Technical Note

Project:	East of Bath Express
Subject:	Demand Modelling Methodology
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Document history

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Client signoff

Client	Bath & North East Somerset Council / West of England Combined Authority
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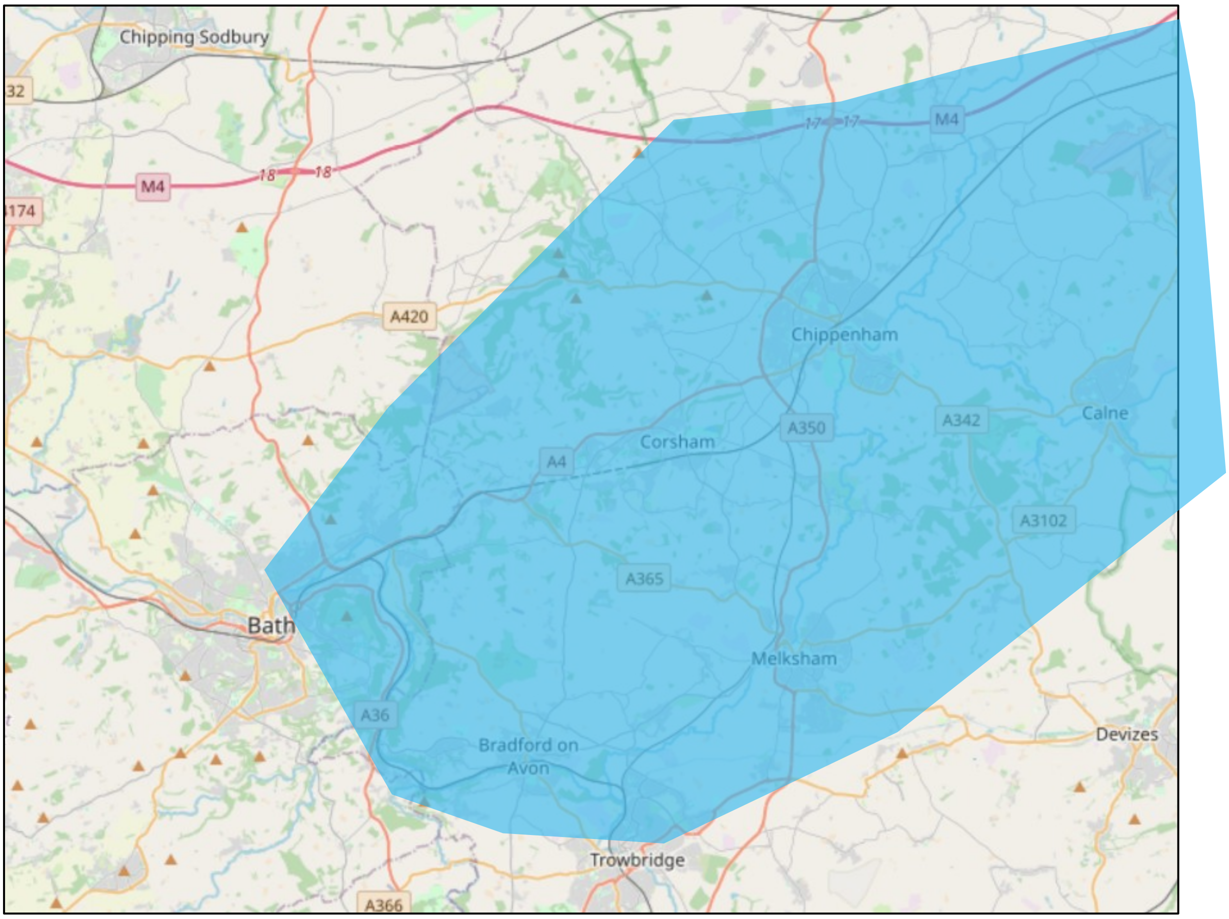
1. Introduction

1.1. Background

There is a long standing and increasing need to reduce private car trips into Bath from the east. With the forthcoming introduction of the Clean Air Zone in central Bath, and Bath & North East Somerset's (B&NES) commitment to carbon neutrality by 2030, high quality sustainable travel options that provide good connectivity and a realistic alternative to the private car are required.

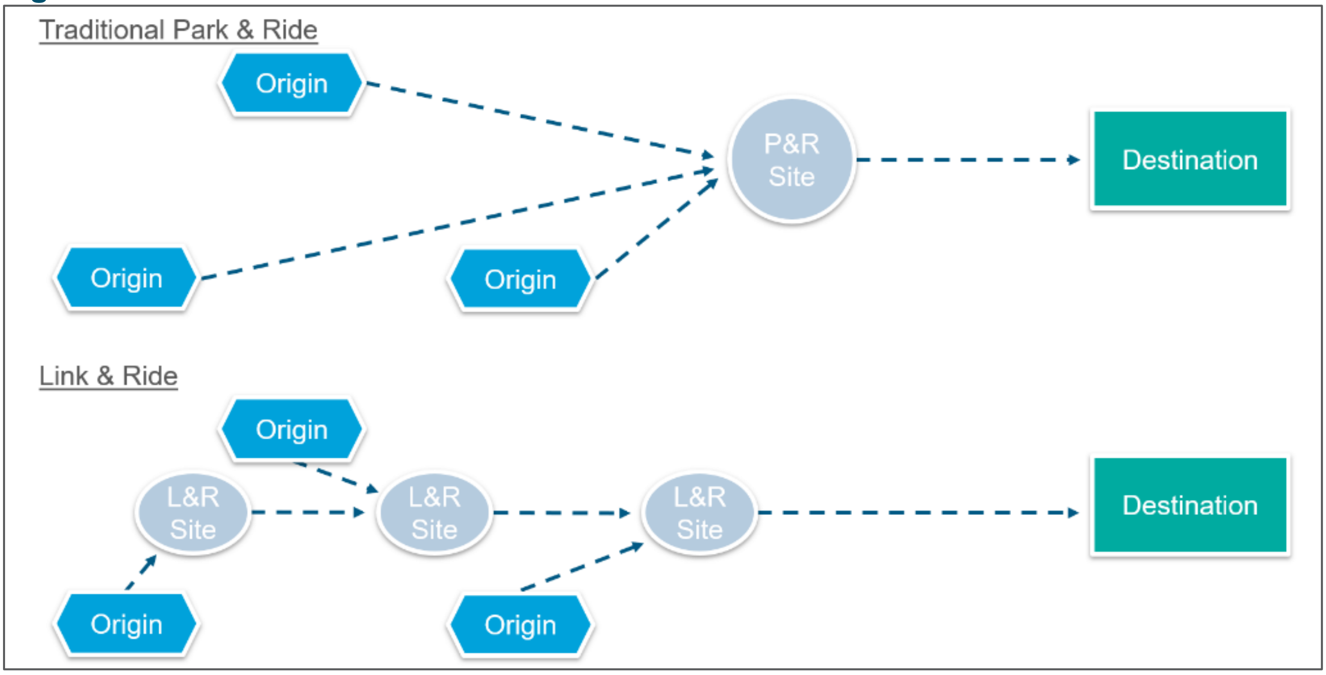
The east of Bath corridor, as shown in Figure 1-1, comprises of residential and employment areas within Bath & North East Somerset (B&NES) and Wiltshire. The A4 is a key route to the east of Bath that connects to North and West Wiltshire including Chippenham, Corsham, Box and a number of other intermediate settlements. The A4 is a single carriageway route running parallel to the rail Great Western Mainline.

Figure 1-1 - East of Bath corridor



This study aims to assess travel demand and how it is currently met from the east of Bath. The study will assess the feasibility of a direct Chippenham to Bath bus offer with local Park & Ride sites which is referred to as a Link and Ride service. The key difference between a P&R scheme and a L&R scheme is that the L&R includes small pockets of parking along a corridor instead of one large parking site, with the aim of reducing the potential environmental impacts and increasing connectivity along the corridor. Figure 1-2 below shows the difference in structure between the two types of scheme.

Figure 1-2 - Park & Ride vs Link & Ride Structure



A demand modelling exercise has been undertaken to understand potential abstraction levels from private car to a new L&R scheme.

This note summarises the methodology followed during this exercise and provides a high-level overview of the results.

1.2. Technical note structure

This technical note is structured as follows:

- Section 2: Model specification overview – A summary of the modelling methodology to be followed to provide context for later sections.
- Section 3: Input data – A summary of the input data used for demand model development, and any associated checks on this data.
- Section 4: Calibration – A summary of the calibration data, the calibration process and calibration results.
- Section 5: Realism testing – A summary of the realism tests undertaken with results.
- Section 6: Forecasting – A summary of the methodology undertaken for forecasting.
- Section 7: Testing & results – A summary of what tests have been undertaken, how they were implemented and what the results were.
- Section 8: Limitations & caveats – A summary of any limitations identified during the demand modelling process and associated caveats.
- Section 9: Summary – A final overview of the demand modelling.

2. Model specification overview

Whilst there is an existing 2014 GBATH SATURN highway assignment model, it was not deemed suitable for the use on this project as the model is deemed too complex for quickly scoping and assessing options. Additionally, the model zones within the study area are too large and therefore would not provide the detail required for option assessment. Therefore, to inform the assessment of the feasibility of the local Link & Ride concept, a bespoke demand model was developed following guidance set out in *TAG: Supplementary Guidance: Bespoke Mode Choice Models*.

An overview of the specification and associated methodology is given here to provide context for the rest of the document.

The demand model comprises of three key elements:

- In-scope demand i.e. identified private car demand accessing Bath from the east.
- The costs for each mode (car and L&R) associated with completing the trip from origin to destination, where the destination is in Bath city centre.
- The logit function to calculate mode split.

Input data has been collated and processed to inform these key elements as detailed in section 3 of this technical note.

Once the key elements are developed, the demand model is then calibrated to achieve mode splits that match those observed at the three existing P&R sites in Bath that lie to the north, west and south of the city. The calibrated demand model then undergoes realism testing as specified by *TAG unit M2-1: Variable Demand Modelling* to determine how responsive the model is to changes in costs. If a model is too responsive it can lead to overestimation of mode shift between modes; if a model is not responsive enough it can lead to underestimation of potential mode shift between modes. The calibration and realism testing of the demand model are detailed in sections 4 and 5 respectively of this technical note.

The above steps are carried out for the demand model base year of 2019. As part of the demand model specification, a forecast year of 2029 is also required. The methodology used to derive this forecast model uses TEMPro 7.2 to develop the forecast demand and standard forecast costs to model the increases in costs from 2019 to 2029. The full methodology is detailed in section 6 of this technical note.

Once the calibrated base year and associated forecast year demand models have been developed, various scenarios are tested to understand how different service options for the L&R could impact on potential mode shift and therefore patronage. Full details of the scenarios tested and the outputs from these tests are given in section 7 of this technical note.

Any identified limitations or caveats associated with the methodology have been specified in section 8 of this technical note.

A summary of the overall methodology, inputs and outputs is given in section 9 of this technical note.

3. Input data

This section summarises the input data used to inform the demand model and the checks undertaken to ensure the inputs are suitable, including:

- Demand and skim information extracted from the GBATH SATURN model and associated checks.
- Zones taken from the GBATH SATURN model and associated refinement.
- Catchment areas developed to enable L&R functionality.
- Generalised time parameters such as values of time (VOTs), vehicle operating costs (VOCs), occupancy factors, city centre parking charges and PT cost elements.

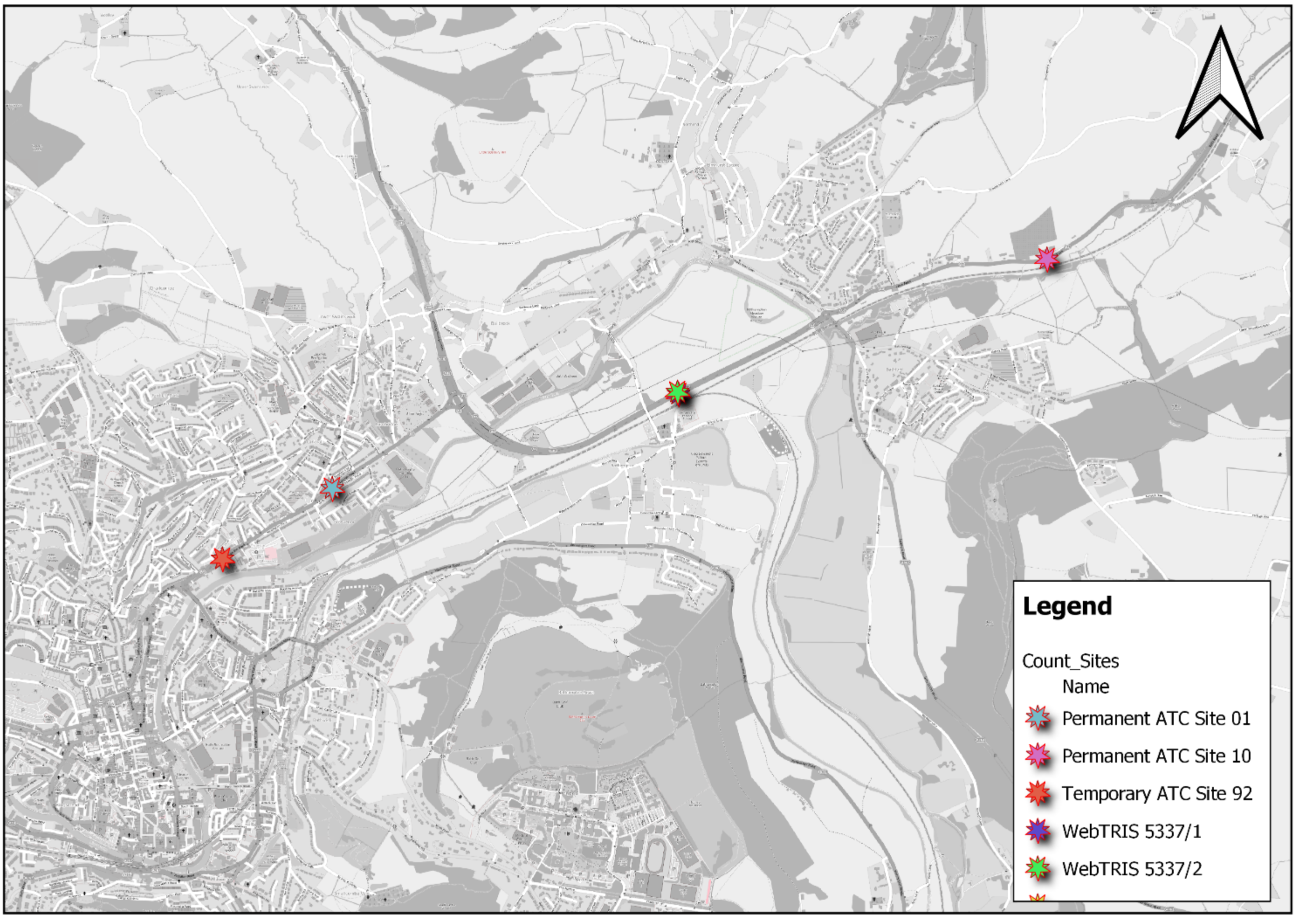
3.1. GBATH flow validation

The existing GBATH SATURN model is a highway assignment model maintained by B&NES that focuses on the city of Bath and surrounding areas. The base year is 2014 and comprises three time periods AM, IP, and PM. Note only the AM peak hour (0800-0900) and the IP average hour (1000-1600) are used for the L&R demand model, because the primary interest of the feasibility study was inbound traffic to Bath most of which typically occurs in the AM peak and inter-peak.

As the GBATH model has a base year of 2014 while the demand model has a base year 2019, it was required to assess the validity / accuracy of the GBATH model along the study corridor. To enable this check, available traffic count data for four sites along the A4 was collected. These sites included permanent ATC sites maintained by B&NES, a temporary ATC site used by B&NES in 2018 and two Highways England Wertis sites.

A map showing all the locations of each of the count sites is shown in Figure 3-1 below.

Figure 3-1 - Map showing all the count sites



Count data was filtered for neutral weekdays (i.e. Tuesday, Wednesday, and Thursday) from 29th September to 24th October for all available data years. These dates were chosen as the existing GBATH model is calibrated and validated to this period in 2014 and therefore it was appropriate to remain with these dates. A summary of the count sites and any limitations observed at each site for this date window is given in Table 3-1.

Table 3-1 – Data Filtered for the Analysis

Name of the Count Site	Data Source	Date Window (Tues-Thurs)	Comments/ Limitations
ATC Site 00000001: A4 London Road - W of Beaufort West	Permanent ATC	29th September to 24th October	Full volume data is available in 2014, 2016 and 2018. Exclusive bus lane data is available from 2015 in Westbound whereas it is missing for few weekdays in 2015 and 2017.
ATC Site 00000010: A4 Box Road - W of County Boundary	Permanent ATC	29th September to 24th October	Full volume data is available in 2014 and 2015.

Name of the Count Site	Data Source	Date Window (Tues-Thurs)	Comments/ Limitations
ATC Site 00000092: 19 - A4 London Road	Temporary ATC	10th November to 16th November	Full volume data is available in 2018.
WebTRIS Site – TMU 5337/1: A4	WebTRIS	29th September to 24th October	Full volume data is available in 2015, 2016, 2017, 2018, and 2019.

The count data was processed to provide average neutral weekday flows for each of the demand model time periods, i.e. AM peak hour and average IP, as shown in Table 3-2 to Table 3-9 below.

For the two permanent ATC sites (Site 01 and Site 10), no 2019 data was available. It was therefore necessary to extrapolate to 2019 using historic data via the Compound Annual Growth Rate (CAGR) method for these sites. The highlighted blue columns indicate which years were used for the extrapolation for each of the sites. Note the underlying trends for Site 01 and Site 10 are generally that traffic flow is decreasing along the corridor in recent years – this is as the corridor is at capacity and experiencing severe delays, therefore leading to traffic finding alternative routes and rat-running along parallel residential roads to avoid the delays on the corridor.

Table 3-2 - October Average Tuesday - Thursday Count for ATC Site 00000001: A4 London Road - W of Beaufort West (Westbound / Inbound)[1]

Description	2014	2015	2016	2017	2018	CAGR* (%)	2019(E)*
AM Peak (0800 - 0900)	809	656	672	623	687	1.1%	694
IP Average (1000 - 1600)	796	712	792	784	787	-0.3%	785

Table 3-3 - October Average Tuesday - Thursday Count for ATC Site 00000010: A4 Box Road - W of County Boundary (Westbound / Inbound)[1]

Description	2014	2015	2016	2017	2018	CAGR* (%)	2019(E)*
AM Peak (0800 - 0900)	605	585	-	-	-	-3.2%	515
IP Average (1000 - 1600)	369	362	-	-	-	-2.1%	335

[1] *CAGR* (%) – Compound Annual Growth Rate is calculated using between the Bold Texted Column Years*
2019(E) - Extrapolated Data for the Year 2019*

Table 3-4 - October Average Tuesday - Thursday Count for ATC Site 00000092: 19 - A4 London Road (Westbound / Inbound)[1]

Description	2014	2015	2016	2017	2018	CAGR* (%)	2019(E)*
AM Peak (0800 - 0900)	-	-	-	-	823	-	-
IP Average (1000 - 1600)	-	-	-	-	855	-	-

Table 3-5 - October Average Tuesday - Thursday Count for WebTRIS Site – TMU 5337/1: A4 (Westbound / Inbound)[1]

Description	2014	2015	2016	2017	2018	CAGR* (%)	2019(E)*
AM Peak (0800 - 0900)	-	1,225	1,189	1,223	1,137	-	1,154
IP Average (1000 - 1600)	-	702	709	725	695	-	733

Table 3-6 - October Average Tuesday - Thursday Count for ATC Site 00000001: A4 London Road - W of Beaufort West (Eastbound / Outbound) [1]

Description	2014	2015	2016	2017	2018	CAGR* (%)	2019(E)*
AM Peak (0800 - 0900)	794	741	778	752	744	-2.2%	727
IP Average (1000 - 1600)	787	742	787	761	779	-0.5%	775

Table 3-7 - October Average Tuesday - Thursday Count for ATC Site 00000010: A4 Box Road - W of County Boundary (Eastbound / Outbound) [1]

Description	2014	2015	2016	2017	2018	CAGR* (%)	2019(E)*
AM Peak (0800 - 0900)	615	570	-	-	-	-7.4%	419
IP Average (1000 - 1600)	369	364	-	-	-	-1.5%	344

Table 3-8 - October Average Tuesday - Thursday Count for ATC Site 00000092: 19 - A4 London Road (Eastbound / Outbound)[1]

Description	2014	2015	2016	2017	2018	CAGR* (%)	2019(E)*
AM Peak (0800 - 0900)	-	-	-	-	877	-	-
IP Average (1000 - 1600)	-	-	-	-	890	-	-

Table 3-9 - October Average Tuesday - Thursday Count for WebTRIS Site – TMU 5337/2: A4 (Eastbound / Outbound) [1]

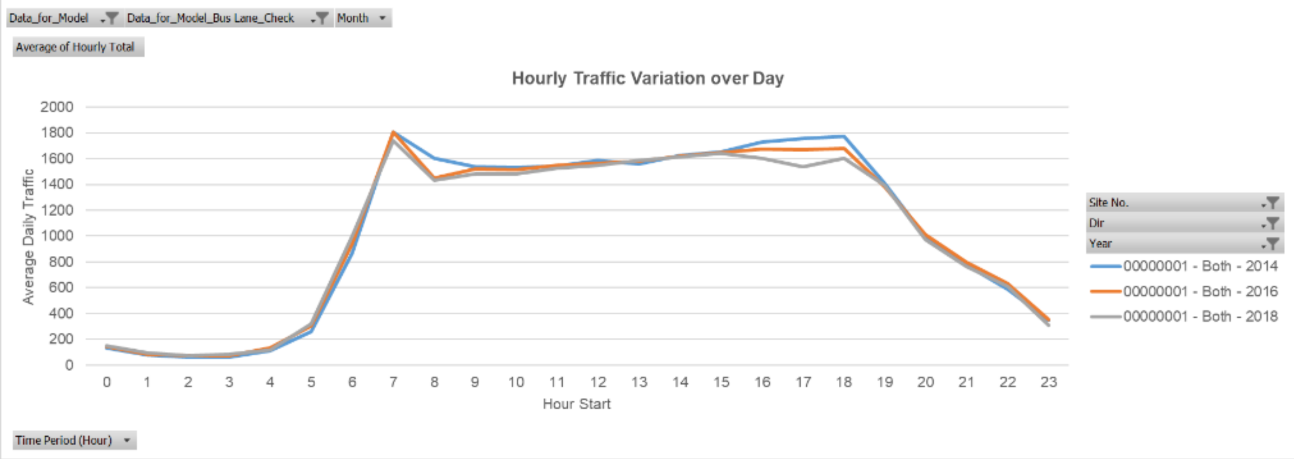
Description	2014	2015	2016	2017	2018	CAGR* (%)	2019(E)*
AM Peak (0800 - 0900)	-	1,095	1,081	1,085	1,064	-	1,086
IP Average (1000 - 1600)	-	688	683	693	680	-	697

To further understand how traffic moves along the study corridor through the day, hourly traffic variation graphs were prepared for each site and are shown in Figure 3-2 below.

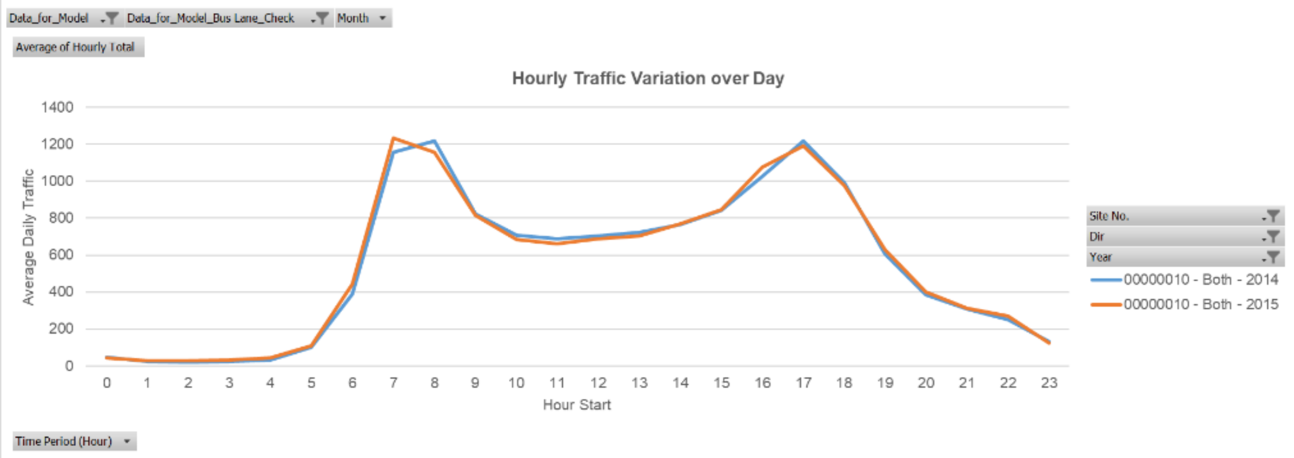
The permanent ATC Site 01 and the temporary ATC Site 92 lie geographically near to each other and highlight that the London Road corridor experiences high levels of traffic from the AM spike at 0700 through to the PM drop off at 1900. The permanent ATC Site 10 is further to the east along the A4 corridor and shows lower levels of congestion during the inter-peak period, with traffic levels spiking only during the AM peaks of 0700-0900 and the PM peak of 1700-1800.

Figure 3-2 - Hourly Variation of Average Day Count for Each ATC Site (Both Directions)

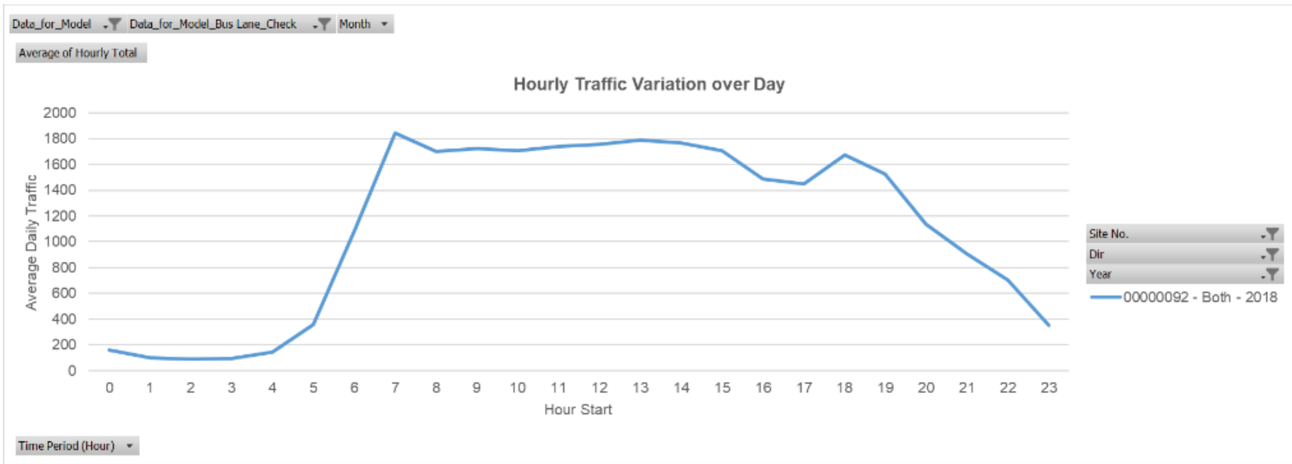
Site 00000001: A4 London Road - W of Beaufort West



Site 00000010: A4 Box Road - W of County Boundary



Site 00000092: 19 - A4 London Road



To understand how well-validated the GBATH model is along the study corridor, and to assess whether any demand scaling is necessary to move from the GBATH base year 2014 to the demand model base year 2019, a comparison between the observed count data and the GBATH modelled flows was undertaken. This validation check was split into three sections:

1. Compare observed 2014 counts (permanent ATC sites only) against 2014 modelled flows (shown in Table 3-10 and Table 3-11).
2. Compare 2019 observed counts (extrapolated permanent ATC sites and WebTRIS sites) against 2014 modelled flows (shown in Table 3-12 and Table 3-13).
3. Compare observed 2018 counts (temporary ATC site only) against 2014 modelled flows (shown in Table 3-14 and Table 3-15).

The first comparison to assess the validation of the 2014 GBATH flows against the 2014 observed count data shows the GBATH model holds a high level of validation for all sites apart from Site 01 inbound in the AM peak hour.

Table 3-10 –2014 observed counts vs 2014 GBATH model flows – AM Peak (0800-0900)

Site Name	Direction	Link ID	Observed Flows (2014)	Modelled Flows (2014)	Diff	% Diff	GEH	Pass / Fail
ATC Site 01	WB / Inbound	6003_6001	809	1,076	267	33%	9	Fail
ATC Site 10	WB / Inbound	23626_2108	605	520	-85	-14%	4	Pass
ATC Site 01	EB / Outbound	6001_6003	794	740	-55	-7%	2	Pass
ATC Site 10	EB / Outbound	2108_23626	615	573	-43	-7%	2	Pass

Table 3-11 –2014 observed counts vs 2014 GBATH model flows – IP Average (1000-1600)

Site Name	Direction	Link ID	Observed Flows (2014)	Modelled Flows (2014)	Diff	% Diff	GEH	Pass / Fail
ATC Site 01	WB / Inbound	6003_6001	796	890	93	12%	3	Pass
ATC Site 10	WB / Inbound	23626_2108	369	371	2	1%	0	Pass
ATC Site 01	EB / Outbound	6001_6003	787	755	-32	-4%	1	Pass
ATC Site 10	EB / Outbound	2108_23626	369	379	10	3%	1	Pass

The second comparison to assess the validation of the 2014 GBATH flows against the 2019 observed (and extrapolated) count data shows the GBATH model validates well against the WebTRIS dataset but is higher than the observed counts for the permanent ATC sites (Site 01 and Site 10). As the 2019 counts for the permanent ATC sites are extrapolated, and therefore have a lower confidence interval compared with the WebTRIS dataset, these differences are determined to be acceptable.

Table 3-12 – 2019 observed counts vs 2014 GBATH model flows – AM Peak (0800-0900)

Site Name	Direction	Link ID	Observed Flows (2019)	Modelled Flows (2014)	Diff	% Diff	GEH	Pass/ Fail
ATC Site 01	WB / Inbound	6003_6001	694*	1,076	382	55%	13	Fail
ATC Site 10	WB / Inbound	23626_2108	515*	520	5	1%	0	Pass
WebTRIS 5337/1	WB / Inbound	2113_4226	1,154	1,050	-104	-9%	3	Pass
ATC Site 01	EB / Outbound	6001_6003	727*	740	12	2%	0	Pass
ATC Site 10	EB / Outbound	2108_23626	419*	573	153	37%	7	Fail
WebTRIS 5337/2	EB / Outbound	4226_2113	1,086	994	-93	-9%	3	Pass

**Extrapolated values rather than observed 2019 data*

Table 3-13 – 2019 observed counts vs 2014 GBATH model flows – IP Average (1000-1600)

Site Name	Direction	Link ID	Observed Flows (2019)	Modelled Flows (2014)	Diff	% Diff	GEH	Pass/ Fail
ATC Site 01	WB / Inbound	6003_6001	785*	890	105	13%	4	Pass
ATC Site 10	WB / Inbound	23626_2108	335*	371	36	11%	2	Pass

Site Name	Direction	Link ID	Observed Flows (2019)	Modelled Flows (2014)	Diff	% Diff	GEH	Pass/ Fail
WebTRIS 5337/1	WB / Inbound	2113_4226	733	697	-24	-3%	1	Pass
ATC Site 01	EB / Outbound	6001_6003	775*	755	-20	-3%	1	Pass
ATC Site 10	EB / Outbound	2108_23626	344*	379	36	10%	2	Pass
WebTRIS 5337/2	EB / Outbound	4226_2113	697	674	-24	-3%	1	Pass

The third comparison to assess the validation of the 2014 GBATH flows against the 2018 observed temporary ATC count data shows the GBATH model validates well except in the AM peak hour for the outbound direction.

Table 3-14 – 2018 observed counts vs 2014 GBATH model flows – AM Peak (0800-0900)

Site Name	Direction	Link ID	Observed Flows (2018)	Modelled Flows (2014)	Diff	% Diff	GEH	Pass/ Fail
Site 92	WB / Inbound	6007_2030	912	868	-44	-5%	1	Pass
Site 92	EB / Outbound	2030_6007	931	759	-172	-18%	6	Fail

Table 3-15 – 2018 observed counts vs 2014 GBATH model flows – IP Average (1000-1600)

Site Name	Direction	Link ID	Observed Flows (2018)	Modelled Flows (2014)	Diff	% Diff	GEH	Pass/ Fail
Site 92	WB / Inbound	6007_2030	888	787	-101	-11%	3	Pass
Site 92	EB / Outbound	2030_6007	947	870	-77	-8%	3	Pass

Due to the limitations identified for the permanent ATC sites and the lower confidence interval associated with the extrapolated 2019 counts at these sites, it was decided that the GBATH model validates for 2019 against the count data and therefore no demand scaling is required to convert from the GBATH 2014 demand to 2019 demand.

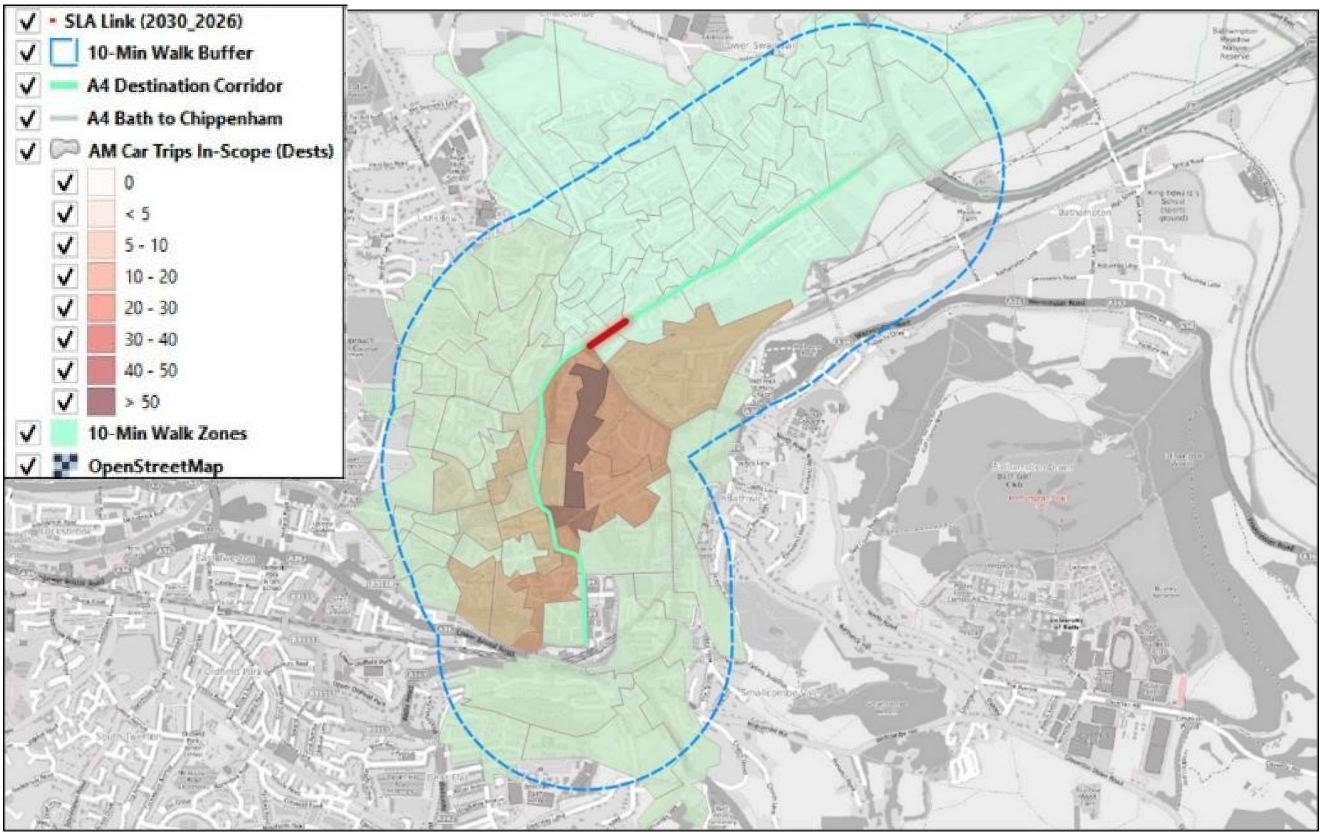
3.2. Identifying demand in-scope

To identify which demand from the GBATH model was relevant for input to the demand model, it was required to develop the in-scope demand. This involved identifying which Bath city centre destination zones from the GBATH model could be considered in-scope, i.e. L&R passengers would be able to access these zones on foot once they had alighted at a city centre bus stop. Following this analysis of the GBATH model was undertaken to understand the origins of the trips going to these zones.

3.2.1. In-scope destinations

A destination corridor for the L&R scheme in Bath city centre was developed based on the existing X31 bus route through the city centre. This corridor was extended to the north-east along London Road following discussions with B&NES. A 10-minute walk buffer around the destination corridor using a walk speed of 4km/hr was created and all model zones within that buffer were designated as in-scope destination zones. Figure 3-3 below shows the destination corridor and the associated in-scope destination zones.

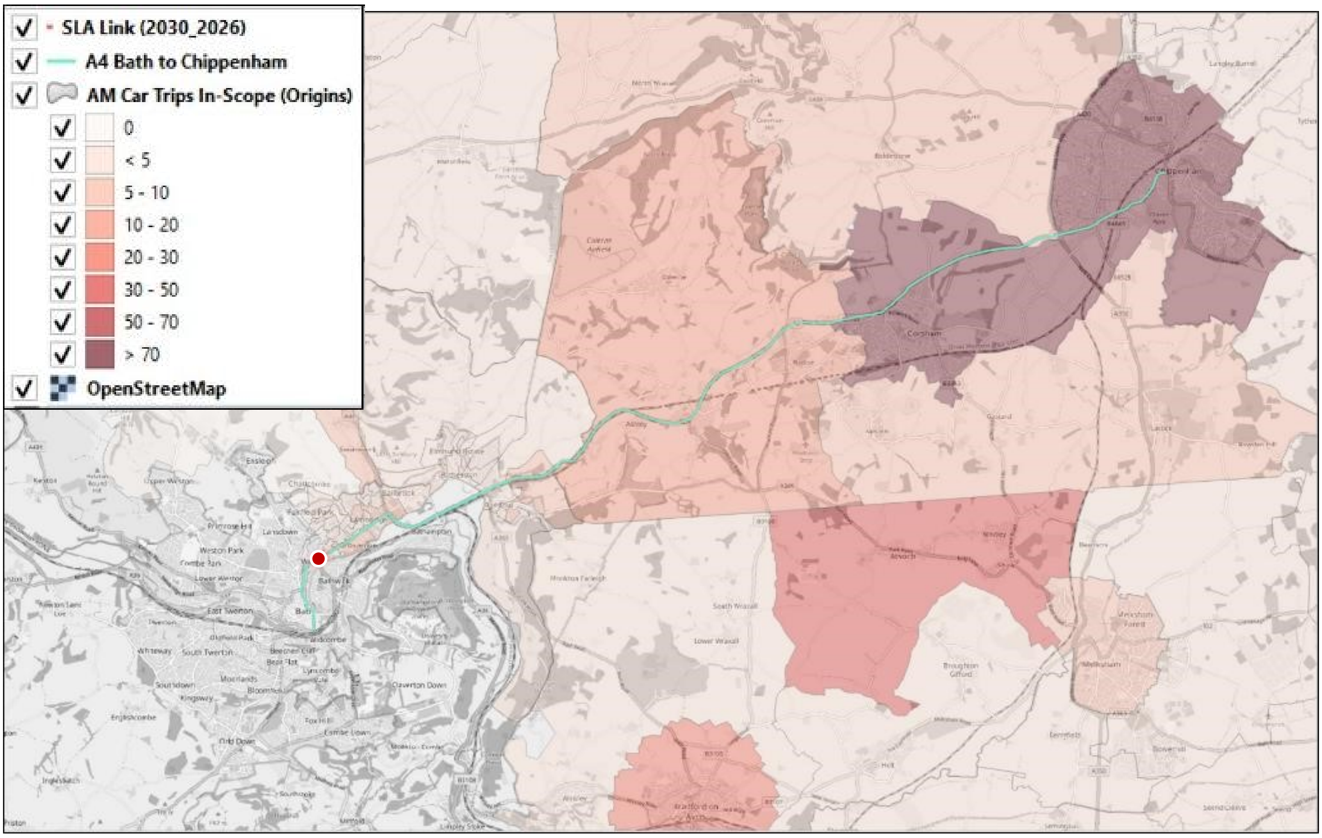
Figure 3-3 - A4 In-scope Destinations (with AM Car Demand from GBATH)



3.2.2. In-scope origins

Using SATURN transport modelling software, it is possible to identify origins and destinations for all trips which travel along a selected route (link); this is called a select link analysis (SLA). To determine in-scope origins, i.e. locations where it is expected potential L&R users would travel from, an SLA was undertaken for the link indicated in Figure 3-4 below (a link between Cleveland Place and the London Road / A4 roundabout). Destinations that were in-scope (as outlined above) were selected and used to select the in-scope origin zones, as shown in Figure 3-4, this produced in-scope origin-destination pairs.

Figure 3-4 - A4 In-scope Origins (with AM Car Demand from GBATH)



The identified in-scope vehicle demand for each purpose and time period are shown in Table 3-16 below. This is broken down into journey purposes as defined by TAG to categorise a range of journey purposes and as applied in the GBATH model.

Table 3-16 - Base year in-scope vehicle demand totals by purpose and time period

Journey Purpose	Base AM Demand	Base IP Demand
Home-based work (HBW)	545	100
Home-based employers' business (HBEB)	28	23
Home-based other (HBO)	495	550
Non home-based employers' business (NHBEB)	15	30
Non home-based other (NHBO)	134	72
Total	*1,216*	*776*

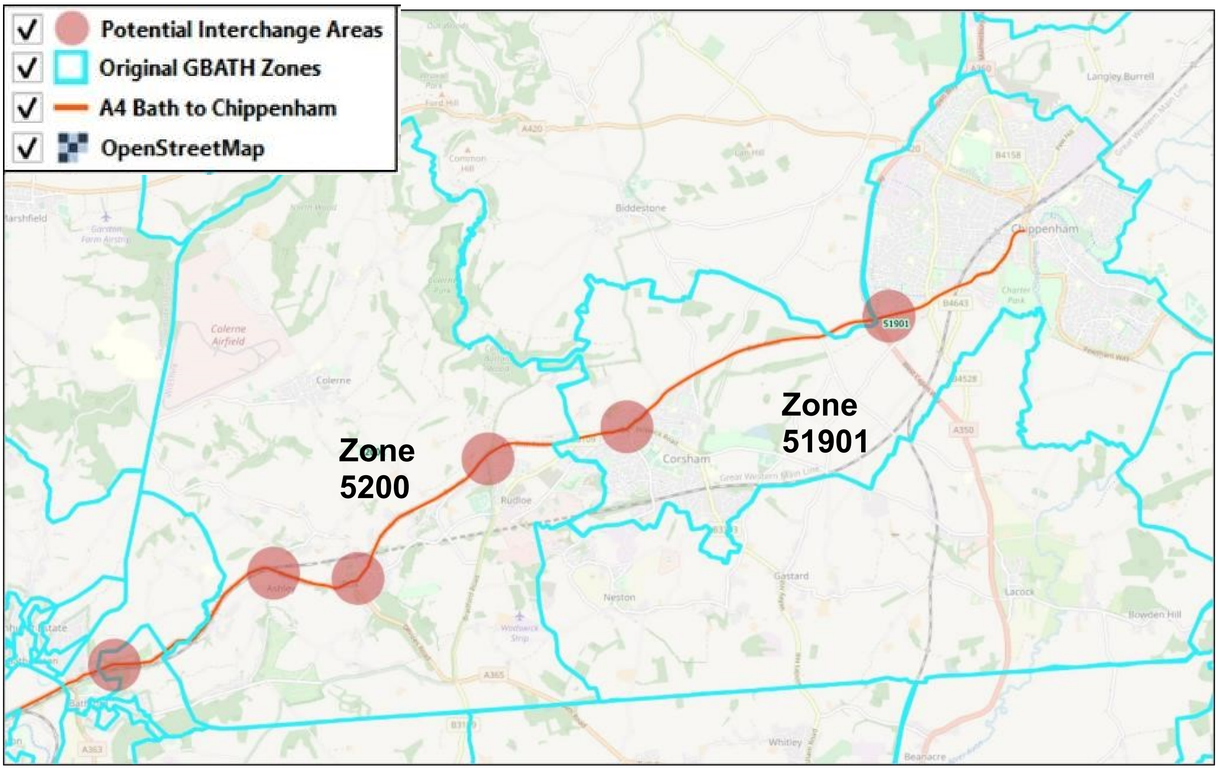
3.3. Refining GBATH zones

The GBATH model zones along the study corridor, as seen below in Figure 3-5, were very large and did not provide a high enough level of detail to allow for the potential interchange L&R sites. Two zones were identified for refinement along the A4 corridor:

1. 52001: Contains the settlements of Ashley, Box, Rudloe, Colerne.
2. 51901: Contains the settlements of Corsham and Chippenham.

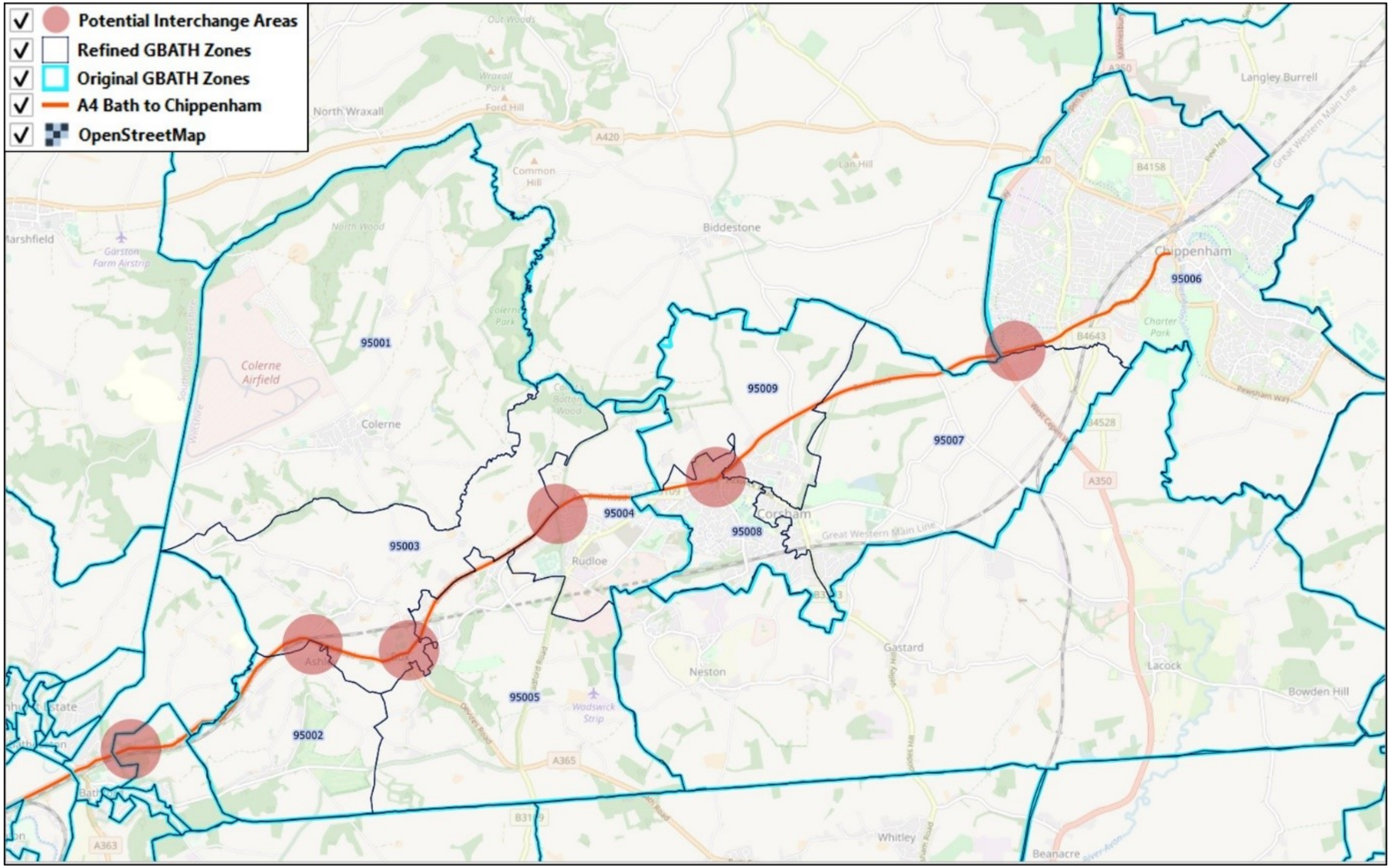
The rational for refining these zones is twofold. Firstly, the model zones need to be small and detailed enough to inform journey time differences associated with accessing the L&R scheme from different sites. Secondly, to fully understand where people are travelling from to use the L&R scheme for reporting to stakeholders a greater level of detail was required.

Figure 3-5 - GBATH Model Zones along A4 Corridor (with Potential Interchanges)



To refine zones 52001 and 51901, Output Area (OA) and Lower Super Output Area (LSOA) boundaries were used as a basis. This allowed the western zone 52001 to be split into five new zones, and the eastern zone 51901 to be split into four new zones. The split is shown in Figure 3-6 below.

Figure 3-6 - Refined Model Zones (with Potential Interchanges)



The refinement for the demand associated with the two original GBATH zones used Census 2011 population data. Total population within each smaller refined zone was calculated and the demand split proportionate to this. The proportions are given below in Table 3-17.

Table 3-17 - Proportions Used for GBATH Zone Demand Refinement

GBATH Zone	Refined Zone	Census 2011 Population	Split Proportion
52001	95001	2,972	39%
52001	95002	522	7%
52001	95003	811	11%
52001	95004	2,152	28%
52001	95005	1,191	16%
52001	*Total*	*7,648*	*100%*
51901	95006	35,800	78%
51901	95007	1,641	4%
51901	95008	5,919	13%
51901	95009	2,423	5%
51901	*Total*	*45,783*	*100%*

It was decided to refine the skim data (matrices containing distance and journey time values for each zone to zone movement) directly within the SATURN model. The methodology used for this is as follows:

1. Split the Origin-Destination matrices using the proportions stated in Table 3-17 for all time periods.
2. Assign population-weighted centroids for the refined zones via OA and LSOA population-weighted centroids.
3. Determine suitable connection points to the SATURN network and code the refined zones.
4. Run the SATURN assignment (process where SATURN selects/assigns routes between origins and destinations in the modelled network) for AM, IP and PM using the same SATURN version as the original GBATH model (11.3.10).
5. Finally, the skims for the refined GBATH model were then extracted for use within the demand model.

3.4. Defining catchment areas

For the L&R mode, catchment areas were defined for the interchange sites along the A4 corridor where users would park their cars (access catchment areas). Catchment areas were also defined for the bus stops in the city centre where users would alight to walk to their destination (egress catchment areas). These catchment areas were defined in order to allocate demand from the origin-destination zones to the most appropriate access points (interchanges) and egress points on the L&R route.

Access catchment areas were defined by identifying how individuals would choose a L&R site based on existing road structures. All in-scope origin zones were allocated an access catchment area.

Egress catchment areas were defined by minimum walk time from an existing X31 bus stop, as it is assumed these bus stops would also be used by the L&R service. All in-scope destination zones were allocated an egress catchment area. Based on the access and egress catchment areas, an access L&R site and an egress city centre bus stop is allocated for each in-scope origin and destination pair.

Figure 3-7 shows the access catchment areas as defined for all in-scope origin zones, and Figure 3-8 shows the egress catchment areas as defined for all in-scope destination zones.

Figure 3-7 - Catchment Areas for each Potential L&R Interchange Area

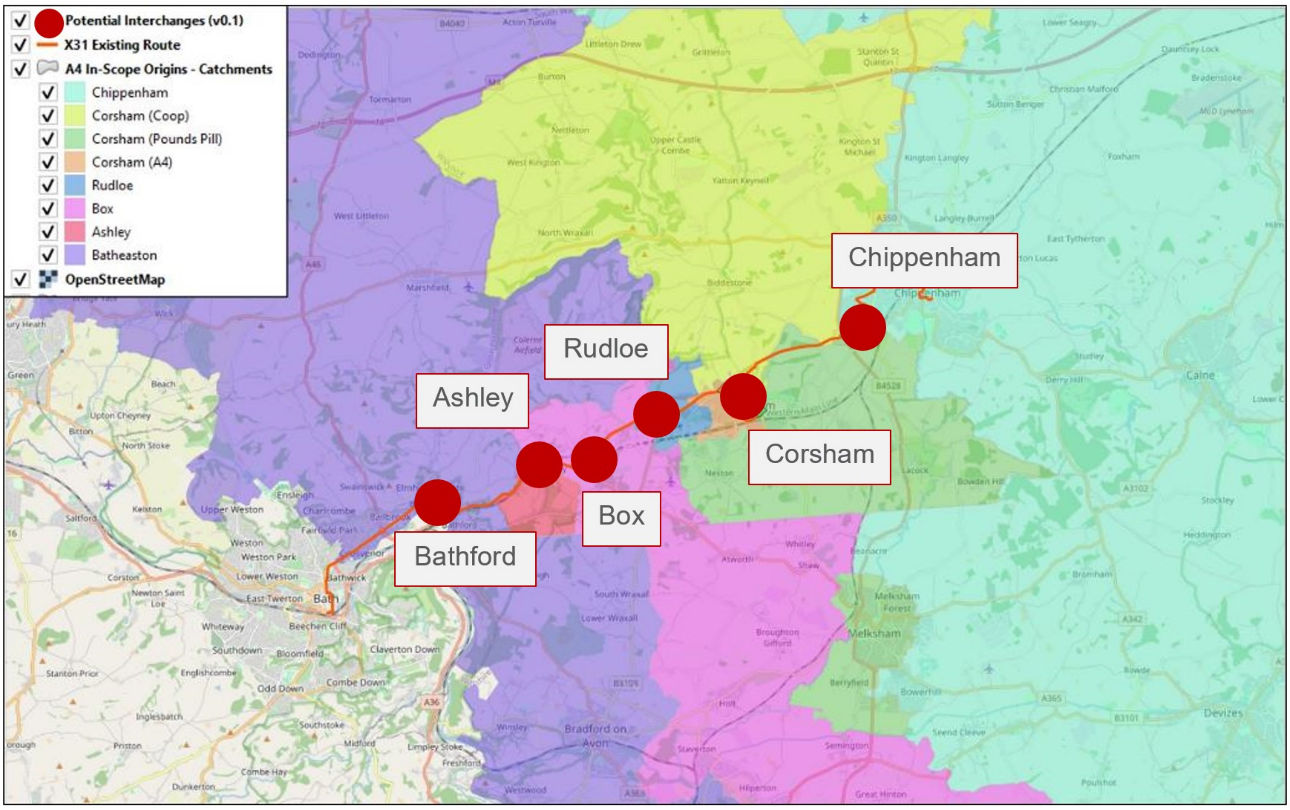
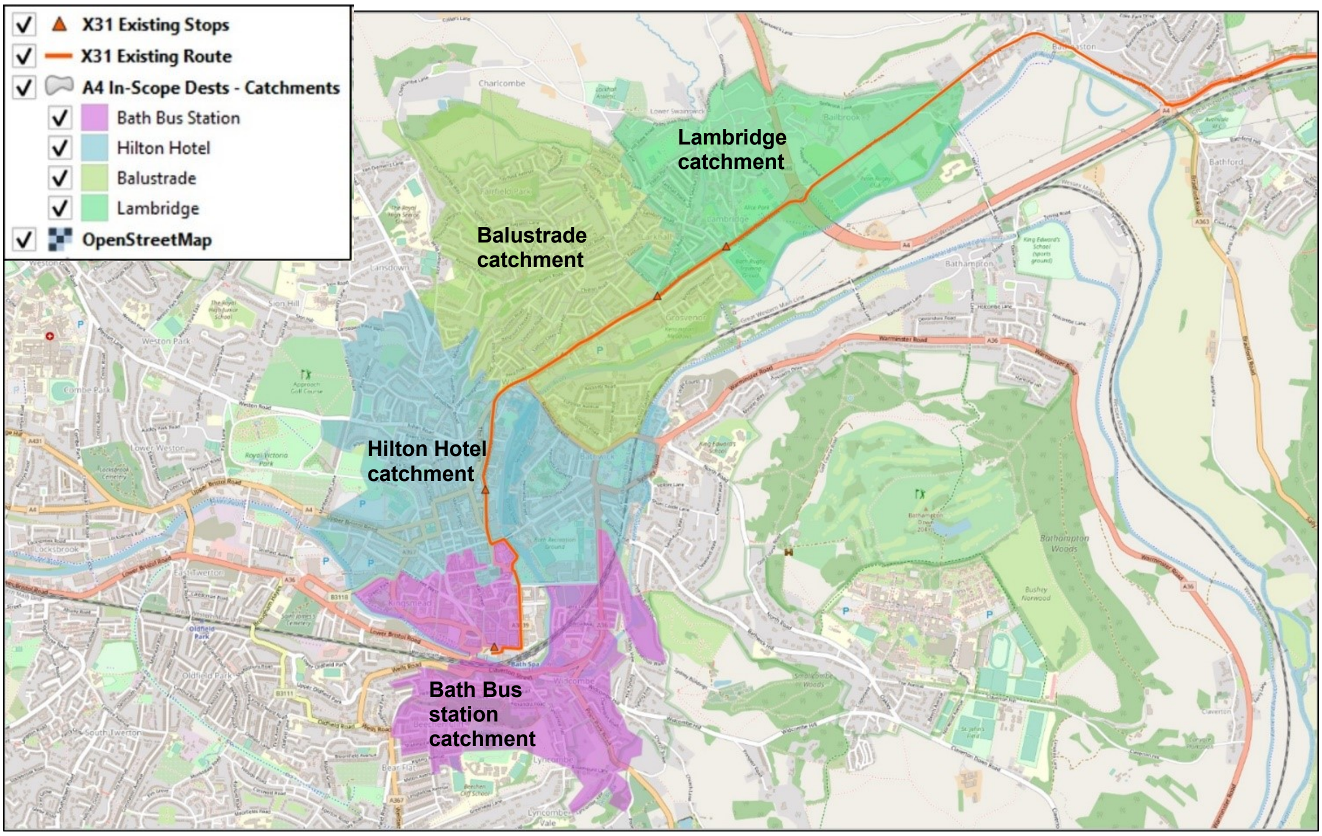


Figure 3-8 - Egress Catchment Areas for each Existing X31 City Centre Bus Stop



3.5. Generalised time formulation

To enable a comparison between the costs associated with completing an origin-destination trip by car versus the costs associated with completing the same origin-destination trip by L&R, generalised times for each mode are calculated.

These generalised times, which include everything from the fuel costs associated with a car trip to waiting times associated with catching a bus, contain different elements for both car and L&R and are built up in different ways. Figure 3-9 and Figure 3-10 show the two different modes and the associated costs that are included in the generalised time along the route for a journey completed by each mode.

As per the approach set out in *TAG: Supplementary Guidance: Bespoke Mode Choice Models*, walk time was added as a cost time for the L&R mode but not the car mode. It is recognised that the nature of Bath city centre's layout means that some car users may have to walk to their final destination from their parking location, however the decision was made to follow the TAG approach for the purpose of this assessment. It is also considered appropriate in that it reflects the perception of car drivers that typically their journey ends at the point of parking their vehicle.

For the car mode, city centre parking and congestions charges are included for the relevant destination zones where these charges exist.

Figure 3-9 - Car Mode: Generalised Time Elements along Route

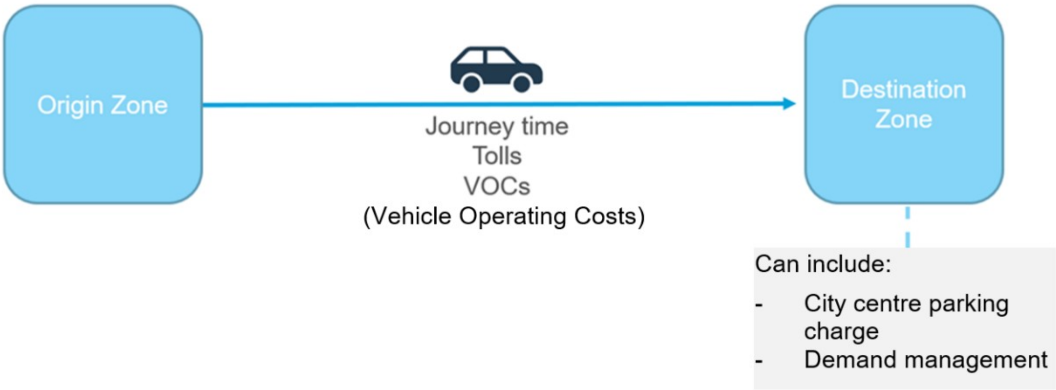
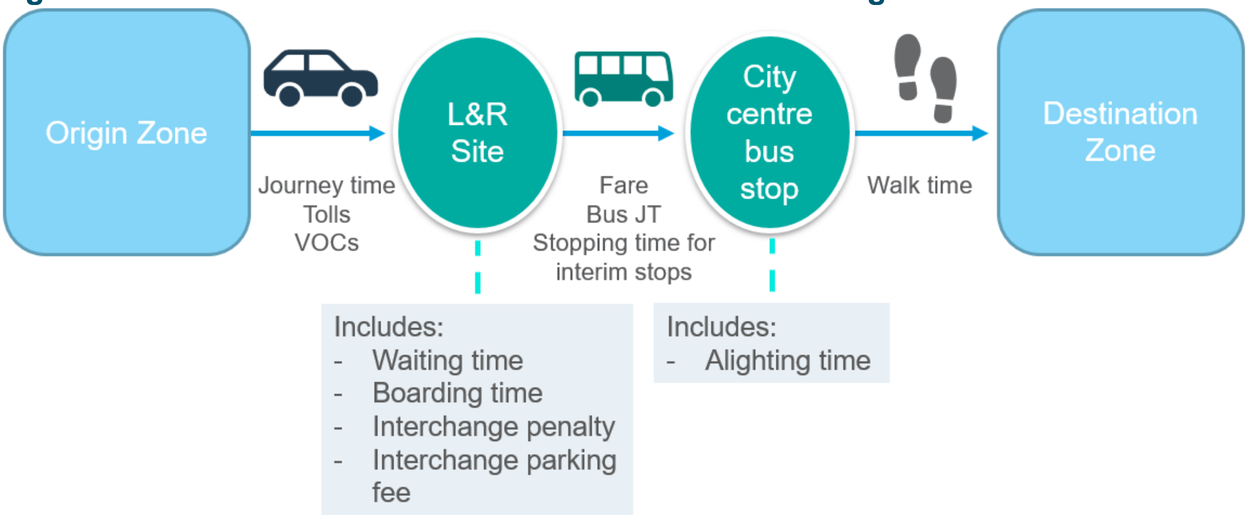


Figure 3-10 - L&R Mode: Generalised Time Elements along Route



The parameters feeding thee equations to calculate generalised time for car mode and L&R mode are presented visually in Figure 3-9 and Figure 3-10 above, are given in the Table 3-18 to Table 3-23 below.

3.5.1. Car skims

Journey time information for travelling between an origin-destination pair by car mode was taken from the refined SATURN assignments (i.e. 2014), along with distance skims for each in-scope origin-destination pair. Any toll information was provided by the refined SATURN assignments, although it is noted no tolls were observed for any of the in-scope origin-destination pairs. These skims were assumed to be same for 2019 and 2029 for input to the demand model – more detail on this is given in sections 6 and 8.

3.5.2. Value of time (VOT)

Values of time (VOT) are taken from TAG data book July 2020 (v1.13.1) for each time period and purpose. Table 3-18 show the perceived values for the AM peak and average IP for individuals travelling via car mode.

Table 3-18 - Perceived Value of Time (pence/min) for the year 2019 at 2010 prices

TAG Purpose	L&R Purpose	AM peak	Average IP
Car business	HBEB, NHBEB	31.03	31.79
Car commute	HBW	20.81	21.15
Car other	HBO, NHBO	14.36	15.29

Table 3-19 - Perceived Value of Time (pence/min) for the year 2029 at 2010 prices

TAG Purpose	L&R Purpose	AM peak	Average IP
Car business	HBEB, NHBEB	35.50	36.38
Car commute	HBW	23.81	24.20
Car other	HBO, NHBO	16.43	17.50

VOTs for public transport users are not defined at both the purpose and time period level within TAG, and it is therefore necessary to develop these. To calculate these values, the ratio between Car Passenger and L&R VOTs at the total level is applied to the car VOTs shown in Table 3-18. Table 3-20 shows the car to L&R ratio that is calculated for 2019 and 2029 and used to derive the L&R VOTs by purpose and time period.

Table 3-20 - Perceived Value of Time (pence/min) by Passenger (2010 prices, Year 2019 and Year 2029 values)

Mode	VOT - 2019	VOT - 2029
Car passenger	27.44	31.40
L&R passenger	15.55	17.79
Ratio of Car to L&R	0.5667	0.5667

Source: TAG_Databook_1.13.1 (July2020)

3.5.3. Vehicle operating cost (VOC)

Vehicle operating costs (VOC) are taken from TAG data book July 2020 (v1.13.1) by purpose and by year and are shown in Table 3-21. Note there is no variation across time periods as the costs associated with operating a vehicle do not vary throughout the day. The difference from 2019 to 2029 highlights that current predictions anticipate it will be cheaper to operate a vehicle in future years.

Table 3-21 - Perceived Vehicle Operating Cost (pence/km) for the Year 2019 and Year 2029 at 2010 prices

TAG Purpose	L&R Purpose	VOC - 2019	VOC - 2029	% Diff
Car Business	HBEB, NHBEB	12.26	10.86	-11%
Car Commuter	HBW	5.81	5.06	-13%
Car Other	HBO, NHBO	5.81	5.06	-13%

Source: TAG_Databook_1.13.1 (July2020); Highways England

3.5.4. Car occupancy factors

Car occupancy factors are taken from TAG data book July 2020 (v1.13.1) and have been applied by purpose. Table 3-22 show the car occupancy values for AM period, the IP period and the PM period.

Table 3-22 – Car Occupancy Values for the Year 2019

TAG Purpose	L&R Purpose	AM Peak	IP Peak	PM Peak
HB Work (Commuter)	HBW	1.17	1.15	1.16
HB Employer's Business	HBEB	1.20	1.19	1.17
HB Other	HBO	1.68	1.65	1.71
NHB Employer's Business	NHBEB	1.20	1.19	1.17
NHB Other	NHBO	1.68	1.65	1.71

Note that according to TAG data book July 2020 (v1.13.1) *Table A1.3.3*, car passenger occupancy values are constant up to 2036.

3.5.5. City centre parking charges

Existing Bath city centre parking charges were collected from the MiPermit website owned by B&NES. The website provides a list of existing parking locations within Bath that are owned and operated by B&NES and the charges associated with each car park. These car parks include both the typical large off-street car parks and the on-street parking. Note no private car parks are included in the list on the MiPermit website as they are not operated by B&NES.

The parking charges have been collected for the different purposes as follows:

- Commuter purpose (HBW) – 8-hour parking tariff.
- Business and Other purposes (HBEB, HBO, NHBEB, NHBO) – 2-hour parking tariff.

Note for some parking sites 2-hour tariffs were not available. In these cases, the nearest available charge has been taken.

For some sites, long stay parking is not an available tariff that can be purchased, i.e. long stay parking is not allowed. There are two ways to deal with this within the model. Option (2) has been assumed for the demand modelling tool:

1. Assume no long stay parking is allowed within the associated model zone and add a large penalty in the Car generalised time for the associated purpose.
2. Assume long stay parking happens in unofficial locations, i.e. workplace car parks and on-street unpaid parking and allocate £0 long stay parking charge for the associated model zone.

The collected car park locations are used to map against GBATH model zones. As there is the case of multiple car parks with different tariffs being within one zone, an average short stay and long stay parking charge has been derived for each model zone. These charges are added to the Car generalised time as a zonal destination attribute for in-scope destination zones.

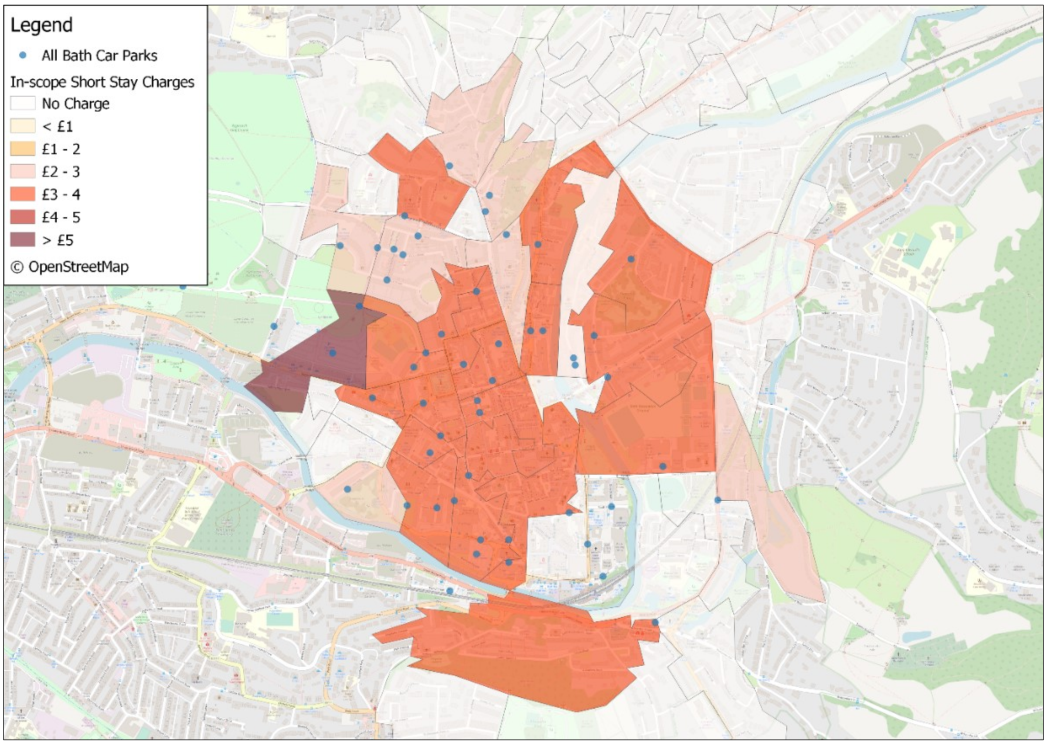


Figure 3-11 and

Figure 3-12 below show the in-scope destination zones with associated short stay and long stay parking charges respectively that will be applied in the demand modelling tool for car trips going to these zones.

Figure 3-11 - Model Zones with Short Stay Parking Charges, In-Scope Destinations Only

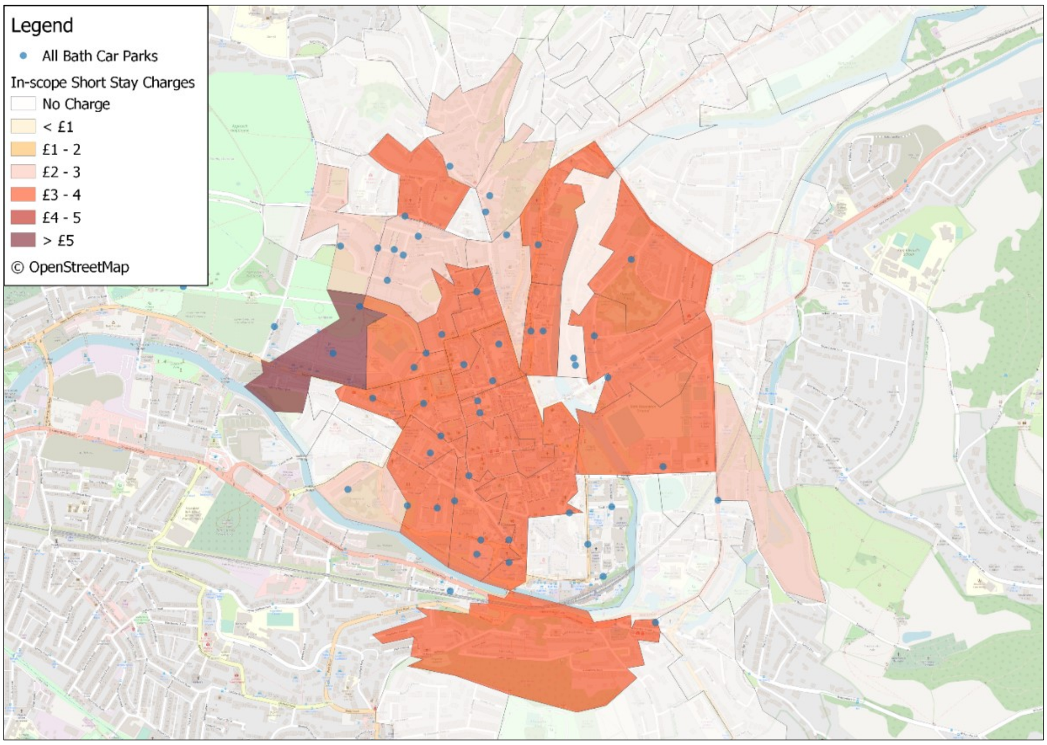
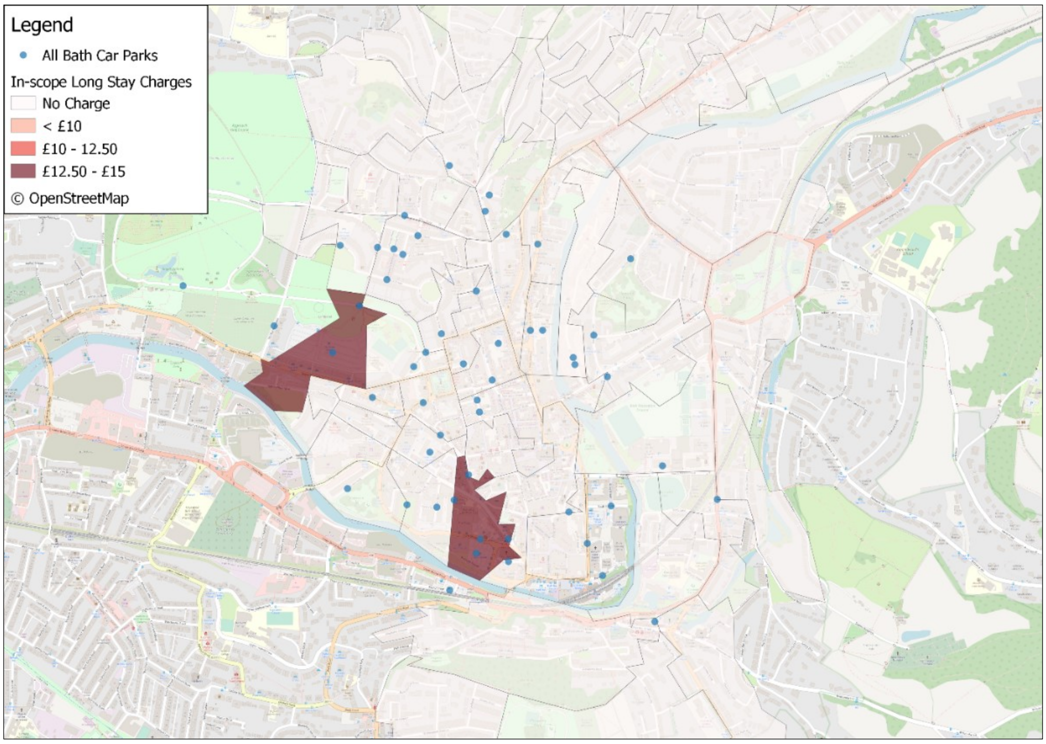


Figure 3-12 - Model Zones with Long Stay Parking Charges, In-Scope Destinations Only



For modelling purposes only base year 2019 parking costs are assumed to increase by 50% for short stay parking and 30% for long stay parking in the forecast year 2029.

3.5.6. Public transport cost elements

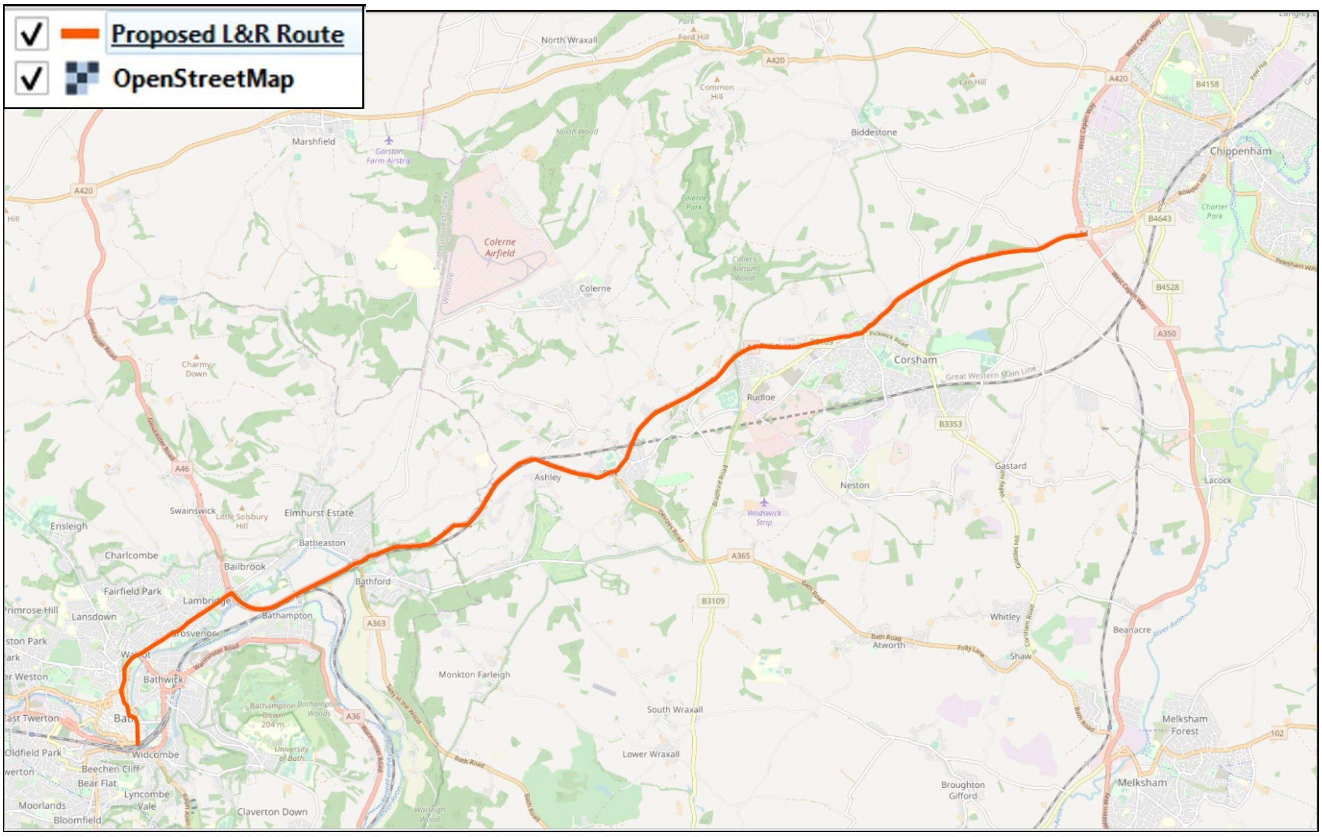
There are several costs associated with the use of public transport that need to be considered when calculating the L&R generalised time. These are namely:

- Bus journey time (including stopping time for interim stops between access and egress point).
- Fare element.
- Waiting time.
- Interchange penalty.

Bus journey times (not including stopping time for interim stops) for the existing X31 route and along the suggested direct L&R bus route (as shown below in Figure 3-13) were taken from the SATURN model. Note this was completed in the refined SATURN assignments to be comparable with the car journey times skims. The joyrides show the journey time from Chippenham to Bath bus station is approximately 35 minutes in the AM peak and approximately 30 minutes in the PM peak via the suggested direct L&R bus route.

In addition to the journey time taken from the SATURN model, additional time must be added for bus stopping time at interim stops. For each interim stop, 15 seconds is added to the bus journey time to account for this. This figure is based on existing studies for similar corridors and reflects the fact that only small numbers of people disembark at interim stops.

Figure 3-13 - Link & Ride concept route



The fare element for the L&R service has been based on the existing X31 fare system as provided by Faresaver. However, an annual inflation of 2% is assumed for forecast years based on previous similar studies and model development tasks.

The waiting time is defined using TAG Unit M3-2 guidance. This states the waiting time factor as shown in Table 3-23 below. Note the headway is defined by the predicted frequency of the service, i.e. if there are six services an hour then the headway is ten minutes.

Table 3-23 - TAG Unit M3-2: Wait Time Factor

Headway	Wait Time Factor / Absolute Time
< 15 mins	0.5
>= 15 mins	7.5 mins

TAG Unit M3-2 gives suggested parameters for an interchange penalty. It suggests between five to ten minutes; therefore, an average of the two has been implemented in the demand modelling tool.

3.5.7. Alternative specific constants (ASCs)

In addition to the costs associated with the journey for each mode, it is standard practice to include an alternative specific constant (ASC) (also referred to as the mode-specific constant) to the generalised journey time. This ASC is used during calibration to obtain a mode share which represents the calibration dataset and is a way of representing the unquantifiable barriers to using a mode of travel. This is in line with the approach set out in *TAG: Supplementary Guidance: Bespoke Mode Choice Models*. Before the calibration process, the ASCs for Car and L&R modes were set to 0. For post-calibration factors, please read Section 4.

3.6. Logit function form

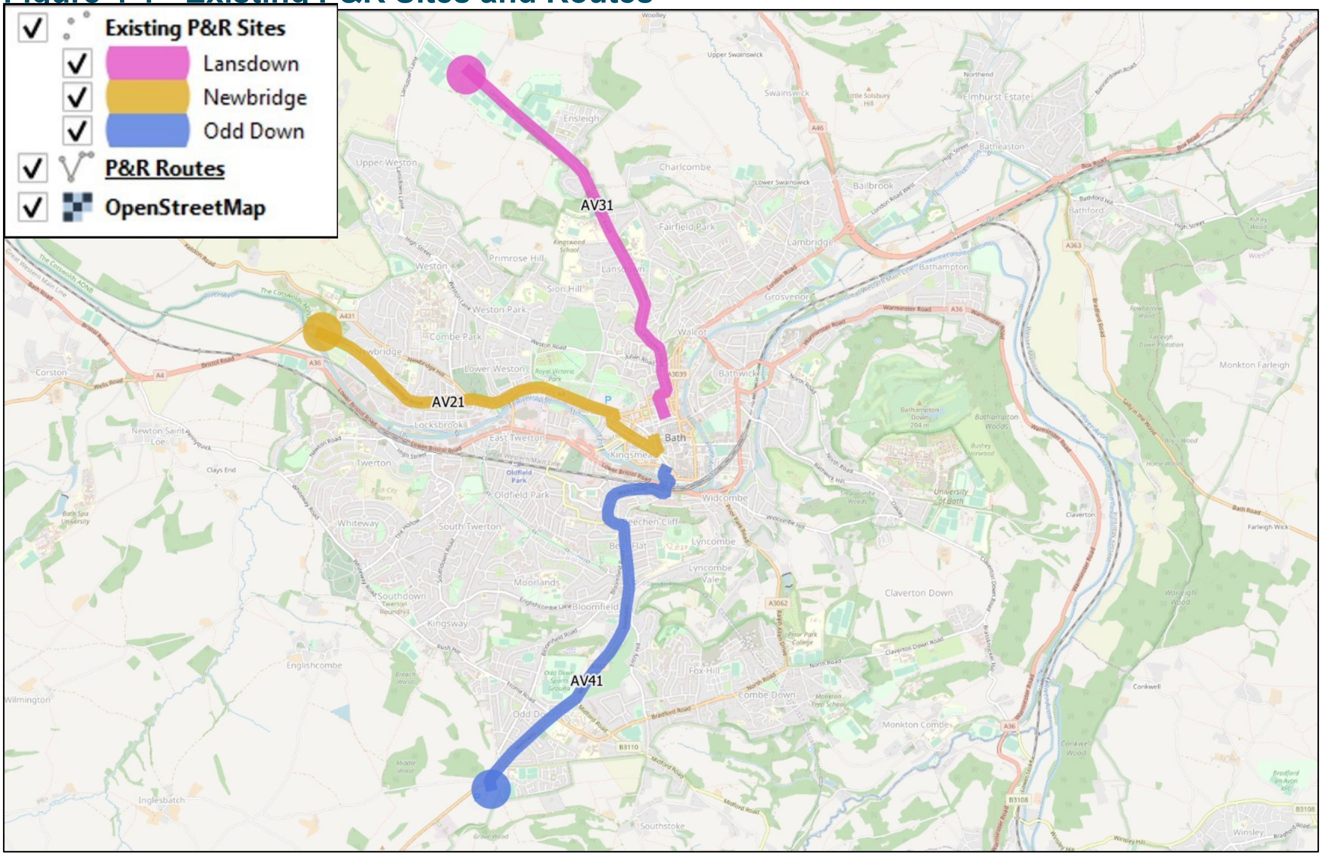
The split of demand by different modes is calculated using the standard logit function as per *TAG: Supplementary Guidance: Bespoke Mode Choice Models* section 3.1.4. The sensitivity parameter for each purpose, commonly referred to as the sensitivity lambda (λ), was originally set to the TAG median value. During calibration this was set to 1 (within TAG guidelines) to obtain a mode share which represents the calibration dataset. The calibration dataset is built from observed data, for example Park & Ride site demand from patronage surveys. The post-calibration sensitivity lambdas are shown in Section 4.

4. Calibration

4.1. Calibration data

There are three existing P&R sites in Bath currently, situated to the north, west and south of the city. These are shown in Figure 4-1.

Figure 4-1 - Existing P&R Sites and Routes



To calibrate the demand model, patronage levels for these sites were used as calibration data, due to the lack of any bespoke L&R data to calibrate it against. Data from First was provided that summarised the number of individuals buying a ticket as they boarded the bus for each stop along the P&R routes, with a timestamp against each ticket purchase to identify when people travelled.

Table 4-1 shows the average weekday tickets purchased at each of the P&R site bus stops across 2019 for each hour of the day. This data is summarised visually in Figure 4-2, which highlights that the AM period is when the highest on-bus ticket purchase levels are seen at the P&R sites. Table 4-2 summarises the data to match the GBATH modelled time periods; this is the data that has been used for calibration of the demand modelling tool.

Table 4-1 - Average Daily Patronage of Existing P&R Sites, 2019

Peak Type	Time Period	Lansdown (Service: AV31)	Newbridge (Service: AV21)	Odd Down (Service: AV41)	All Sites
AM	06-07	17	26	51	94
AM	07-08	73	95	166	334
AM	08-09	133	188	195	516
AM	09-10	112	127	168	408
IP	10-11	120	118	161	399
IP	11-12	89	92	136	317
IP	12-13	60	64	80	204
IP	13-14	33	44	57	134
IP	14-15	17	31	30	79
IP	15-16	9	14	88	112
PM	16-17	6	7	17	31
PM	17-18	3	4	8	14
PM	18-19	2	2	5	8
PM	19-20	0	0	1	2
PM	20-21	1	0	0	1
	Average Daily Total Patronage	675	814	1,164	2,653

Figure 4-2 - Hourly Variation of Average Daily Patronage for Existing P&R Sites, 2019

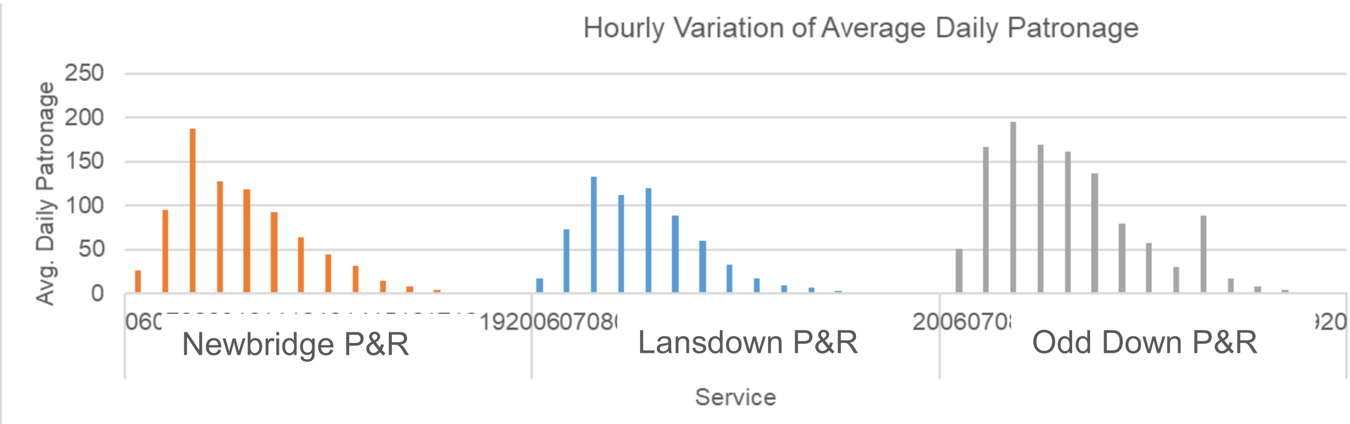


Table 4-2 - Peak Hour Patronage and Shares of Existing P&R Sites, 2019

Description	Lansdown (Service: AV31)	Newbridge (Service: AV21)	Odd Down (Service: AV41)	All Sites
AM peak (0800 - 0900)	133	188	195	516
Average IP (1000 - 1600)	55	61	92	208
AM Peak + Average IP to Daily Conversion Factor	*3.304*	*3.654*	*4.074*	*3.699*

4.2. Calibration results

The demand model calibration involves comparing the observed and modelled patronage for the three existing P&R sites operating in Bath and adjusting the demand model sensitivity parameters until the observed and modelled patronage levels are comparable.

The only sensitivity parameters available in a binary mode choice model are the Alternative Specific Constants (ASCs). These were iteratively adjusted until the modelled patronage levels were representative of the observed patronage levels for each of the three existing P&R sites. The final calibrated parameters are presented in Table 4-3 below.

Table 4-3 – Final Calibrated Parameters of Mode Choice Model, 2019

Description	AM Peak (08-09)	Average IP Peak (10-16)
ASC (Car)	51.6	46.0
ASC (L&R Mode)	0.0	0.0

As the ASC forms a part of the generalised time for each mode, it is important to understand what proportion of the total generalised time relates to “hard” costs i.e. monetary costs and what proportion corresponds to the ASC (which is often considered as representation of the “soft / behavioural” costs i.e. perceived costs, such as wait time). It is observed the ASC forms, on average, 56% of the car generalised time in the AM peak and 57% of the car generalised time in the average IP. This implies the car mode share within the study area depends more on external factors such as vehicle ownership and fixed behaviours than the “hard” costs such as fuel costs or journey time.

The calibration results for the demand model are presented in Table 4-4 and Table 4-5.

Table 4-4 – Post Calibration - Observed and Modelled P&R Patronage, 2019 – AM Peak (0800-0900)

Description	Observed	Modelled	Modelled - Observed	Flow Diff (%)	GEH	Pass / Fail
Lansdown (Service: AV31)	133	146	13	10%	1	Pass
Newbridge (Service: AV21)	188	178	-10	-5%	1	Pass
Odd Down (Service: AV41)	195	72	-123	-63%	11	Fail

Table 4-5 – Post Calibration - Observed and Modelled P&R Patronage, 2019 – IP Average (1000-1600)

Description	Observed	Modelled	Modelled - Observed	Flow Diff (%)	GEH	Pass / Fail
Lansdown (Service: AV31)	55	55	0	0%	0	Pass
Newbridge (Service: AV21)	61	83	23	37%	3	Pass
Odd Down (Service: AV41)	92	70	-22	-24%	2	Pass

It is observed that all sites except Odd Down in the AM peak pass the calibration criteria. The Odd Down site fails in the AM peak due to large differences between the car and L&R generalised times that could be overcome by drastically increasing the car ASC, but this would be to the detriment of the calibration at all other sites for all time periods.

The base year 2019 mode share was derived from the calibrated logit model for each purpose and is shown in **Error! Reference source not found.** and Table 4-7.

Table 4-6 – Base Year Mode Share, 2019 – AM Peak (0800-0900)

Purpose	Lansdown (Service: AV31) - Car	Lansdown (Service: AV31) - P&R	Lansdown (Service: AV31) - Total	Newbridge (Service: AV21) - Car	Newbridge (Service: AV21) - P&R	Newbridge (Service: AV21) - Total	Odd Down (Service: AV41) - Car	Odd Down (Service: AV41) - P&R	Odd Down (Service: AV41) - Total
HBW	91.4%	8.6%	100.0%	89.9%	10.1%	100.0%	95.3%	4.7%	100.0%
HBEB	63.1%	36.9%	100.0%	61.9%	38.1%	100.0%	48.9%	51.1%	100.0%
HBO	98.5%	1.5%	100.0%	95.7%	4.3%	100.0%	99.9%	0.1%	100.0%
NHBEB	34.6%	65.4%	100.0%	35.3%	64.7%	100.0%	46.0%	54.0%	100.0%
NHBO	98.6%	1.4%	100.0%	96.1%	3.9%	100.0%	99.9%	0.1%	100.0%
Total	*93.6%*	*6.4%*	*100.0%*	*91.0%*	*9.0%*	*100.0%*	*96.3%*	*3.7%*	*100.0%*

Table 4-7 – Base Year Mode Share, 2019 – IP Average (1000-1600)

Purpose	Lansdown (Service: AV31) - Car	Lansdown (Service: AV31) - P&R	Lansdown (Service: AV31) - Total	Newbridge (Service: AV21) - Car	Newbridge (Service: AV21) - P&R	Newbridge (Service: AV21) - Total	Odd Down (Service: AV41) - Car	Odd Down (Service: AV41) - P&R	Odd Down (Service: AV41) - Total
HBW	95.6%	4.4%	100.0%	94.4%	5.6%	100.0%	91.7%	8.3%	100.0%
HBEB	75.4%	24.6%	100.0%	79.4%	20.6%	100.0%	40.5%	59.5%	100.0%
HBO	99.5%	0.5%	100.0%	98.3%	1.7%	100.0%	99.9%	0.1%	100.0%
NHBEB	68.0%	32.0%	100.0%	60.1%	39.9%	100.0%	48.6%	51.4%	100.0%
NHBO	99.4%	0.6%	100.0%	98.2%	1.8%	100.0%	99.8%	0.2%	100.0%
Total	*96.5%*	*3.5%*	*100.0%*	*93.9%*	*6.1%*	*100.0%*	*94.4%*	*5.6%*	*100.0%*

5. Realism testing

5.1. Approach

In line with *TAG Unit M2-1: Variable Demand Modelling*, the logit model validation has been undertaken for 'Realism' testing to ensure that the elasticity (or responsiveness) of the model is within appropriate limits. The tests which were carried out on the base year model include:

- **Car Fuel Cost Test**: Changing fuel cost by 10% and ensuring the elasticity of demand for private car trips (i.e. vehicle-km) with respect to fuel price is within the expected range -0.35 to -0.25.
- **Public Transport Fare Test**: Increasing public transport fares by 10% and ensuring the elasticity of demand for public transport trips (i.e. person trips) with respect to fare is within the expected range -0.9 to -0.2.
- **Car Journey Time Test**: Increasing journey time by 10% and examining the outturn elasticity of demand for private car trips (i.e. vehicle/ person trips) with respect to journey time, which should be less than-2.0.

The elasticity formulation recommended by TAG was used for the realism testing for a 10% increase in cost:

$$e = \frac{log(T^1)-log(T^0)}{log(C^1)-log(C^0)} = \frac{log(T^1)-log(T^0)}{log(1.1)},$$

where the superscripts 0 and 1 indicate values before and after the change in cost respectively.

5.2. Realism results

The results of the realism tests for the L&R demand model, along with TAG anticipated ranges, are shown below in Table 5-1.

The elasticity of the model in response to changing car fuel cost and public transport fare falls outside the range recommended in TAG. However, these ranges are more suited to a fully-featured Variable Demand Model, whereas the binary choice model being used to assess the East of Bath Express concept only considers demand in scope on the corridor and does not account for any redistribution or reassignment impacts.

Any interpretation of outputs from the model should take the reported elasticities into consideration. Careful review and scrutiny of the results for the options tested confirmed that the predicted mode shift was in line with expectations, both in terms of the relative impact of each parameter tested, and the resulting patronage volumes.

Table 5-1 - Realism test results (undertaken for Lansdown P&R model)

Test	Measure	TAG Elasticity	Model Elasticity - AM Peak	Model Elasticity – Average IP
Car fuel cost	Car vehicle-kms	-0.25 to -0.35	-0.01	-0.01
PT fare	PT trips	-0.2 to -0.9	-3.5	-3.9
Car journey time	Car trips	0 to -2	-0.1	-0.0

6. Forecasting

6.1. Methodology overview

A forecast year of 2029 has been developed to understand how increases in demand and costs could impact upon people's mode choices, and whether a L&R service would still be an attractive option in a future scenario.

As no appropriate GBATH forecast model was available, the methodology used to develop the forecast demand model is as follows:

- Use TEMPro 7.2 to factor the demand from base year 2019 to forecast year 2029.
- Update fuel costs and values of time based on the TAG Databook.
- Increase PT fares by 2% per annum (based on previous studies completed by Atkins).
- Increase short-term parking charges by 50% and long-term charges by 30%.
- Base year values are used for skims (distance, journey time), as there is no forecast model to extract these from.

6.2. Summary of values

To develop the demand for forecast year 2029, origin and destination growth factors from 2019 to 2029 were extracted by region and trip purpose from TEMPro for the AM period (0700-0959) and the IP period (10:00-15:59). The GBATH zones were categorised by region, and the factors extracted from TEMPro were applied to the base year demand to develop the forecast demand.

Table 6-1 and Table 6-2 summarise the growth factors by region for the AM period and the IP period respectively.

Table 6-1 – TEMPro Growth Factors (2019-2029) by region and purpose for the AM period (07:00-09:59)

Region Name	HBW Origin	HBW Destination	HBEB Origin	HBEB Destination	HBO Origin	HBO Destination	NHBEB Origin	NHBEB Destination	NHBO Origin	NHBO Destination
B&NES	1.01	1.05	1.02	1.05	1.07	1.09	1.06	1.05	1.08	1.08
Bristol	1.08	1.05	1.09	1.06	1.11	1.10	1.05	1.06	1.08	1.08
Wiltshire	1.04	1.05	1.04	1.05	1.09	1.09	1.05	1.05	1.08	1.08
Somerset	1.05	1.05	1.06	1.06	1.09	1.09	1.06	1.06	1.08	1.08
Gloucestershire	1.05	1.05	1.06	1.06	1.08	1.08	1.06	1.06	1.07	1.07
Devon, Cornwall	1.05	1.05	1.06	1.06	1.09	1.09	1.06	1.06	1.07	1.07
Dorset	1.05	1.05	1.05	1.05	1.07	1.07	1.05	1.05	1.06	1.06
East	1.04	1.05	1.05	1.06	1.12	1.12	1.06	1.06	1.10	1.10
Eastern Midlands	1.05	1.05	1.06	1.06	1.08	1.08	1.06	1.06	1.07	1.07
London	1.08	1.06	1.08	1.06	1.13	1.12	1.06	1.06	1.10	1.10
Scotland	1.06	1.06	1.07	1.07	1.08	1.08	1.06	1.06	1.07	1.07
South East	1.05	1.06	1.06	1.06	1.10	1.10	1.06	1.06	1.09	1.09
Wales	1.05	1.05	1.06	1.06	1.06	1.06	1.05	1.05	1.06	1.06
West Midlands	1.05	1.05	1.06	1.06	1.08	1.08	1.06	1.06	1.07	1.07
YH, North East and North West	1.06	1.06	1.07	1.07	1.07	1.07	1.06	1.06	1.07	1.07

Table 6-2 – TEMPro Growth Factors (2019-2029) by region and purpose for the IP period (10:00-15:59)

Region Name	HBW Origin	HBW Destination	HBEB Origin	HBEB Destination	HBO Origin	HBO Destination	NHBEB Origin	NHBEB Destination	NHBO Origin	NHBO Destination
B&NES	1.03	1.02	1.04	1.04	1.09	1.09	1.06	1.06	1.09	1.08
Bristol	1.05	1.06	1.08	1.07	1.11	1.11	1.05	1.06	1.08	1.08
Wiltshire	1.04	1.04	1.05	1.05	1.11	1.11	1.05	1.05	1.08	1.08
Somerset	1.04	1.04	1.06	1.06	1.11	1.11	1.06	1.06	1.09	1.09
Gloucestershire	1.05	1.05	1.06	1.06	1.09	1.09	1.06	1.06	1.07	1.07
Devon, Cornwall	1.04	1.04	1.06	1.06	1.09	1.09	1.06	1.06	1.07	1.07
Dorset	1.04	1.04	1.06	1.06	1.08	1.08	1.05	1.05	1.06	1.06
East	1.04	1.04	1.06	1.06	1.14	1.14	1.06	1.06	1.11	1.11
Eastern Midlands	1.04	1.04	1.06	1.06	1.09	1.09	1.06	1.06	1.07	1.07
London	1.06	1.07	1.07	1.07	1.14	1.14	1.06	1.07	1.10	1.10
Scotland	1.05	1.05	1.07	1.07	1.08	1.08	1.06	1.06	1.07	1.07
South East	1.05	1.05	1.06	1.06	1.11	1.11	1.06	1.06	1.09	1.09
Wales	1.04	1.04	1.06	1.06	1.07	1.07	1.05	1.05	1.06	1.06
West Midlands	1.04	1.04	1.06	1.06	1.09	1.09	1.06	1.06	1.07	1.07
YH, North East and North West	1.05	1.05	1.07	1.07	1.08	1.08	1.06	1.06	1.07	1.07

When these factors are applied to the in-scope demand via a furnessing method, the forecast 2029 in-scope vehicle demand (with comparison to the base year totals) is as shown in Table 6-3 below.

Table 6-3 - Forecast in-scope vehicle demand by purpose (w. base year totals)

Purpose	Base Year (2019) - AM	Base Year (2019) - IP	Forecast Year (2029) - AM	Forecast Year (2029) - IP	Abs. Growth - AM	Abs. Growth - IP	% Growth - AM	% Growth - IP
HBW	545	100	571	103	26	3	5%	3%
HBEB	28	23	29	24	1	1	4%	4%
HBO	495	550	539	599	44	49	9%	9%
NHBEB	15	30	16	32	1	2	7%	7%
NHBO	134	72	144	78	10	6	7%	8%
Total	*1,216*	*776*	*1,299*	*835*	*83*	*59*	*7%*	*8%*

In addition to updating the in-scope demand to reflect anticipated 2029 demand levels, all other input parameters affecting generalised time formulation in the forecast year required an update to 2029 values. These values are detailed in section 3.5 of this report, with a high level summary provided in Table 6-4 below.

Table 6-4 – Forecast year parameters

Generalised Time Component	Change in Forecast Year w.r.t Base Year	Source
Car skims	Same	GBATH SATURN highway assignment model (2014, validated to 2019)
Value of time (VOT)	Detailed in section 2.6.2	TAG data book (v1.13.1), July 2020
Vehicle operating cost (VOC)	Detailed in section 2.6.3	TAG data book (v1.13.1), July 2020
Car occupancy factors	Same	TAG data book (v1.13.1), July 2020
City centre parking charges	Short-stay parking +50% Long-stay parking +30%	B&NES
PT Fare	+2% per annum	Previous Atkins studies

7. Testing & results

7.1. Scenarios

To understand how the different L&R service options impact on potential patronage levels (and therefore the potential removal of cars from the roads), several scenarios were specified to be tested in the demand model.

A baseline test for the do minimum service option has been undertaken to understand the baseline potential levels of mode shift from car to L&R (and is labelled test A). The baseline service test models the existing X31 service from Chippenham to Bath, with L&R passengers able to board the bus at the identified L&R interchanges.

To understand how changes to the do minimum option could impact patronage levels, several do something tests were developed to test different service and external policy measures:

- Direct bus service route along the A4 with no diversions (all of the other tests use this same direct route unless specified).
- Increased bus frequency.
- Fares capped at existing Bath P&R fare structure.
- Bus priority measures at the A4 / London Road roundabout.
- Implementation of an interchange parking charge.
- Implementation of demand management measures (external policy measure for reference only).
- Increased city centre parking charges (external policy measure for reference only).
- Complete suite of changes (all service/policy measures applied, apart from interchange parking charge).
- Combined option (direct service with increased frequency, fares capped and bus priority measures at the A4 / London Road roundabout).
- Alternating direct service route and X31 service route offer.

Table 7-1 summarises the full eleven tests undertaken and whether they were testing a potential L&R service option or the impact of external policy measures.

Table 7-1 - Demand modelling tests undertaken

Test Name	Service option / policy
A - Baseline	-
B - Direct route	Service option
C - Complete suite of changes	Service option and policy measure
D - Frequency	Service option
E - Fares	Service option
F - Bus priority measures	Service option
G - Interchange parking charge	Service option
H - Demand management measures	Policy measure
I - City centre parking charges	Policy measure
J - Combined option	Service option
K – Alternating direct & X31 service offer	Service option

A more detailed summary of the tests undertaken, and exact values implemented for each of the tests is shown below in Table 7-2.

Table 7-2 - Inputs to demand model tests

Test	Name	Route	AM bus frequency	IP bus frequency	Fare	Bus priority (JT change)	Interchange parking charge	Demand management measures	City centre parking charge
A	Baseline	X31	4 bph	3 bph	X31	-	-	-	-
B	Direct route	Direct	4 bph	3 bph	X31	-	-	-	-
C	Complete suite of changes	Direct	6 bph	4 bph	Capped at £3.60 return	✓	-	Applied	Charges increased
D	Frequency	Direct	6 bph	4 bph	X31	-	-	-	-
E	Fares	Direct	4 bph	3 bph	Capped at £3.60 return	-	-	-	-
F	Bus priority measures	Direct	4 bph	3 bph	X31	✓	-	-	-
G	Interchange parking charge	Direct	4 bph	3 bph	X31	-	£1 per car	-	-
H	Demand management measures	Direct	4 bph	3 bph	X31	-	-	Applied	-
I	City centre parking charges	Direct	4 bph	3 bph	X31	-	-	-	Charges increased

J	Combined option	Direct	6 bph	4 bph	Capped at £3.60 return	✓	-	-	-
K	Alternating direct & X31 service offer	Alternating direct/X31	6 bph (3 direct, 3 X31 route)	5 bph (2 direct, 3 X31 route)	X31	-	-	-	-

7.2. Scenario test results

The scenario test results for the base year and forecast year demand model are presented below in Table 7-3 to Table 7-8. The results show that scenario A (baseline test) has the lowest potential for abstracting car users to the L&R scheme, whilst scenario J (combined option test) has the greatest potential for car mode abstraction of the service option only tests.

In scenario J (combined option test), the L&R mode share is 10% in the AM peak in 2019 compared to 2% in scenario A (baseline test). In the IP, L&R mode share is 3% for option J compared to 1% in scenario A. For scenario J, the primary L&R demand is from home-based work trips in the AM peak and from non-home-based employers' business trips in the IP.

Comparing single service option measures (as opposed to scenarios with combinations of measures) highlights scenario D (frequency test) and scenario E (fares test) as the two scenarios that have the largest potential impact on L&R patronage levels. It is noted the response seen in scenario E could be an overestimation as realism testing showed the model is elastic to changes in public transport fare.

As anticipated, scenario G shows that an additional charge to L&R users via an interchange parking charge of £1 per car has a negative impact on L&R patronage. Scenario F (bus priority measures test) shows that the introduction of bus priority measures at the A4 / London Road roundabout would have a minimal impact on patronage. This is because the journey time savings created by bus priority measures are a very small proportion of the overall bus journey time and therefore do little to increase the attractiveness of the service. However, it is noted the response seen for scenario F could be an underestimation as realism testing showed the model is stiff to changes in journey time.

Scenarios C, H and I considered how external policy measures could impact on L&R patronage levels. These showed that the introduction of demand management would considerably increase the abstraction rate from car mode to the L&R bus service, while increasing city centre parking charges has a limited impact on mode shift as the potential increase is capped by the nationally set penalty charge notice (PCN) figure. If this figure were exceeded the cost of a PCN would be cheaper than the cost to park a car, therefore it could be expected that drivers would choose to accept a PCN by parking illegally, as opposed to paying for parking or shifting mode to L&R.

Scenario K (alternating direct and X31 service offer) performs similarly to Scenario B (direct route) with both tests predicting an L&R mode share of 2% in the AM peak (220 daily passengers for Scenario K and 215 for Scenario B). This suggests that alternating services across the two routes is not expected to improve patronage levels for the L&R bus service compared to using only the direct route. This is likely due to the slower journey time on the X31 route.

For every scenario, the potential intercept rate for the L&R scheme reduces in the forecast year i.e. there is lower abstraction from car in the 2029 model. This is due to the relative changes in costs of travel by bus versus car. Following TAG parameters, the perceived costs associated with using the car decrease in forecast years whilst the perceived costs associated with using the L&R increase. Therefore, the L&R mode share decreases in the the forecast year.

Table 7-3 - Scenario testing base year (2019) results – vehicle trips (service option tests only)

Test	Name	AM Peak - Car	AM Peak - L&R	IP Avg. - Car	IP Avg. - L&R
A	Baseline	1,186	30	767	8
B	Direct route	1,180	37	763	13
D	Frequency	1,170	46	763	13
E	Fares	1,115	101	749	26
F	Bus priority	1,176	41	763	13
G	Interchange parking charge	1,185	31	765	11
J	Combined option	1,069	147	769	26
K	Alternating direct & X31 service offer	1,696	46	764	12

Table 7-4 - Scenario testing base year (2019) results – person trips and daily L&R patronage (service option tests only)

Test	Name	AM Peak - Car	AM Peak - L&R	IP Avg. - Car	IP Avg. - L&R	Daily L&R patronage	% patronage increase vs test A
A	Baseline	1,707	35	1,195	10	166	-
B	Direct route	1,699	43	1,190	15	215	29%
D	Frequency	1,688	55	1,190	15	257	54%
E	Fares	1,619	123	1,173	32	574	245%
F	Bus priority	1,694	48	1,190	15	233	40%
G	Interchange parking charge	1,705	37	1,192	13	183	10%
J	Combined option	1,560	182	1,173	32	793	376%
K	Alternating direct & X31 service offer	1,695	46	1,192	13	220	32%

Table 7-5 - Scenario testing base year (2019) results – mode share (service option tests only)

Test	Name	AM Peak - Car	AM Peak - L&R	IP Avg. - Car	IP Avg. - L&R
A	Baseline	98%	2%	99%	1%
B	Direct route	98%	2%	99%	1%
D	Frequency	97%	3%	99%	1%
E	Fares	93%	7%	97%	3%
F	Bus priority	97%	3%	99%	1%
G	Interchange parking charge	98%	2%	99%	1%
J	Combined option	90%	10%	97%	3%
K	Alternating direct & X31 service offer	97%	3%	99%	1%

Table 7-6 - Scenario testing forecast year (2029) results – vehicle trips (service option tests only)

Test	Name	AM Peak - Car	AM Peak - L&R	IP Avg. - Car	IP Avg. - L&R
A	Baseline	1,269	30	826	9
B	Direct route	1,264	35	822	13
D	Frequency	1,259	40	822	13
E	Fares	1,216	83	810	25
F	Bus priority	1,262	37	822	13
G	Interchange parking charge	1,267	32	824	11
J	Combined option	1,175	124	810	25
K	Alternating direct & X31 service offer	1,264	35	824	11

Table 7-7 - Scenario testing forecast year (2029) results – person trips and daily L&R patronage (service option tests only)

Test	Name	AM Peak - Car	AM Peak - L&R	IP Avg. - Car	IP Avg. - L&R	Daily L&R patronage	% patronage increase vs test A
A	Baseline	1,831	35	1,290	10	166	-
B	Direct route	1,825	42	1,285	15	210	26%
D	Frequency	1,819	48	1,285	15	235	41%
E	Fares	1,763	104	1,269	31	498	199%
F	Bus priority	1,823	44	1,285	15	221	33%
G	Interchange parking charge	1,829	38	1,287	13	189	13%
J	Combined option	1,708	159	1,269	31	702	322%
K	Alternating direct & X31 service offer	1,264	35	1,288	13	203	22%

Table 7-8 - Scenario testing base year (2029) results – mode share (service option tests only)

Test	Name	AM Peak - Car	AM Peak - L&R	IP Avg. - Car	IP Avg. - L&R
A	Baseline	98%	2%	99%	1%
B	Direct route	98%	2%	99%	1%
D	Frequency	97%	3%	99%	1%
E	Fares	94%	6%	98%	2%
F	Bus priority	98%	2%	99%	1%
G	Interchange parking charge	98%	2%	99%	1%
J	Combined option	92%	8%	98%	2%
K	Alternating direct & X31 service offer	98%	2%	99%	1%

Maps showing where the users of the L&R service have travelled from for option J (combined option test) and where they are travelling to within Bath city centre are given below in Figure 7-1 and Figure 7-2. These maps represent the base year (2019) AM demand. These clearly show that the highest contributor of demand to the L&R service is Chippenham, with Bradford-on-Avon and Trowbridge the second highest. Within Bath city centre, the most popular destinations for the L&R service are those nearest to the anticipated city centre bus stops such as the Bath Abbey and near to the Bath bus station.

Figure 7-1 - Option J - 2019 AM origin L&R person trips

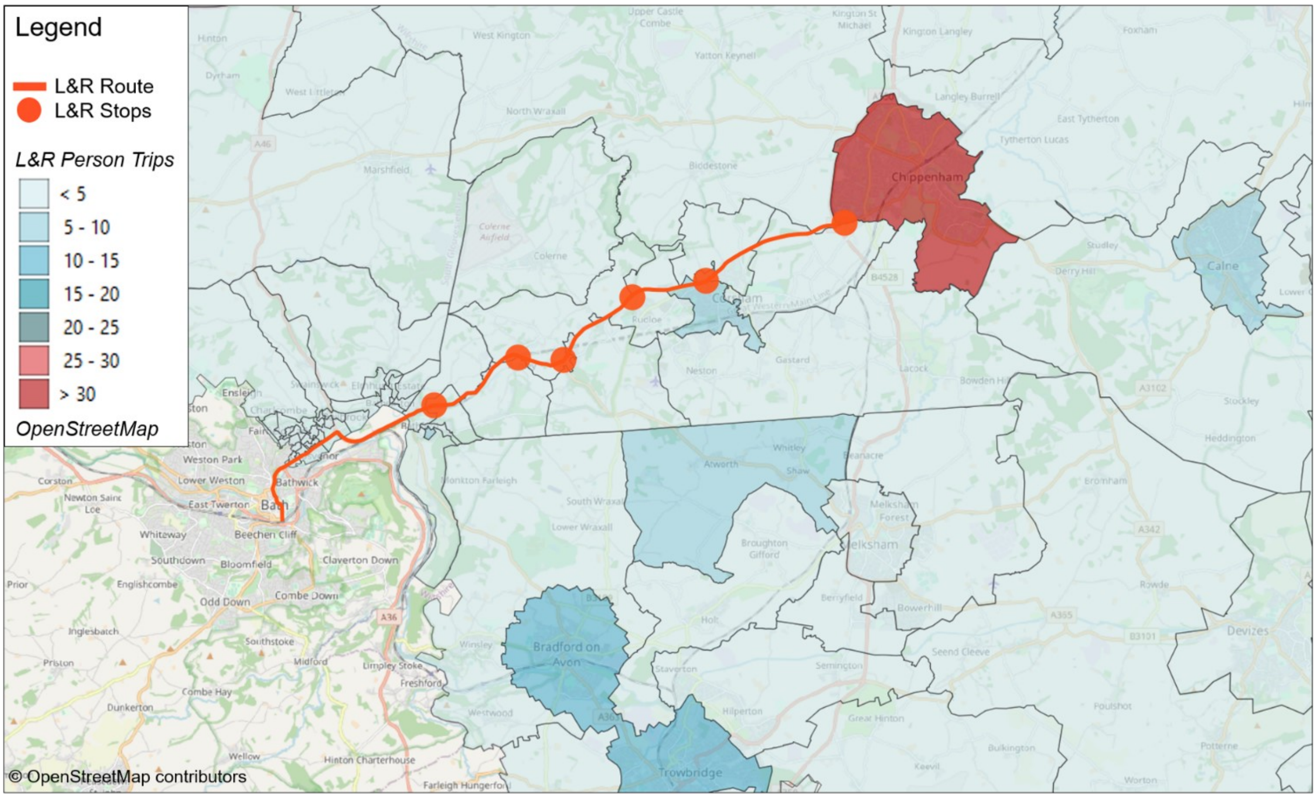
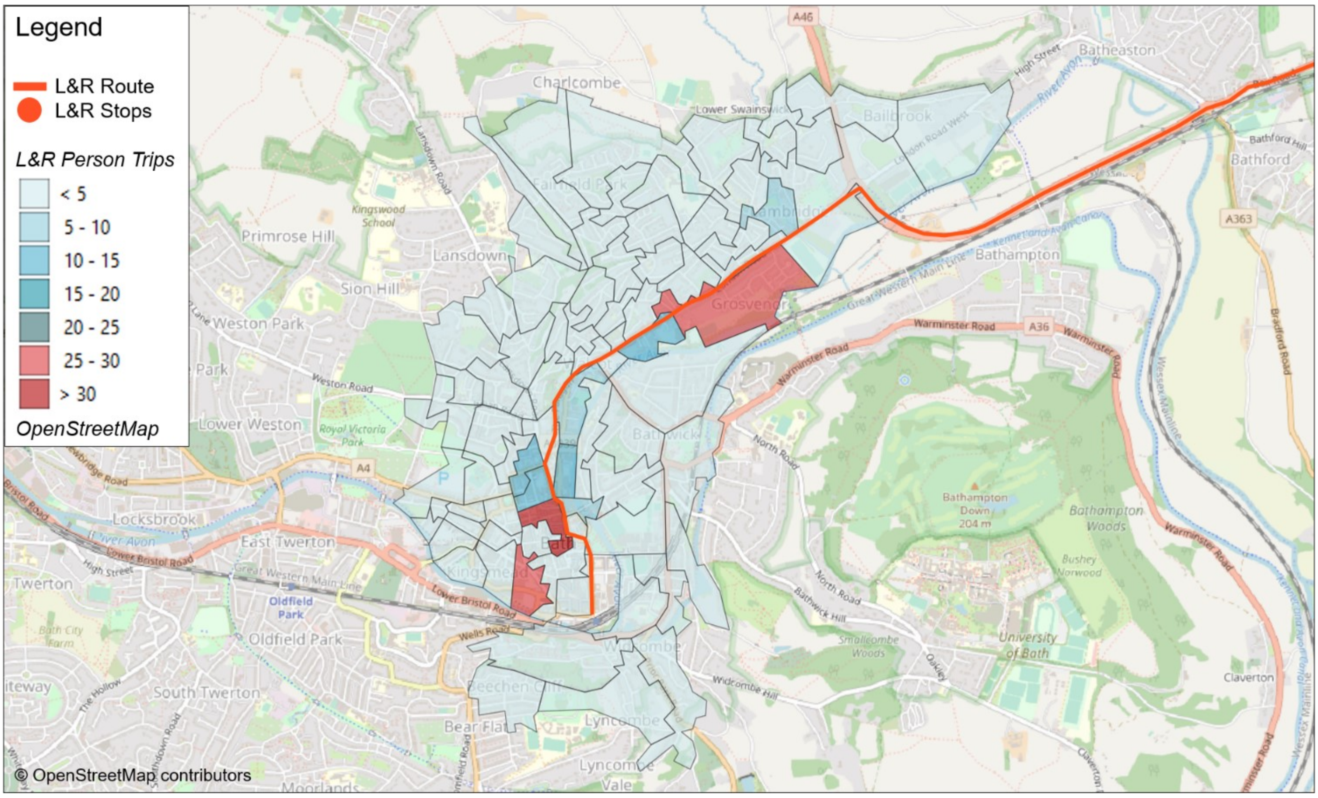


Figure 7-2 - Option J - 2019 AM destination L&R person trips



8. Limitations & caveats

8.1. Mode shift overestimation

8.1.1. Binary mode choice

As the demand model considers only mode shift from private car to L&R service it will not consider any potential mode shift from existing bus services. It is anticipated the number of individuals likely to shift from an existing bus service to the L&R service is negligible, therefore it is proportionate not to include them in the choice model.

Additionally, as there are only two mode choices given to in-scope demand there is a risk of over-estimating mode shift to the L&R service when testing external policy measures. If something such as a demand management measure were implemented in Bath users of the east of Bath corridor would have the option of existing X31 service, existing rail service, cycling, walking etc in reality, but these options are not present in the model. Therefore, modelled demand can only shift to the L&R service while, in reality, this would capture only a proportion of the shifted car demand.

8.1.2. Lack of assignment iteration

As there is no feedback loop between the demand modelling tool and the highway assignment model, it is acknowledged the tests are likely to over-estimate the downturn in Car mode share.

In a fully integrated model, the initial mode shift away from Car that will be seen in the demand modelling tool would be fed back to the highway assignment model. The decrease in congestion due to decreased Car demand leads to better journey times and cheaper Car journeys, therefore making Car more attractive for the next iteration of the demand model and creating a mode shift back towards Car. This feedback loop iterates until there is stability between the demand model and the assignment model.

However, as the demand modelling tool does not interact with the highway assignment model in this instance this feedback stabilisation does not occur, and the demand model only provides the reduced first demand iteration of the car mode share level. Any interpretation of outputs from the model should take the reported elasticities into consideration. Careful review and scrutiny of the results for the options tested confirmed that the predicted mode shift was in line with expectations, both in terms of the relative impact of each scheme tested, and the resulting patronage volumes.

8.2. L&R catchment areas

To avoid over-complicating the model it was agreed to implement L&R catchment areas for each of the L&R interchange sites. These catchment areas are a limitation to the function of the model, as in reality there is the potential for individuals to drive further to park at a L&R site nearer to Bath city centre which will not be reflected in the model. However, the impact of this is likely to be negligible (as demonstrated in the case of the Nottingham L&R).

8.3. Concessionary fares

As the demand was not provided from GBATH with any age segmentation, concessionary fares and passes are not included in the modelling. This is a proportionate approach but could lead to potentially underestimating patronage or overestimating the impact changes in fares for the L&R service would have.

8.4. Patronage build-up

TAG: Supplementary Guidance: Bespoke Mode Choice Models section 5.5 notes that whilst the mode choice model will show mode switching as occurring instantaneously, this is not likely due to inertia within the market. It is therefore understood that initial patronage forecasts need to be considered as absolute maximums by any interpreter or results, with the expectation that full mode shift will take place within 2 years of the scheme opening.

8.5. Forecasting

As the journey time skims remained at base year levels, increased congestion along the corridor due to increased forecast demand is not reflected. However, the risk associated with this is negligible as firstly, the analysis of count data on the A4 London Road has shown that traffic volumes have not increased on the A4 London Road in recent years which suggests it is operating at capacity. Secondly, car and L&R journey times are taken from the same highway model, thereby meaning any increased congestion experienced by car would also be experienced by L&R where bus priority is not in place and so the relative differences between generalised times would not change.

9. Summary

Given the age of age of the existing strategic GBATH model and it no longer being WebTAG compliant a bespoke spreadsheet logit mode choice model was developed. This used 2014 GBATH SATURN model outputs validated to observed 2019 count data, TAG parameters and existing bus fare data to estimate the potential demand abstraction from private car that could be achieved by introducing a L&R scheme along the east of Bath (A4) corridor.

Given the lack of any existing L&R scheme with which to calibrate the model, the model has been calibrated to the existing P&R sites that lie to the north, west and south of Bath. Observed 2019 patronage levels for AM peak and IP average were used for this calibration, and the model is well-calibrated to all three existing P&R sites apart from the southern Odd Down P&R site in the AM peak.

The model has also undergone realism testing to establish how stiff / elastic the model is regarding changes to the three key factors specified within TAG unit M2-1. These three key factors are:

1. Car fuel costs.
2. Public transport fares.
3. Car journey times.

The results of this realism testing revealed the model is stiff to changes in car fuel costs and car journey times, whereas it is elastic for any change in bus fares. The model cannot be adapted to change the underlying elasticity without sacrificing the calibration; therefore, it is instead noted that the model is likely to overestimate mode shift when testing measures such as changes in the fare structure and is likely to underestimate mode shift for tests such a journey time changes.

To understand how different L&R service options along the corridor could impact the abstraction from private car to the L&R service, ten scenarios were developed to test the estimated patronage levels. Of these ten scenarios, three included external policy measures including demand management and increasing Bath city centre parking charges (and the complete suite of changes which includes both).

Table 9-1 to Table 9-4 summarise the demand outputs for AM Peak and IP average for the eight scenarios relating to L&R service options only (i.e. no external policy measures included in the scenario as these are just for reference purposes only). The results indicate that the combined option (option J) that includes running a direct, high frequency service with bus priority measures along the corridor and capped fares maximises the potential mode shift from car to L&R.

Table 9-1 – Summary of the Service Test Options – Base Year 2019, AM Peak

Test	Description	Person Trips - Car	Person Trips - L&R	Person Trips - Total	% Mode Share - Car	% Mode Share - L&R	% Mode Share - Total	Private Vehicle Kilometres - Car	Private Vehicle Kilometres - L&R	Private Vehicle Kilometres - Total
A	Baseline	1,707	35	1,742	98%	2%	100%	40,600	1,181	41,781
B	Direct route	1,699	43	1,742	98%	2%	100%	40,232	1,467	41,700
D	Frequency	1,688	55	1,742	97%	3%	100%	40,120	1,564	41,683
E	Fares	1,619	123	1,742	93%	7%	100%	37,413	3,434	40,847
F	Bus priority	1,694	48	1,742	97%	3%	100%	40,184	1,507	41,692
G	Interchange parking	1,705	37	1,742	98%	2%	100%	40,314	1,402	41,716
J	**Combined option**	**1,560**	**183**	**1,742**	**90%**	**10%**	**100%**	**35,758**	**4,635**	**40,393**
K	Alternating direct & x31 service	1,695	46	1,742	97%	3%	100%	40,321	1,409	41,730

Table 9-2 – Summary of the Service Test Options – Forecast Year 2029, AM Peak

Test	Description	Person Trips - Car	Person Trips - L&R	Person Trips - Total	% Mode Share - Car	% Mode Share - L&R	% Mode Share - Total	Private Vehicle Kilometres - Car	Private Vehicle Kilometres - L&R	Private Vehicle Kilometres - Total
A	Baseline	1,831	35	1,867	98%	2%	100%	43,707	1,257	44,964
B	Direct route	1,825	42	1,867	98%	2%	100%	43,359	1,533	44,892
D	Frequency	1,819	48	1,867	97%	3%	100%	43,276	1,602	44,879
E	Fares	1,763	104	1,867	94%	6%	100%	40,938	3,287	44,225
F	Bus priority	1,823	44	1,867	98%	2%	100%	43,319	1,567	44,885
G	Interchange parking	1,829	38	1,867	98%	2%	100%	43,450	1,461	44,911
J	**Combined Option**	**1,708**	**159**	**1,867**	**92%**	**8%**	**100%**	**39,461**	**4,316**	**43,776**
K	Alternating direct & x31 service	1,825	42	1,867	98%	2%	100%	43,514	1,420	44,934

Table 9-3 – Summary of the Service Test Options – Base Year 2019, IP Average

Test	Description	Person Trips - Car	Person Trips - L&R	Person Trips - Total	% Mode Share - Car	% Mode Share - L&R	% Mode Share - Total	Private Vehicle Kilometres - Car	Private Vehicle Kilometres - L&R	Private Vehicle Kilometres - Total
A	Baseline	1,195	10	1,205	99%	1%	100%	18,100	101	18,472
B	Direct route	1,190	15	1,205	99%	1%	100%	18,100	333	18,433
D	Frequency	1,190	15	1,205	99%	1%	100%	18,100	333	18,433
E	Fares	1,173	32	1,205	97%	3%	100%	17,420	856	18,276
F	Bus priority	1,190	15	1,205	99%	1%	100%	18,100	333	18,433
G	Interchange parking	1,192	13	1,205	99%	1%	100%	18,135	300	18,435
J	**Combined Option**	**1,173**	**32**	**1,205**	**97%**	**3%**	**100%**	**17,420**	**856**	**18,276**
K	Alternating direct & x31 service	1,192	14	1,205	99%	1%	100%	18,327	143	18,470

Table 9-4 – Summary of the Service Test Options – Forecast Year 2029, IP Average

Test	Description	Person Trips - Car	Person Trips - L&R	Person Trips - Total	% Mode Share - Car	% Mode Share - L&R	% Mode Share - Total	Private Vehicle Kilometres - Car	Private Vehicle Kilometres - L&R	Private Vehicle Kilometres - Total
A	Baseline	1,290	10	1,300	99%	1%	100%	19,802	110	19,912
B	Direct route	1,285	15	1,300	99%	1%	100%	19,525	348	19,873
D	Frequency	1,285	15	1,300	99%	1%	100%	19,525	348	19,873
E	Fares	1,269	31	1,300	98%	2%	100%	18,911	820	19,731
F	Bus priority	1,285	15	1,300	99%	1%	100%	19,525	348	19,873
G	Interchange parking	1,287	13	1,300	99%	1%	100%	19,568	308	19,876
J	**Combined Option**	**1,269**	**31**	**1,300**	**98%**	**2%**	**100%**	**18,911**	**820**	**19,731**
K	Alternating direct & x31 service	1,288	13	1,300	99%	1%	100%	19,769	142	19,911

Using daily conversion factors derived from the observed patronage for the three existing P&R sites in Bath, the values above have been expanded to total daily L&R patronage levels for 2019 and 2029 (note the same expansion factor has been used for both years, based on 2019 observed data).

The estimated daily patronage modelled for each L&R service option is presented below in Table 9-5. These daily demand figures highlight again that option J (combined option) shows the highest potential mode shift from car to L&R. However, it is noted that as this test involves a change in L&R fare, and the realism testing showed the model is sensitive to PT fare changes, the modelled mode shift could be an overestimate.

Table 9-5 – Summary of the Service Test Options – Daily

Test	Description	L&R Patronage - 2019	L&R Patronage - 2029	Absolute increase in L&R patronage compared to A - 2019	Absolute increase in L&R patronage compared to A - 2029	% Increase in L&R patronage compared to A - 2019	% Increase in L&R patronage compared to A - 2029
A	Baseline	166	166	-	-	-	-
B	Direct route	215	210	49	44	29%	26%
D	Frequency	257	235	91	69	54%	41%
E	Fares	574	498	408	332	245%	199%
F	Bus priority	233	221	67	55	40%	33%
G	Interchange parking	183	189	17	23	10%	13%
J	**Combined Option**	**793**	**702**	**627**	**536**	**376%**	**322%**
K	Alternating direct & x31 service	220	203	54	37	32%	22%