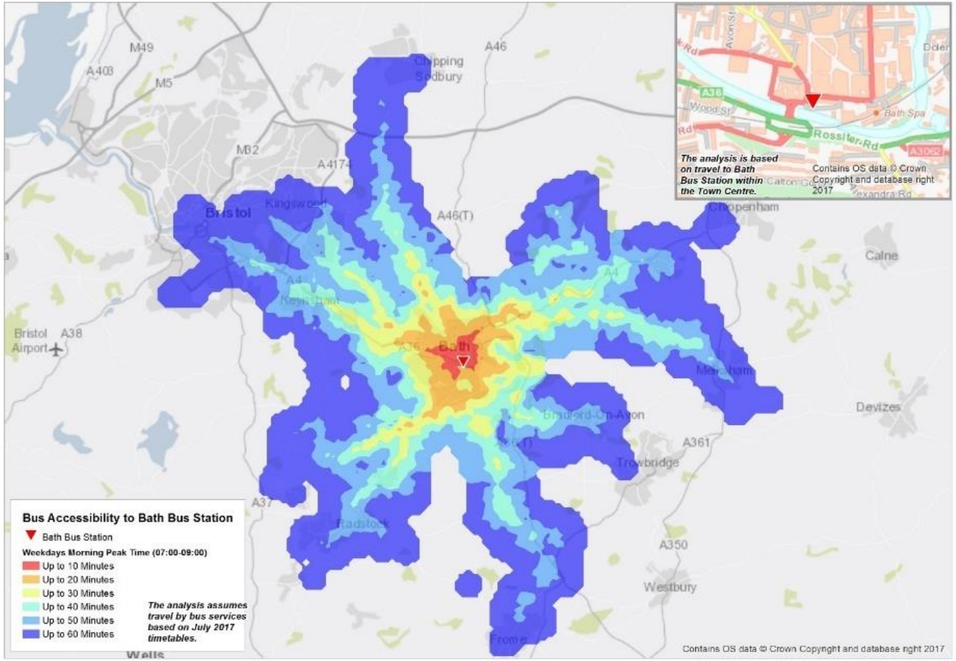
2.3 Bus accessibility

Bus accessibility data was analysed using the TRACC software tool. This tool analyses how long it takes to reach a certain point (in this case Bath Bus Station in the city centre) from the surrounding area, and maps this in time bands (of up to 60 minutes) to present accessibility to the centre by bus.

This was analysed using the morning peak, which is when the greatest number of buses would be expected to be available.

The map shows that Bath is generally accessible within 60 minutes to nearby cities and towns, such as Bristol, Bradford-on-Avon, Chippenham, Melksham, Radstock and Yate. However there are gaps in coverage, such as directly north to the M4, and also to the east towards Trowbridge and Westbury.

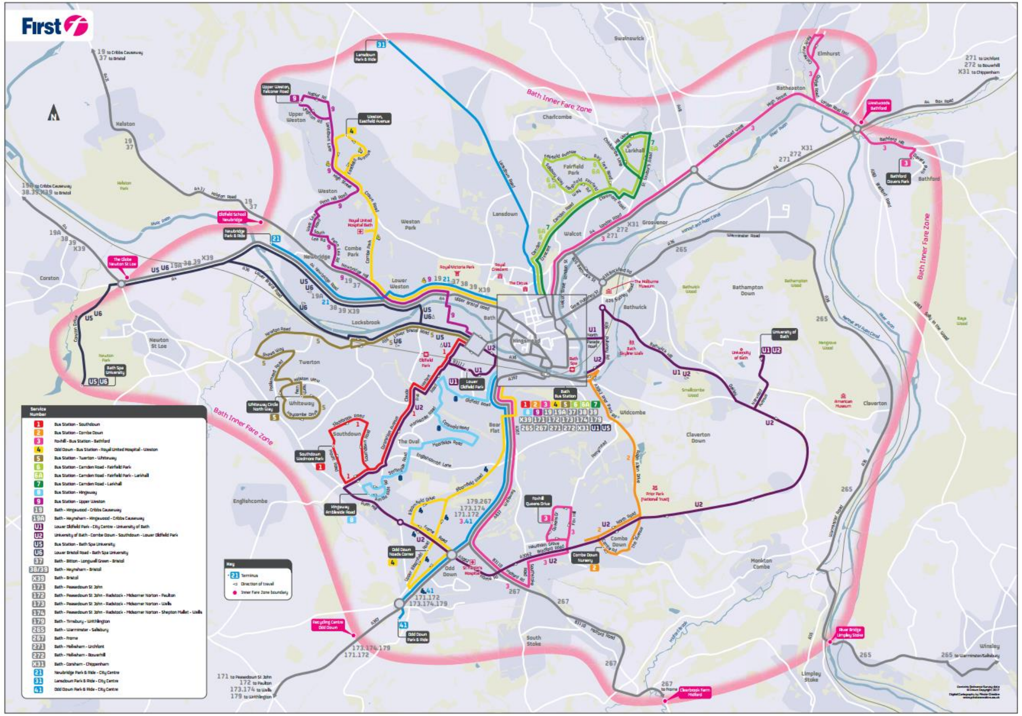
This accessibility data broadly fits in with the key corridors used by commuters on the bus, as seen in the Census Travel to Work data.



2.4 Bus route map

The current bus services available in Bath correspond broadly to the bus accessibility presented by the TRACC data.

There are a large number of services to the south of Bath, where there is high usage of both bus and car by commuters, as shown in the Census data.

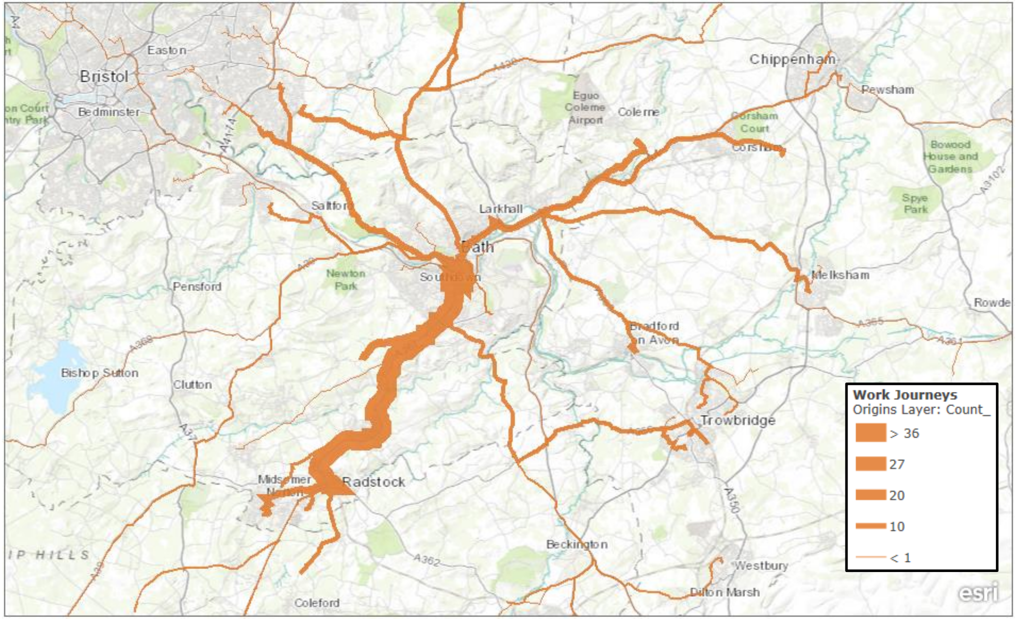


2.5 Journey purpose – work journeys

This map shows the origins and routes of traffic crossing a cordon around the city centre, for commuting and business journey purposes.

The map re-emphasises that the A367 to the south of Bath is a key corridor for people who travel to Bath for work. The map also shows high use of the B3110 from the south east, the A4 from both east and west directions, and Lansdown Road from the north.

There does not appear to be high usage of the A36 and A46 for trips into Bath. This is likely to be due to these being more long distance routes, and journeys with local origins are less likely to use these routes for short journeys.



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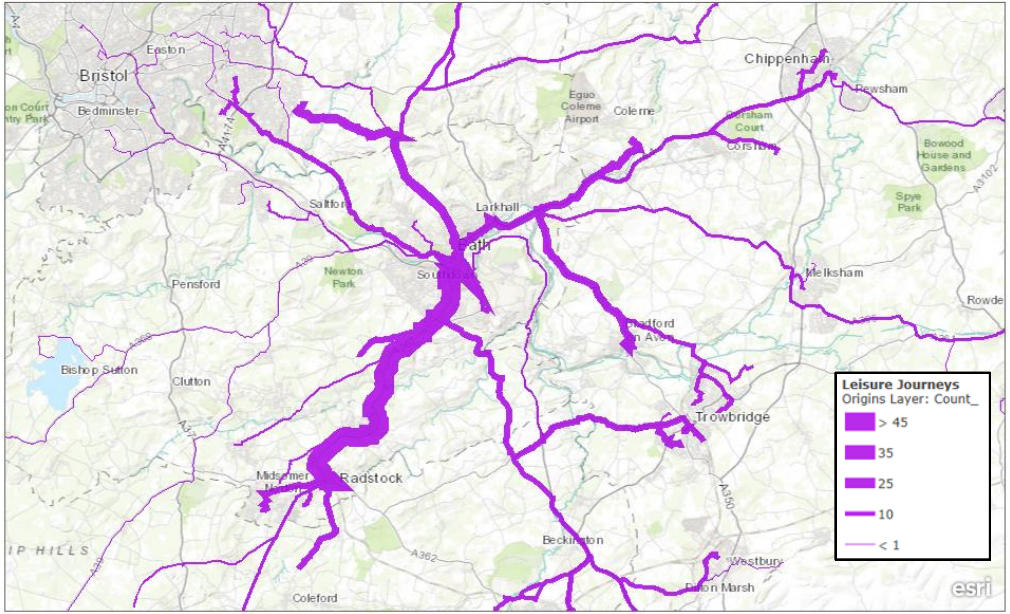
2.6 Journey purpose – leisure journeys

This map shows the origins and routes of traffic crossing a cordon around the city centre, for leisure and personal journey purposes.

The map shows that the optimal corridors used by people travelling into Bath for leisure purposes are similar to those used for work.

Most significantly, the southern A367 corridor is heavily used, more than any other corridor, and many of the origins of these trips appear to be in or near Midsomer Norton and Radstock. To the west and north, the A4 and Lansdown Road are also key routes. The three Park & Ride sites for Bath are located on these three corridors.



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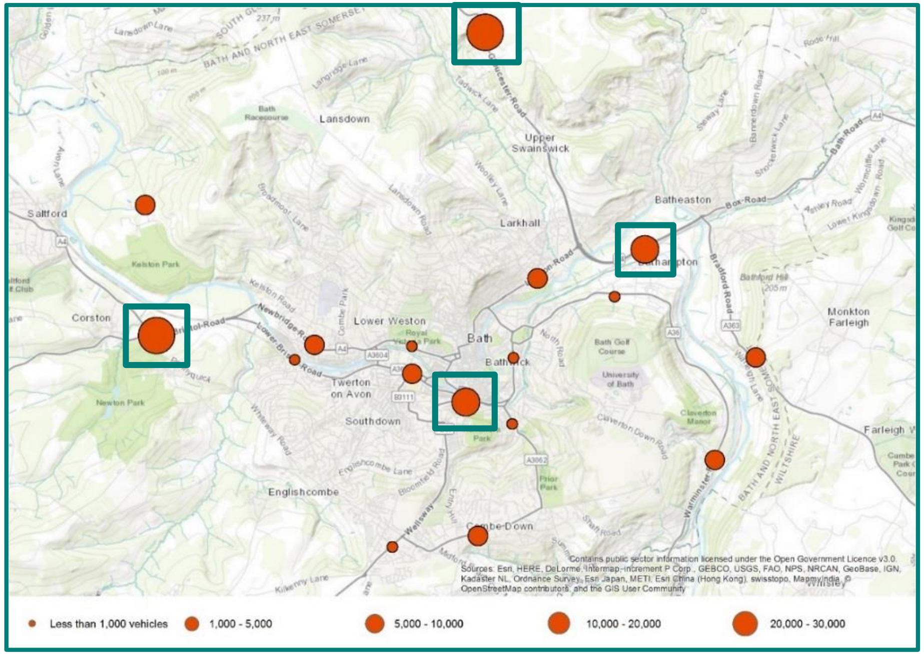
2.7 Traffic volumes

Highways England count data for 2016 has been mapped and indicates where there are high levels of traffic (all modes):

- To the north, there are high flows on the SRN (A46) to and from M4 J18;
- To the east, high traffic flows on the A4 Batheaston Bypass. For traffic using the city centre, A46 and A4 traffic converges onto the A4 London Road;
- To the west, high flows on the A4 Bristol Road from Saltford. This subsequently splits onto the A36 and A4 (Upper and Lower Bristol Roads) into the city; and
- To the south, high flows on the A367 Wells Road.



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2.8 Key corridor identification

The preceding analyses have been used to identify the most significant origins of travel into Bath. The map to the right shows areas with high concentrations of movement into the city centre.

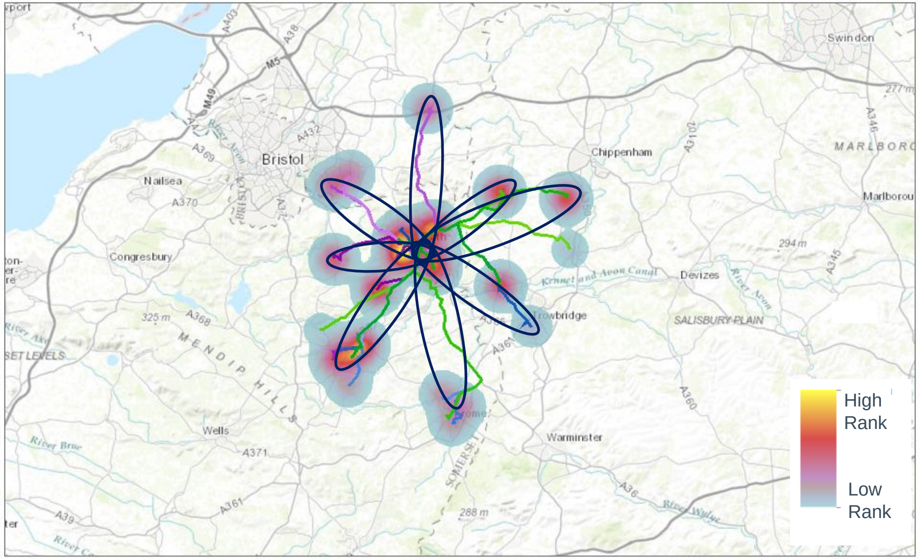
A large number of movements into Bath city centre originate from the surrounding suburbs, and in particular along the Riverside from Weston in the west.

Outside of Bath, the largest number of journeys originate from the Midsomer Norton and Radstock area, with other origins including Frome, Bradford-on-Avon, Corsham, Chippenham, and the eastern fringes of Bristol.

There is also implicit travel demand to and from key sites that are not captured in the previous strategic evidence analysis. These include the Royal United Hospital Bath, located in Weston, Bath Spa University located to the far west of Bath just off the A39, and the University of Bath, to the east of Bath city centre.

This suggests that a localised demand might support the implementation of a tram system. However, it would require modal shift from car drivers, existing bus users and Park & Ride routes.

More detailed forecasting will be required to inform any future business case (economic case, operational costs, and passenger revenue forecasting), but there are existing public transport routes that could by utilised by a tram system.



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2.9 Key route identification

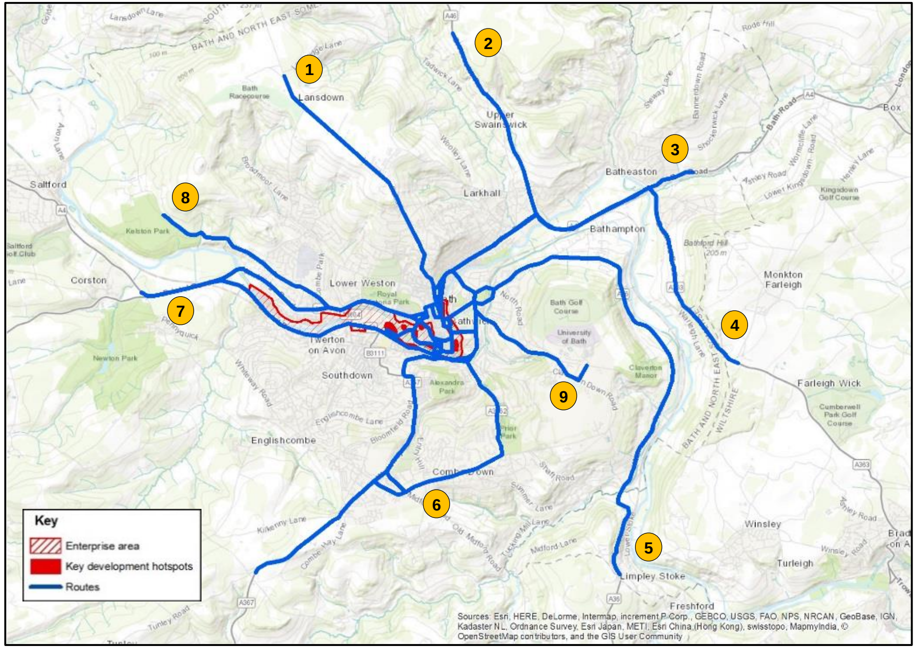
Taking into account the identification of the key corridors on the previous page, as well as the strategic evidence review (Census Travel to Work, journey purpose, bus accessibility and traffic count data), potential tram routes can be identified based on existing travel demand.

For the identification of the routes, a five kilometre radius from Bath city centre was used. This is largely to minimise the capital and running costs of tram services. The route serving the University of Bath (Corridor 9) is shorter than 5km, due to being localised to the university campus.

The corridors might also serve key destinations and major development areas within the city. The demand to these destinations is implicit at this stage as no passenger forecasting has been undertaken.

Corridors 7 and 8 to the west could serve the Western Riverside Enterprise Area and other clusters of development, along with, for example Bath Spa University and Royal United Hospital respectively. Corridor 9 would serve the University of Bath, and the end of Corridor 1 would serve Bath Racecourse.

This is not an exhaustive list of routes. It also intentionally includes, at this stage, routes which may not be suitable for tram operation (e.g. the A46 / A4 Batheaston Bypass). The technical feasibility of running trams on these routes will be addressed in Section 4.



1. Lansdown - Centre
2. A46 Gloucester Road - Centre
3. A4 Batheaston - Centre
4. A363 Farleigh Wick - Centre
5. A36 Warminster Road - Centre
6. A367 Odd Down - Centre
7. A4/A36 Newbridge - Centre
8. A431 Kelston - Centre
9. Bathwick Hill - Centre

Note: For the purpose of this study, the centre of Bath has been defined as Stall Street, adjacent to the Roman Baths.

3. Technology Assessment

Following the discussion on travel demand and the subsequent identification of potential tram corridors, this section presents analysis of the technology requirements of delivering a tram system, as well as potential constraints to delivery.

This section presents analysis of:

- Power systems & Technology
- Station and stop requirements
- Depot requirements
- Road space requirements
- Gradients and turning radii at junctions
- Structural support requirements
- Track construction requirements
- Safety implications
- Indicative costings
- Supplier market and delivery models.

3.1 Power systems & Technology

Most of the light rail and tram networks in the UK are powered by DC Overhead Electrification Equipment (OLE). The engineering design companies, construction companies and the UK supply chain as a whole are familiar with this system and many, if not all, of the elements required for the system already exist as off-the-shelf products. This familiarity and pre-existence of products would help drive down the cost of design and construction.

However there are many other technology options for powering tram systems that do not require OLE. These are generally less common and more expensive, thus consideration of suppliers and funding for the extra costs would have to be taken into account. Technologies include:

- Supercapacitors – are capable of climbing steep gradients. This may be preferable for Bath due to World Heritage Status, however supercapacitors are currently very expensive.
- Batteries – are cheaper than supercapacitors, however less capable of ascending steep gradients. They also require more unit replacements due to shorter life cycles.
- Groundfeed – offers a continuous supply of power, unlike batteries and supercapacitors, which are power storage systems. However this requires additional work to fit in the road and this would need to be considered carefully in relation to Bath vaults.
- Hydrogen – is an emerging technology as an alternative to OLE which can remove all emissions from the vehicles (but is only completely emission free if the source of hydrogen is also emission free). However it is extremely expensive even when compared to supercapacitors, storage of compressed hydrogen fuel is difficult, and vehicles cannot travel long distances without refuelling. This may only be an option for very short stretches, or potentially the very centre of Bath.

If the tram system is intended to extend beyond Bath, it may be worth considering the use of dual-voltage light rail tram-trains, which can operate on the main line railways between Bath and its neighbouring towns and cities. However, given the capacity constraints on the current rail network between Bristol Bath there would be significant technical challenges to overcome to deliver this option. Gauge would need to be a consideration if this option was progressed.

In conjunction with power systems, consideration should be given to all stations and stops, lighting, ticket machines, CCTV, signalling systems and points heating equipment, which will require independent power supplies along the route.

3.1.1 Ultra-light rail

The Bath Tram Re-introduction Group support the use of Ultra-light rail. Currently, Ultra-light rail is not yet a fully defined term, but it sits between a Tram and a Train in terms of its characteristics (although it must be stated that it is not a tram-train). There are aspirations for systems in Hereford and a pilot in Preston. However, the best known example is the Parry People mover, which has only three vehicles in operation.

Parry People Mover (PPM)
The system operating in Stourbridge uses a rail alignment, rail gauges and rail standards. The advantage is that smaller vehicles can be operated resulting in less initial infrastructure cost, less track wear, lower speeds and lower cost all due to the lighter vehicle. It is a bus type vehicle with bogies bolted on and generally low capacity.

- The PPM currently runs on only one line between Stourbridge Town and Stourbridge Junction, with a journey time of 3 minutes between the two stations, a distance of 1.3km at a speed of 32kph.
- There are currently only three in operation, therefore it is difficult to assess its reliability. There are claims of high reliability based on its short mileages at low speeds and simple vehicle design.
- It operates at standard gauge and requires elevated platforms.
- Maximum capacity approximately 130 (including standing passengers); 60 seats and 2 wheelchair positions.
- Two powered chassis each featuring 2 litre LPG engine and 12V battery for LPG unit.
- Flywheel and energy store: 2 x 500kg 1m diameter flywheels with an effective speed range 1000-2600rpm and regenerative braking.

Disadvantages:
- It operates on the conventional rail network and would be incompatible with operation on the road network.
- Simple bus style construction – passenger experience low (reminiscent of the Pacer vehicles)
- Incompatible with a low floor design which requires equipment to be roof mounted and therefore requires a much more rigid/strong structure.
- Requires elevated platforms – a challenge for street operation in mixed traffic.
- Limited passenger carrying capacity and passenger access – 130 compared to Bombardier Flexity of 295 passengers.

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3.2 Station and stop requirements

UK Tram guidance states that *"the needs of passengers, pedestrians and other road users should be reflected in the design of tramstops and associated pedestrian routes. Design factors include: sightlines, gradients and curvature, lighting and pedestrian desire lines."*

The guidance states that the platforms themselves should be designed in accordance with Disability Discrimination Act (DDA)[1], requirements including contrasting colours and tactile surfaces where required.

The height and length of the platform is dependent upon the height and length of the vehicles; +5m of additional length at each end to account for any overrunning trams. The pedestrian approach to platforms should meet DDA requirements, with ramps of between 1/20 and 1/12 being provided at both ends (dependent upon available space).

Platform widths should be no less than 1500mm clear width for side platforms, and 3000mm clear width for island platforms. The stepping distance between platform edge and tram door threshold should be no greater than 75mm, and is usually designed as being 40mm to allow for construction and operation tolerance.

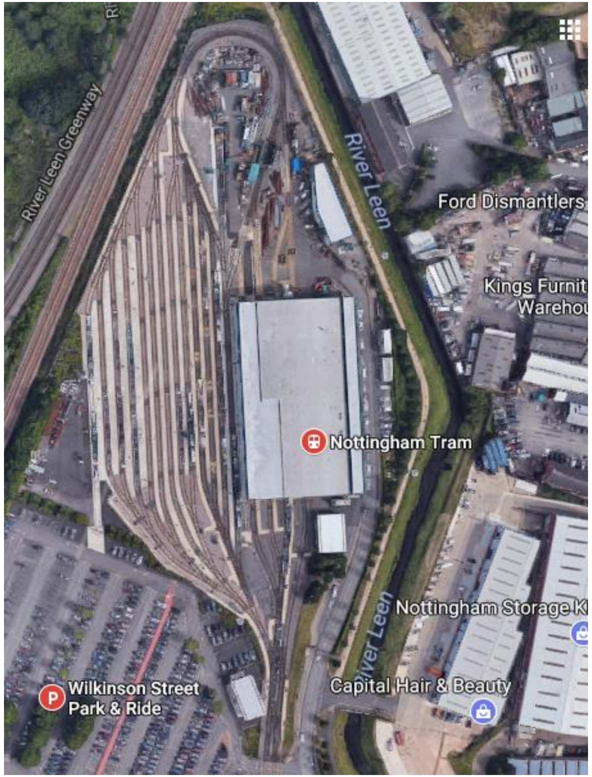
Tram stops, where possible, should incorporate links to bus services and Park & Ride facilities to promote multi-modal journeys.

1: Since UK Tram Guidance publication, the DDA has been replaced by The Equality Act (2010)

3.3 Depot requirements

Depots provide stabling, maintenance and cleaning facilities for a large number of trams, and therefore take up a large area. Subsequently, these are likely to be located away from the city centre, as is the case with Nottingham. In this instance, the depot has been combined with a Park & Ride facility nearby.

Walkways of 400mm minimum width should be provided between trams, with an allowance of 100mm between the developed kinematic envelope (DKE) and walkway, but this is subject to the maintenance and equipment requirements of the depot.



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3.4 Road space requirements

The clearances between the DKEs of two adjacent trams should be not less than 100mm without centre traction poles and 600mm (but at least 100 mm from the face of the nearest side of a pole to each DKE) where there are traction poles between the two DKEs.

The clearances between a DKE and other highway features or fixed structures should be 100mm to an isolated obstruction in the centre of the carriageway or on a side reservation, 200mm to the edge of a traffic lane, 300mm to a kerb and 600mm to a continuous obstruction in the centre of the carriageway or on a side reservation.

Lanes used by both trams and other large vehicles, such as buses, coaches and heavy goods vehicles, should be 3650mm wide for a two-lane carriageway.

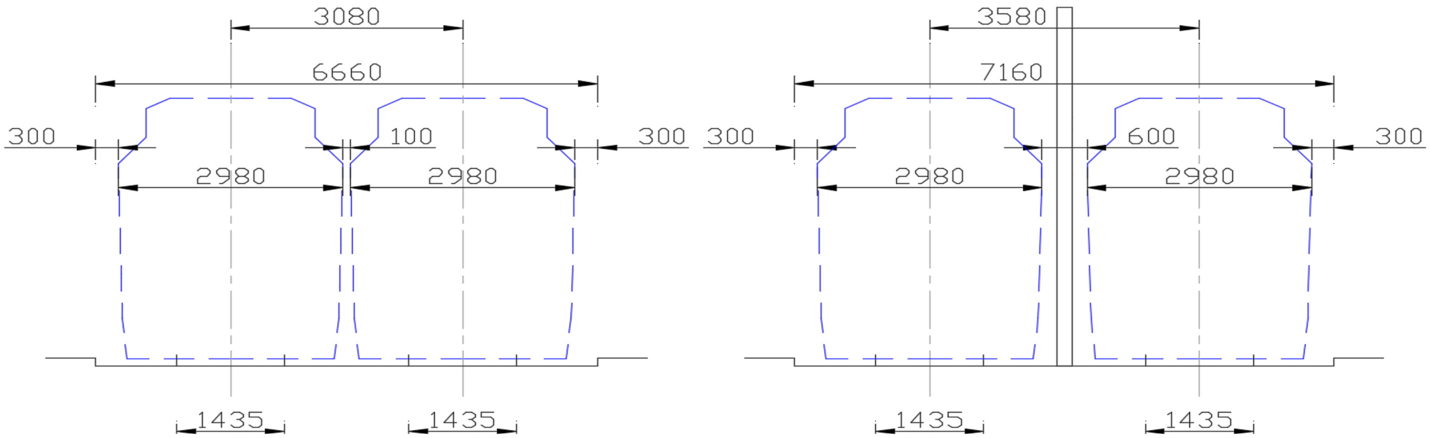

Figure shows typical cross section with no central OLE masts and then with central OLE masts, based on a 'typical' tram vehicle DKE. Clearances taken from *Guidance on Tramways* document

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3.5 Turning radii and gradients

The minimum radii for the tramway are largely determined by the type of tram selected, and in particular, by the overhangs and wheel spacing. Therefore, the track alignment, the tram design and the highway constraints form part of an iterative process upon which little specific guidance can be given until the type of vehicle is determined. In practice, some of the tightest turning radii for trams in the UK are approximately 25m (sections of the Manchester Metrolink and Midland Metro through Birmingham city centre), but this is subject to specifications on street furniture and proximity to junctions.

As stated in *Guidance on Tramways*, ideally “locations at which a tram may routinely ‘turn back’, or other places where the tram driver is routinely required to leave the driving position, should not be on a gradient steeper than 1 in 500 (0.2%).”

When designing tram systems, it is generally best to avoid street-running gradients of greater than 1/14 (6.5%), as this is the level that a common light rail vehicle is able to ascend safely. In certain instances, steeper gradients are possible (for example sections of the Sheffield Supertram have gradients of 1/10 (10%)), but this depends on a number of factors including the make and model of the trams adopted, the street furniture, turning radii, and can be increased by adding tyres for adhesion and increasing the power input.

3.6 Structural support requirements

The loading and structural support requirements are a key consideration for bridging the vaults under the streets of Bath city centre.

The buried structures and services can be mapped using a 3D CAD model, which can then be accessed via computer or adopted on tablets to be used on site to check the position of services and structures on site.

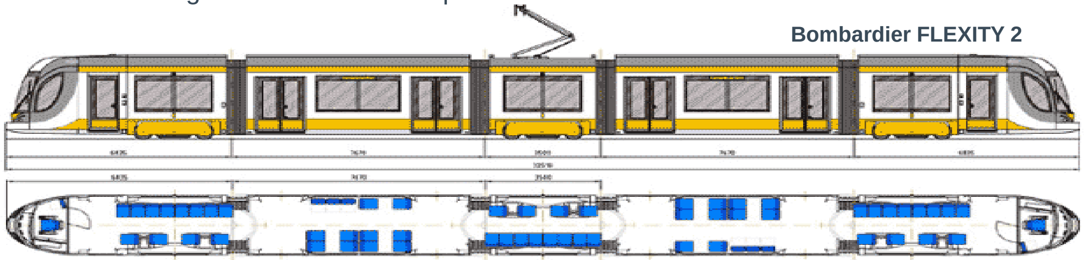
Often services can be moved to the side of track so that they are not subject to tram vehicle loading, do not obstruct the slab track construction and are easily accessible should they need maintenance in the future.

Tram vehicle loading depends upon the vehicle selected – light rail vehicles typically weigh around 20 tonnes, with the load spread between 3 bogies consisting of 2 axles each (6 axles in total per tram car). The slab track in on-street running areas is typically designed to be rigid enough to bridge any buried services or structures beneath the alignment.

In Birmingham for example, where the crowns of a number of basements were at a shallow depth, the slab was not only designed to span them, but a sufficiently thick compressible layer was introduced to ensure that minimal noise and vibration was transferred as trams passed above.

The vaults and utilities will be a significant factor for consideration in the designing of any Bath tram system. As the Birmingham scheme has shown, there could be design solutions to overcome issues the vaults pose. However the specific design considerations and cost implications would need to be assessed in the next stages of scheme development.

Bombardier FLEXITY 2



3.7 Track construction requirements

Track slab does not usually favour pre-fabrication, especially in places where there is concern regarding the structural support. It is best to pour the concrete on site to suit the final position of the rails.

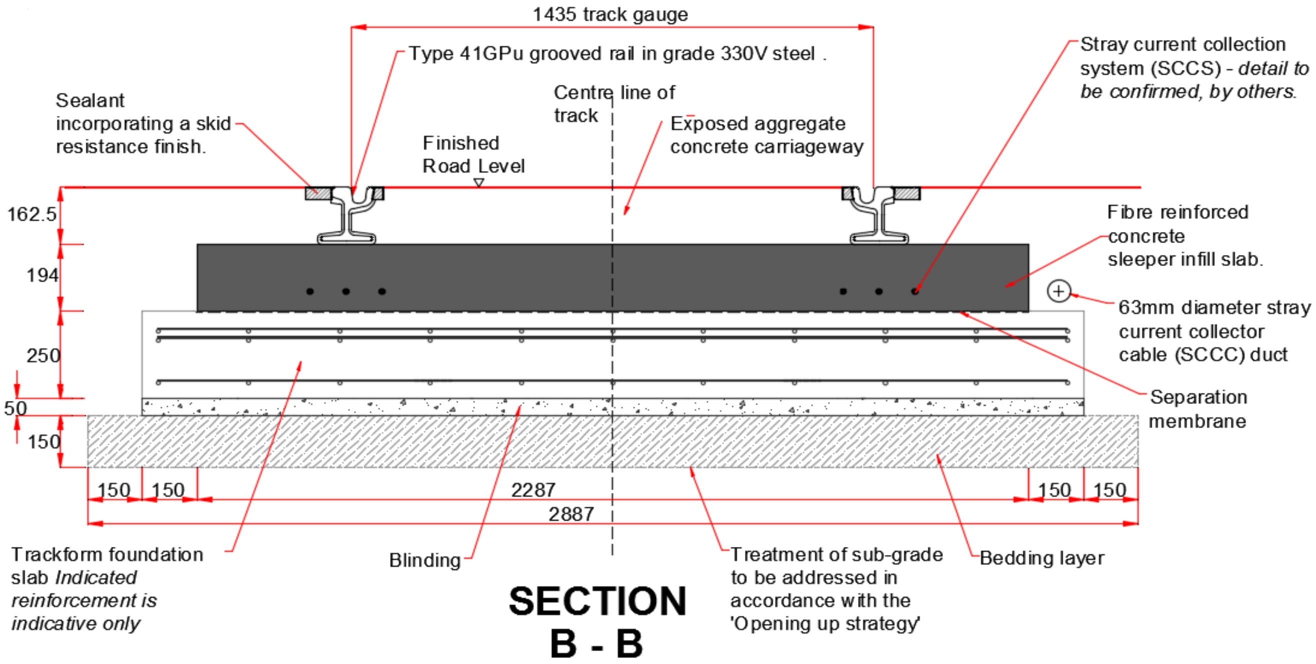


Figure shows typical city centre track slab cross section

3.8 Safety implications

The system would be designed in accordance with UKTram technical guidance notes, which covers the consideration of pedestrian and cyclist safety in the design of tramways.

Considering all of the light rail systems currently operating in the UK, particularly Manchester, Birmingham and Nottingham where tram vehicles operate on-street in heavily built up areas, cyclists and tram vehicles generally operate safely in the same environment. This is because trams, cyclists and other road users are travelling at low speeds with a high awareness of their surroundings in the busy environment. Additionally, trams are highly predictable in their nature and anticipated direction of travel, therefore making them easy to avoid.

As the tram route heads out of these city centres, it is typical to have a segregated cycle path, designed in accordance with established standards, increasing the safety of cyclists overall. Bath's existing cycle route network, could be developed further to ensure the safety and segregation of cyclists and pedestrians where possible, as road space is reallocated.

Where cyclists and pedestrians are required to cross the line, the design will be developed in order to encourage crossing the tracks at an angle of between 45°and 90° or make appropriate alternative provision where it is not possible to provide track crossings at such an angle.

3.9 Cost Benchmarking

Benchmark costings from recent tram projects are shown here. It is important to recognise whilst these figures provide a broad overall estimate of the costs of introducing a tram system, costings are often not directly transferable. Many of the original tram systems were based on historic rail and tram routes, which reduced costs compared to the extensions. Furthermore the requirements outlined in this section such as gradient and road space, are individualised in their impact on the overall costs of the trams depending on the location requirements.

System	Date Opened	Actual construction cost (£ millions)	Construction cost at (2017 Prices) (£ millions)	Length of track (kilometres)	Construction cost per km (2017 Prices) (£ millions)
Manchester Metrolink	1992	150	210	31	7
Sheffield Supertram	1994	240	340	29	12
Midland Metro	1999	150	180	21	9
Croydon Tramlink	2000	200	240	28	9
Nottingham Express Transit	2004	180	200	14	14

Extensions	Date Opened	Actual construction cost (£ millions)	Construction cost at (2017 Prices) (£ millions)	Length of track (kilometres)	Construction cost per km (2017 Prices) (£ millions)
Manchester Metrolink	2000	160	190	8	24
Nottingham Express Transit	2015	570	570	18	33
Midland Metro	2015	40	45	1	39
Manchester Metrolink (Airport)	2014	400	410	15	28

All costs are rounded and approximate.
2017 prices have been calculated using the applicable rate of inflation from the construction date.

3.10 Supplier market conditions and delivery models

Supplier Market Conditions

Tram technology is well developed in the UK, but the diversity of suppliers is relatively low.

The technology employed in each city that currently has a tram network varies to some degree, and indeed, the technology in different sections of the same network can vary in some cases, as research into technology and design progresses.

The suppliers to the UK market also supply the rest of the world, and are able to take lessons learned and improved technologies from those markets and bring them to the UK. The current UK light rail and tram systems continue to see growth, as recent DfT figures present record numbers of passenger journeys and vehicle miles2.

Lessons learned from some difficult design projects, such as Edinburgh and Birmingham city centre tramways, have activity contributed to the development of tram design guidance documents. It is anticipated that the design of the Bath tram network would encounter similar issues with regards to underground structures and buried services, which will be covered by these guidance documents, and would therefore be consulted in detail before and during the design phase.

Delivery Models

The Local Authority (LA) usually has a stake in the Operating Company formed to operate the light rail system. Nottingham, Birmingham and Manchester all operate in this fashion.

The LA often has a 50% stake, to be able to retain control and governance of the system. The other 50% usually consists of one or two private companies which are appointed on a 5 or 10 year framework. For example, on the Nottingham tram, the private company was previously one of the local bus operating companies, but this recently came up for renewal and has switched to the other major bus operating company in the area.

Sometimes the franchise is made up of several companies forming a JV, incorporating track maintenance, operation and vehicle maintenance specialists (as in the case of Metrolink in Manchester).

2 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/623366/light-rail-tram-ending-march-2017.pdf

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4. Corridor Assessment

Based on the review of travel demand (section 2) and technology review (section 3), this section presents a desk-based review on the high-level deliverability of trams on the identified key corridors:

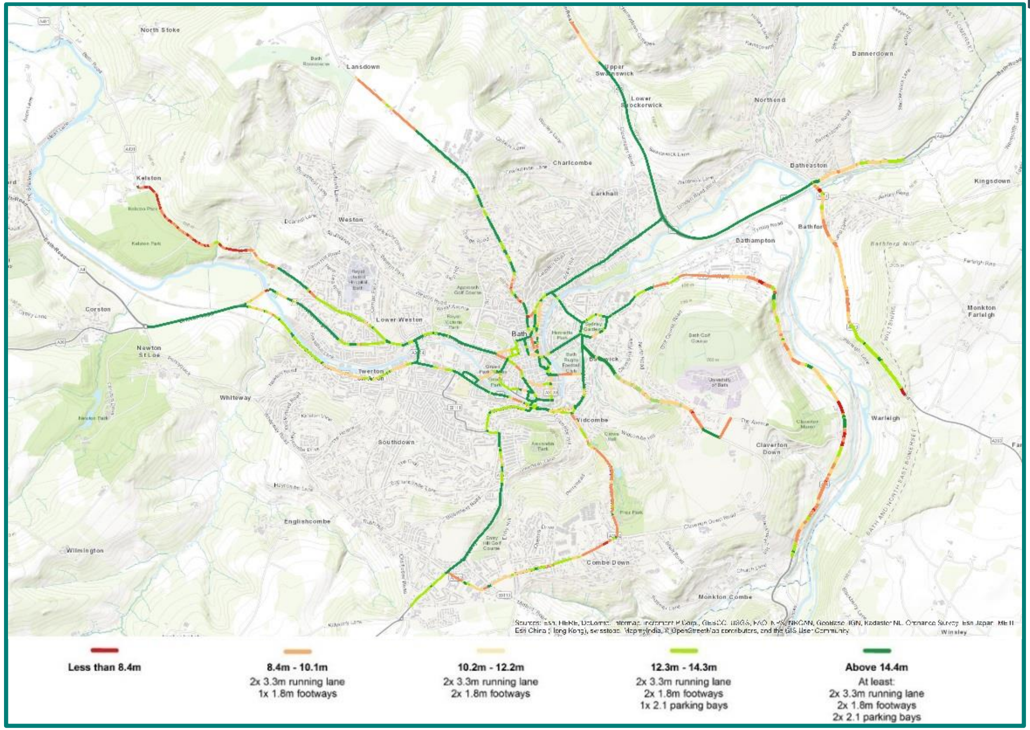
- The road space widths along each corridor have been analysed using GIS to establish where there are key pinch points, areas along the corridor where road space is limited and which could be an obstacle to delivering trams.
- The gradients along each corridor have also been analysed using GIS in order to identify where roads are steep and may be an obstacle in delivering tram services.
- Environmental factors (Green Belt, Bath's Air Quality Management Area (AQMA), Areas of Outstanding Natural Beauty (AONB) and flood zones) have been mapped to establish how corridors are affected by environmental designations.

4.1 Highway widths

A five-point scale has been used to review the widths of the roads along key corridors into Bath. This is shown in the map to the right.

It is assumed that 10.2m is the minimum road width required to allow two running lanes shared between trams and vehicles along with two footways. Treatment of the built environment and reallocation of road space, including on-street parking, will need careful consideration. The following characteristics can be identified:

- From the west, the A36 and A4 are relatively wide, with pinch points including the bridge near Newbridge Park & Ride. The A431 has significant width constraints, particularly through Kelston.
- From the east, the A4 London Road is relatively wide, while the A36 Warminster Road, the A363 and the area around University of Bath all have width constraints.
- From the north, the route is generally wide, with some constraints towards Lansdown.
- From the south, the A367 from Odd Down is relatively wide, while the A3062 is narrow, with pinch points through Combe Down.



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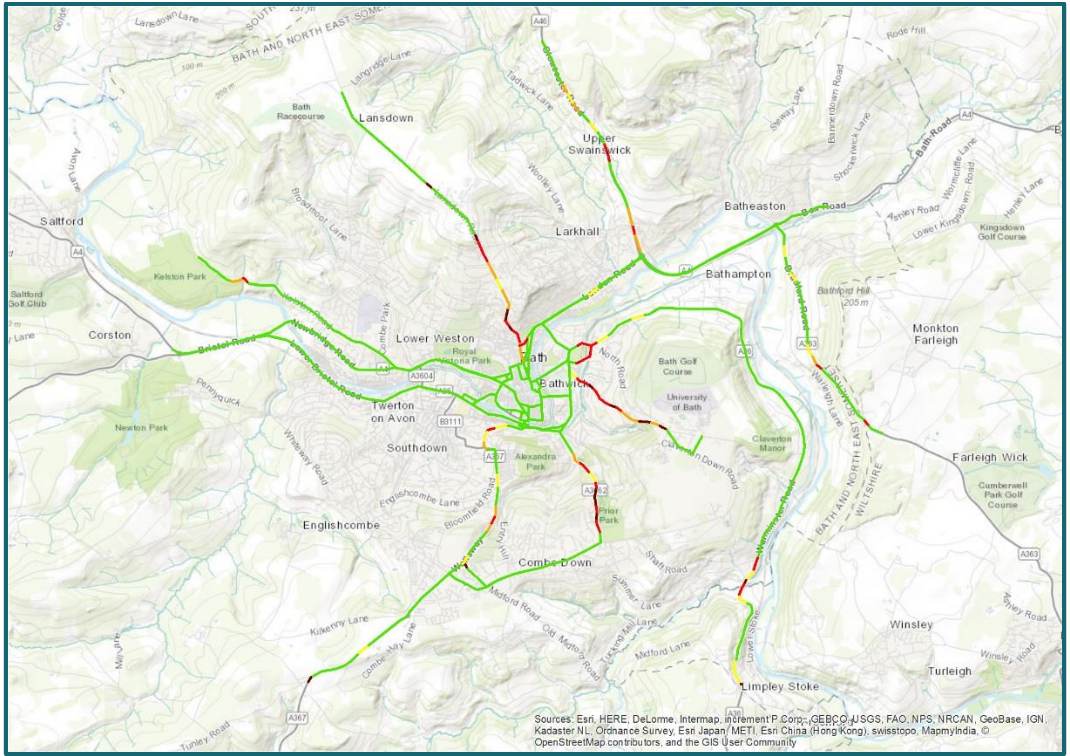
4.2 Gradients

A five-point scale has been used to review the gradients of the roads along key corridors into Bath. This is shown in the map to the right.

The following characteristics can be identified:

- From the north, there are significant gradients north of the city centre on Lansdown Road.
- There are also steep gradients on the A46 through Upper Swainswick as well as on the approach to the A4/A46 junction.
- From the south, the A367 varies in gradient, while there are steep gradients on the A3062 near to Prior Park.
- Steep gradients are present on the majority of Bathwick Hill towards the University of Bath to the east of the city centre.

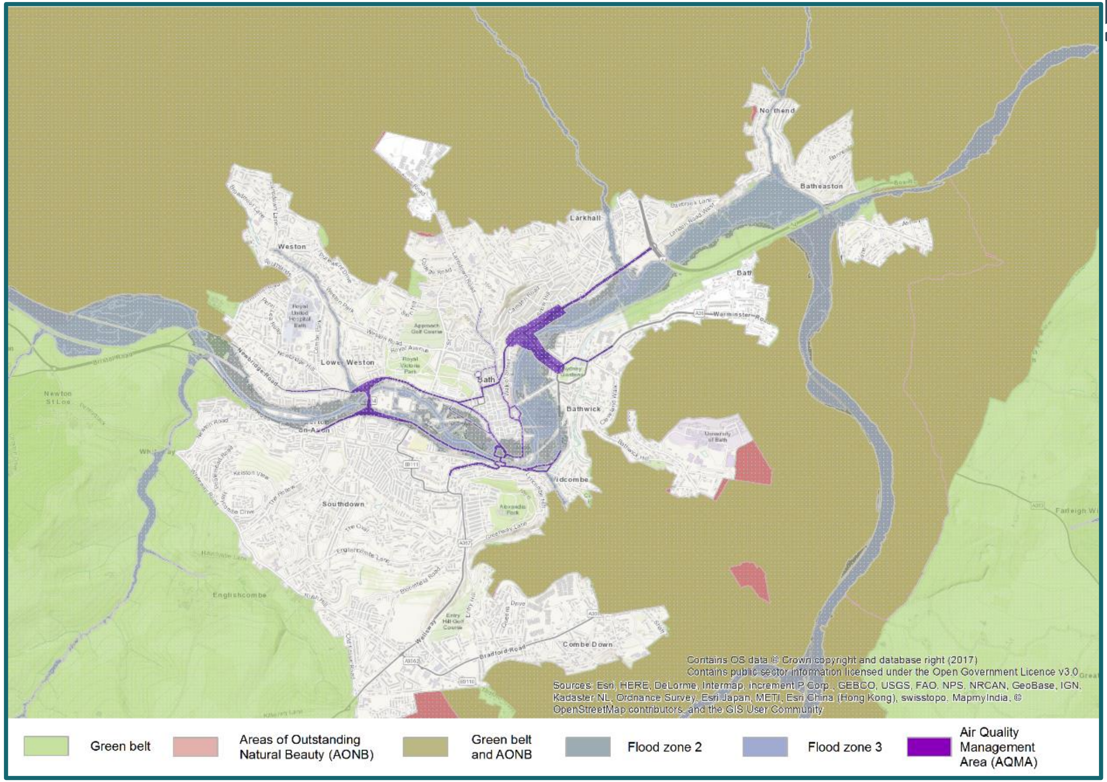


6.6% or above	5% - 6.6%	4% - 5%	3.3% - 4%	3.3% or below

4.3 Environmental constraints

Three key environmental indicators are mapped: the Cotswold Area of Outstanding Natural Beauty (AONB), Green Belt and flood zone designations. The Bath Air Quality Management Area (AQMA) is also added for reference.

- Green Belt surrounds Bath's built-up area. This could affect the delivery of trams in Lansdown, A36/A4 Upper and Lower Bristol Roads, and A46.
- The Area of Outstanding Natural Beauty covers the south, east and north of Bath. This may affect delivery of trams in Lansdown.
- Flood zones follow the River Avon and run through the city centre. These would need to be considered on the A36/A4 Upper and Lower Bristol Roads, A4 London Road and the southern edge of the A367.
- Trams could assist in reducing harmful air quality impacts through encouraging mode shift from cars. All corridors run through the AQMA to varying degrees and could support reductions in emissions.



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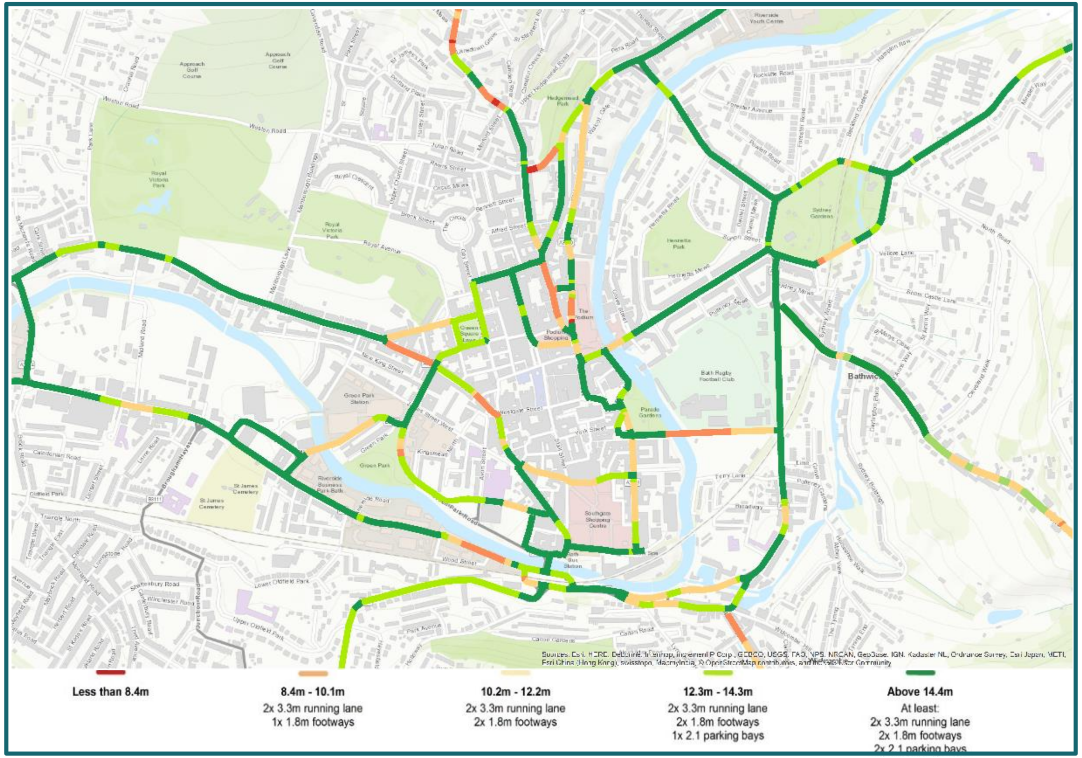
4.4 City centre – Highway widths

City centre routing:

- The built environment and reallocation of on-street parking will need careful consideration.
- Some city centre routes may be required to be closed to general traffic to segregate trams and allow them to move freely, however this greatly depends on different route considerations.
- Modelling is required in the next stages to assess the traffic impacts of road closures and rerouting, and taking into account mode shift to tram. This will be dependent on further investigation of routing constraints.

The following characteristics can be identified:

- The majority of highway widths in the city centre are above 10.2m.
- Highway width constraints are located east of Queen Square (Charlotte Street and Monmouth Place).
- There are highway width constraints to the north of the city centre at Broad Street/Walcot Street.



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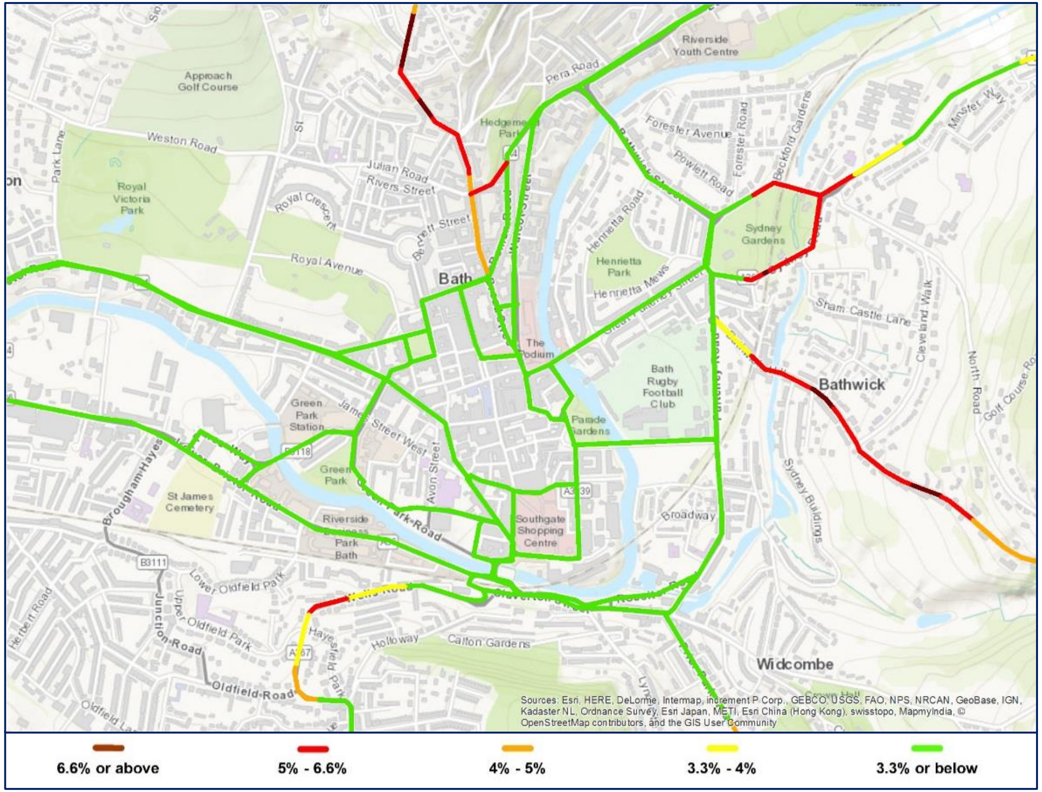
4.5 City centre - Gradients

The following characteristics can be identified:

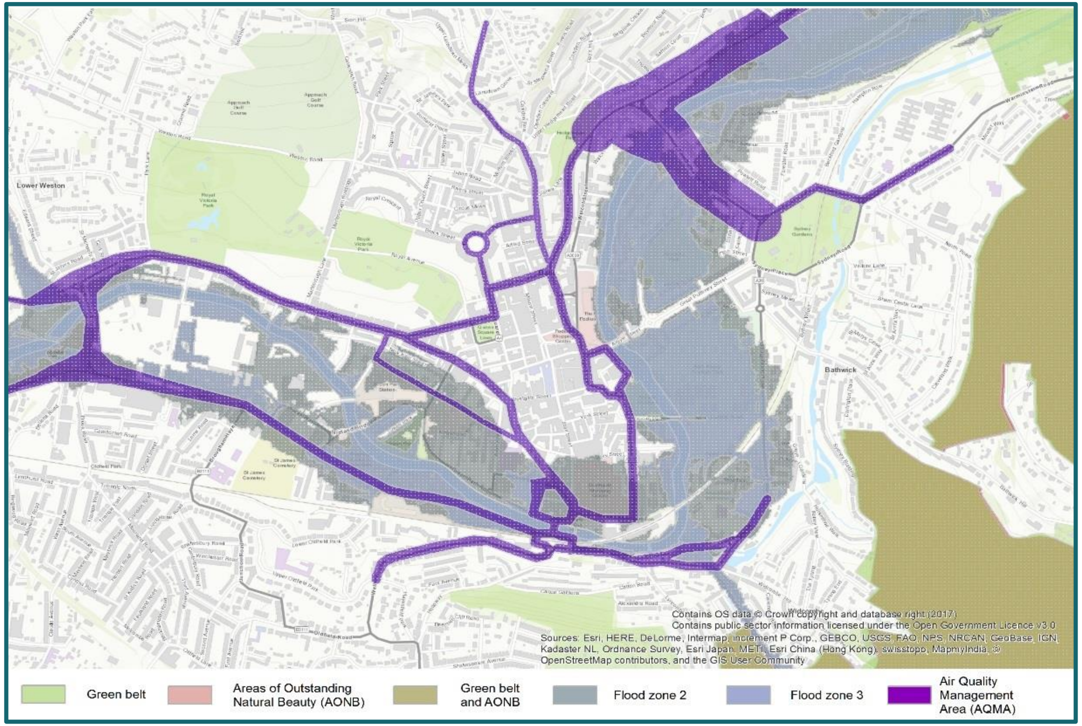
- The city centre is generally flat, posing few problems to feasibility in terms of gradient.
- To the north of the city centre, there are gradient constraints on Lansdown Road.
- To the east of the city centre, there are constraints east of Sydney Gardens and on Bathwick Hill.
- To the south of the city centre, there are constraints on the A367.



4.6 City centre – Environmental constraints

The following characteristics can be identified:

- The AQMA covers the main routes into the city centre. This is likely linked to the high volumes of slow moving traffic.
- Flood risk follows the River Avon to the south and east of the city centre. It encompasses the Southgate shopping area, and covers the key developments sites and enterprise zone.
- AONB and Green Belt designations do not affect the city centre.



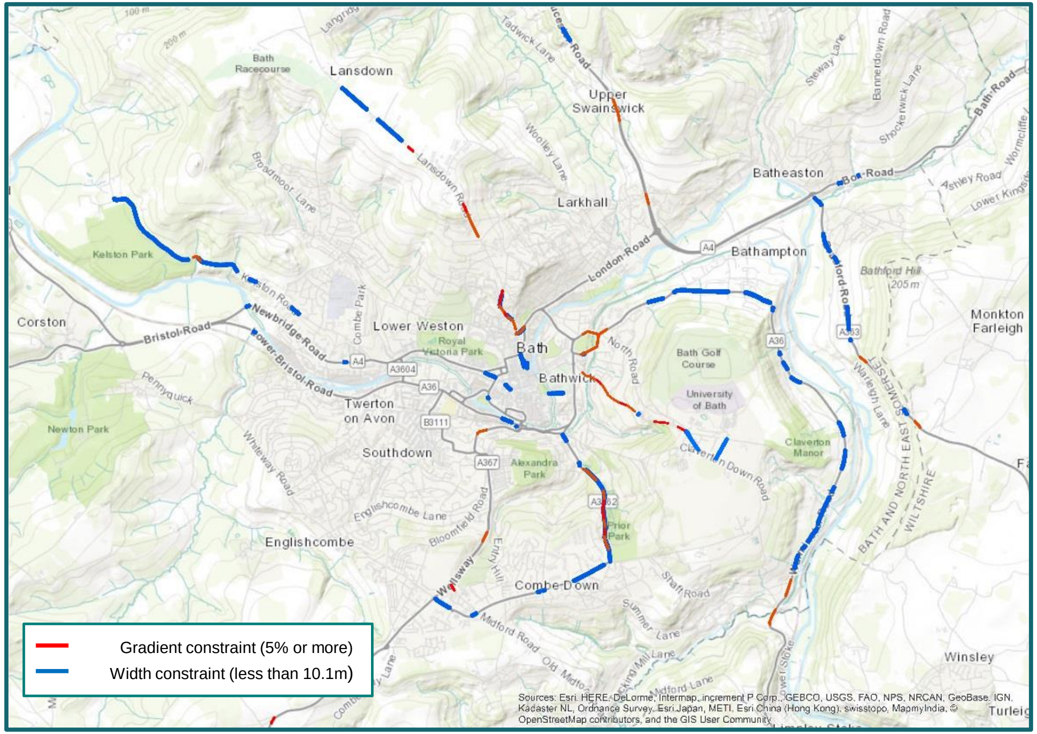
4.7 Summary of corridor constraints

Overlaying the gradient and highway width constraints, a number of constrained areas can be identified.

The individual route constraints would need further consideration to assess their impact on the wider corridor in the next stage of scheme development.

A number of areas may create an obstacle to the deliverability of a tram system, due to significant highway width and gradient constraints. Areas include:

- The A431 through Kelston;
- The A3062 through Combe Down;
- Bathwick Hill to the east of the city centre;
- Lansdown Road, north of the city centre and towards the Park & Ride; and
- A36 through Bathampton to the city boundary.



5. Summary

The strategic evidence section of this report has shown that there is demand for public transport solutions in Bath. Key corridors into Bath have been identified, through the assessment of a number of data sources.

The technology assessment has provided an overview of the tram technologies that are available, and a high level assessment of their merits in relation to Bath. The corridor assessment has identified where the highway network offers a relatively wide and flat surface where trams could be delivered. The assessment has also suggested where some sections of the corridors have narrow widths and steep gradients which may need to be avoided/mitigated and could pose a problem to deliverability in these areas.

In this section a Red-Amber-Green (RAG) assessment has been used, to assess each identified corridor according to demand into Bath, existing Park & Ride site on corridor, width constraints, gradient constraints, environmental constraints, and depot potential. For each of these factors each corridor has been assessed on a RAG scale, whereby:

- Red means there are immediate constraints that would need to be considered in detail as they could be obstructive to delivering trams;
- Amber means there are potential constraints to successful introduction of trams but they do not pose immediate threat / may be mitigated; and
- Green means there does not appear at this initial scoping stage to be any barriers to trams being introduced.

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5.1 Indicative RAG assessment

Corridor	Demand	Existing Park & Ride site on corridor	Width constraints	Gradient constraints	Environmental constraints	Potential for depot along corridor
1 – Lansdown to Centre	High demand	Lansdown Park & Ride	Some constrained areas	Some constrained areas	Green Belt and AONB throughout	Location near to existing Park & Ride site could considered
2 – A46 Gloucester Road to Centre	Relatively low demand	No current Park & Ride site	Some constrained areas	Some constrained areas	Green Belt and AONB throughout	Unlikely to be viable
3 – A4 Batheaston to Centre	Relatively high demand	No current Park & Ride site	No width constraints	Relatively few gradient constraints	Flood risk and Green Belt	Potential site options on A4 at Batheaston
4 – A363 Farleigh Wick to Centre	Relatively low demand	No current Park & Ride site	Limited widths	Some constrained areas	Flood risk, AONB and Green Belt	Potential site options on A4 at Batheaston
5 – A36 Warminster Road to Centre	Relatively low demand	No current Park & Ride site	Some width constraints	Some constrained areas	Green Belt and AONB throughout	Unlikely to be viable
6 – A367 Odd Down to Centre	Very high demand	Odd Down Park & Ride	Significant constraints on A3062, few on A367	Significant constraints on A3062, few on A367	Green Belt and AONB on A3062, none on A367	Location near to existing Park & Ride site could considered
7 – A4/A36 Newbridge to Centre	High demand	Newbridge Park & Ride	Few width constraints	Few gradient constraints	Green Belt and AONB on edge, flood risk throughout	Location near to existing Park & Ride site could considered
8 – A431 Kelston to Centre	Relatively low demand	No current Park & Ride site	Significant width constraints	Slight gradient concerns	Green Belt and AONB	Unlikely to be viable
9 – Bathwick Hill to Centre	Expected high demand	No current Park & Ride site	Significant width constraints	Significant gradient constraints	World Heritage Site; no flood zone, AONB or Green Belt	Unlikely to be viable

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5.2 Summary of corridor assessment

The RAG assessment suggests that corridors 1 (Lansdown), 7 (Newbridge), and in particular, corridor 6 (Odd Down) could be most suited to delivering a tram system going forward, based on relatively high demands along the corridor, existing Park & Ride facilities and relatively limited environmental, gradient and width constraints.

- **Corridor 1 (Lansdown)** could be complemented by the existing Lansdown Park & Ride and has relatively high levels of travel demand. However there could be challenges in delivering trams along sections of the corridor with steep gradients and width constraints. Trams would be required to share roadspace with general traffic, and it would be necessary to consider how reliable tram services could be delivered. It would be challenging to deliver traffic restrictions due to Lansdown Road serving residential areas in the north of the city. However, **this initial assessment indicates that the corridor could be considered further.**
- **Corridor 2 (A46)** has relatively few width constraints. However, there are steep gradients, and its function as a dual carriageway on the Strategic Road Network is unlikely to be consistent with tram operation. Furthermore, this runs through a rural area and there is currently no current Park & Ride facility. **This is unlikely to be a priority for further consideration.**
- **Corridor 3 (A4 east)** has relatively few width constraints and few gradient constraints. However, the A4 dual carriageway is unlikely to be suitable for operation of trams. At present, there are high traffic flows into the east of Bath on the A4, but relatively low bus demand. The lack of a Park & Ride site would be a major constraint to achieving mode shift on this corridor. It would also be necessary to consider options for delivering a tram depot in this corridor (which would need to be near the A4 in the Batheaston area). **However, given the transport needs in this part of the city, serious consideration must be given to a package of measures to improve public transport in this corridor.**
- **Corridor 4 (A363)** has significant width constraints. It runs through a rural area that is not appropriate for tram operation. It currently has low levels of bus demand and there would be challenges in delivering Park & Ride on the corridor. The railway line between Bath, Bradford-on-Avon and Trowbridge runs parallel to the corridor and improved rail services are likely to be more effective in serving the travel needs of this corridor. **This is unlikely to be a priority for future consideration.**
- **Corridor 5 (A36 east)** has significant gradient, width and environmental constraints which would affect deliverability on the corridor. Furthermore, demand is likely to be relatively low, and there is no realistic scope for Park & Ride to intercept car trips entering the city on this corridor. **This is unlikely to be a priority for future consideration.**

5.2 Summary of corridor assessment

- **Corridor 6 (A367)** has high demand for journeys into the city centre. The corridor already benefits from the presence of the Odd Down Park & Ride site (the largest of the three sites), which could intercept demand at the edge of the city onto tram services. This area also has relatively few environmental constraints. The A3062 is likely to be a less suitable route option due to its significant gradient and width constraints and is likely to have lower demand. The A367 has fewer technical constraints to the delivery of tram services: the road corridor is wider and has less steep gradients. There could be challenges in ensuring sufficient priority for trams within the available roadspace but **the initial assessment indicates that this corridor could be considered further.**

- **Corridor 7 (A4/A36 west)** has high demand along the A36 Lower Bristol Road and the A4 Newbridge Road/Upper Bristol Road. Both roads have fewer width and gradient constraints owing to its position adjacent to the river. However, there could be some localised flood risk constraints, which would need to be considered further. This corridor would serve the Bath Enterprise Zone, which will generate high levels of travel demand in the future, which could significantly boost tram patronage. The corridor could also serve Bath Spa University, where demand is expected to be high. The corridor is also served by Newbridge Park & Ride, which could intercept demand at the edge of the city. **The initial assessment indicates that this corridor could be considered further.**

- **Corridor 8 (A431)** has significant constraints beyond the edge of the built-up area, including entering the Area of Outstanding Natural Beauty. Travel demand is relatively low compared with other corridors and there is no realistic prospect of intercepting car trips with a new Park & Ride site (due to the road being within the Area of Outstanding Natural Beauty). However, it is necessary to consider the high levels of travel demand generated by Royal United Hospital, which is located within Weston. Within the city, there are fewer roadspace and gradient constraints, and there could be a case for considering a spur from the route serving Corridor 7. **This could therefore be considered as a later opportunity, potentially as a spur from Corridor 7.**

- **Corridor 9 (Bathwick Hill)** has relatively few width constraints. However, there are significant sections of steep gradient. The demand for this corridor would need to be carefully assessed if taken forward, as the strategic evidence does not currently show high levels of demand for trips into the city centre on this corridor. Although there is expected to be implicit demand generated by trips to/from the University of Bath, this will be limited to teaching semesters. The route is not within the AONB or Green Belt, but the considerable gradient constraints mean that it is unlikely to be suitable as a depot location. Whilst this route would serve the university, it does not serve large employment and residential areas. **This is unlikely to be a priority for future consideration.**

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5.2 Summary of city centre assessment

While detailed city centre routing information is as yet unknown, the following challenges relating to highway widths, gradients and environmental constraints can be highlighted.

- Highway widths on the assessed city centre roads suggest that there may be challenges for Corridors 7 and 8 if they were to use Charlotte Street and/or Monmouth Place. Constraints at Walcot Street/Broad Street could pose challenge for tram routes heading into the city from the north, routes 1, 2, 3 and 4. Corridor 7 could be affected by constrained widths on A36 Lower Bristol Road.
- Gradients are largely flat in the city centre, although Corridors 1, 2, 3 and 4 would be affected by steep gradients on Lansdown Road if trams were to run there, while to the east, routes 5 and 9 could be affected by Sydney Gardens and Bathwick Hill respectively.
- The AQMA is a constraint for all routes into the city centre. However, there may be opportunities to enhance air quality on key AQMA corridors through a tram system. Air quality assessments will need to be undertaken as appropriate in the scheme design process, taking into account changes in traffic flows and speeds.
- Flood risk could affect all routes except for Corridors 1 and 2. Flood risk mitigation is clearly a key consideration for highway infrastructure, but also to support planned growth in key development sites and the Enterprise Zone.

5.3 Recommendations

This initial assessment has demonstrated that there is a case for further consideration of the potential for introduction of trams on certain corridors into the city.

- **Corridor 6 (A367 Odd Down)** would appear to have the strongest potential, based on the potential travel demand and the ability to overcome engineering and environmental constraints. This corridor is not currently served by the rail network, and the creation of a tram route between Odd Down and the city centre could significantly improve connectivity from the south of the city.
- **Corridor 7 (Newbridge)** also has relatively strong potential, particularly given the likely increase in travel demand from the Bath Enterprise Zone. Different route options could be considered via the A4, A36 or through the Enterprise Zone. This could also be integrated with the ambition in the JTS for a new rapid transit corridor between Bath and Bristol. From this line, consideration could then be given to a spur to Royal United Hospital in Weston.
- **Corridor 1 (Lansdown)** could also have potential, particularly in intercepting travel demand into the city from the north, but there would be significant engineering challenges in relation to the road widths and gradients. It would also be necessary to consider how to manage traffic on the corridor to ensure that reliable tram services could be delivered.
- **Corridor 3 (A4 east)** has significant transport challenges, with relatively poor public transport choices and high levels traffic entering the city. There is sufficient space to introduce tram services on the A4 corridor from the Lambridge area, and there is a high level of travel demand into the city on this corridor; at present, there is no attractive public transport alternative for Corsham, Box and other communities on the A4. However, a tram service would not be sufficient to tackle the problems on the A4 into the city without a means of intercepting traffic entering the city from the east (with, for example, a Park & Ride site). This will therefore be much more challenging.
- There is a much weaker case for introducing trams on other corridors. The four corridors identified above should therefore form the basis for more detailed consideration at a later date.

5.4 Conclusions and Next steps

The conclusions, from this phase of work, are as follows:

- It is expected that any tram system would require mode shift from car drivers, existing bus users and Park & Ride routes.
- Issues relating to the built environment and reallocation of road space, including on-street parking, will need careful consideration.
- The vaults and utilities will be a significant factor for consideration in any design for a Bath tram system. To reduce the risk of cost increases it will be important to identify these in the next stages of work when developing designs and scheme costs.
- UK light rail and tram systems continue to see growth, as recent DfT figures present record numbers of passenger journeys and vehicle miles.

The next phase of work could include:

- Further development of the network concept, building on the identification of potential corridor priorities that have been identified in this report;
- More detailed analysis of potential demand, building on the initial analyses of markets in this phase of work;
- Potential passenger revenue forecasting, including estimating potential abstraction from bus and Park & Ride;
- Redesign of the Bath bus network to complement Bath Tram proposals and consider options for how this could be delivered;
- Potential operating costs, and subsequent assessment of ongoing financial viability of services;
- Potential construction costs, drawing on more detailed engineering assessments, including allowance for major project risks such as utilities, unforeseen ground conditions and the city vaults;
- Potential wider economic benefits, including the benefits of mode shift in reducing congestion (offset by the effects of shutting city streets to traffic), improved air quality and wider impacts on public realm; and
- Overall assessment of the potential Strategic, Economic and Financial Case, including prospects for securing government and private sector investment.

Methodology – Census Travel to Work

Travel to Work Census (2011) data was extracted from Datashine at a Middle Super Output Area (MSOA) level for both car and bus commuting trips to Bath.

Centroids of origin MSOAs with over 6 journeys to Bath were progressed, while the place of work origin was set as a combination of Bath and North East Somerset MSOAs 007 and 009.

Using the network analysis tool, origin MSOAs and the ‘destination’ Bath MSOAs were linked, presenting the most time-efficient route to undertake the journey. Line thickness represents the number of trips along the road, thicker lines representing more trips.

Methodology – journey purpose

Journey purpose data was extracted from Road Site Interview Surveys that were undertaken at 14 locations around (but not within) Bath city centre in 2014.

Drivers were asked a number of questions, including their journey origin and intended destination, and the purpose of their journey. Results were sifted to only include those with destinations within Bath city centre (approximately 1000 journeys), and origins were then grouped by MSOA, to provide comparability with the Travel to Work data.

The trips were separated into journeys made for work purposes, and those made for leisure reasons. Network analysis was undertaken, to map the routes that these journeys would most likely have taken to travel between their origin and destination points. As trips are overlaid on the map, the thicker the line, the more journeys that are made on that section of road to complete the journey into the centre.

Methodology – key corridor identification

For both the RSI and Census data, the origins of car journeys have been ranked according to their frequency. These ranked “hot spots” have been combined across the two datasets to create a list of the most common origins of journeys to Bath city centre.

The top 30 origins are displayed in the map. Ellipses have been placed over this map, to try and broadly identify the key corridors used to enter Bath. Network analysis has then been undertaken to link the hotspots by road to Bath city centre; the tool selects its route based on the lowest journey time.

Methodology – highway widths

Using the adopted highways GIS layer provided by BANES, highway widths were extracted.

At intervals along a corridor, cross-sections of the highway were analysed to determine how its road space could accommodate trams. Each corridor section was placed into a grouping according to its width (the five parameters set out on the map key) to suggest whether there is sufficient road width for trams to run alongside one footway, or two footways and/or one or two lanes of parked cars.

The process enables the visual highlighting of key pinch points along the network where delivering trams could be difficult according to the existing width of the highway. On the other hand, it highlights where the corridors can accommodate multi-modal transport needs.

While the process is robust in enabling a desk-based review of highway widths, a detailed engineering survey would need to be undertaken as the scheme progresses.

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Methodology – gradients

Using Ordnance Survey contour (10 metre) data and the eight potential routes, gradient information was extracted.

The OS data provides contour lines at 10m intervals. Gradient percentages could then be extracted, measuring the distance between the contour lines along a potential route, based on the fact that their heights were at 10 metre intervals.

Document History

Job number: 5137782			Document ref:			
Revision	Purpose description	Originated	Checked	Reviewed	Authorised	Date
Rev 1.0	Draft	MH/SG	KM	JFC	JFC	21/08/17
Rev 2.0	Final	MH/SG	KM	JFC	JFC	22/09/17
Rev 3.0	Final	MH/SG	KM	JFC	JFC	30/10/17

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