

Meadows to George Street – Modelling Report

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Executive Summary

This report describes the microsimulation modelling work undertaken as part of the Community Links PLUS Meadows to George Street (MGS) project, which aims to transform the quality of cycling, walking and public realm along the major multi-modal transport corridor from Middle Meadow Walk to George Street in the heart of Edinburgh.

The microsimulation model of the area was created in VISSIM to assess and define traffic management and cycle infrastructure options, which were designed by the AECOM Streets team. The information about the development of the base model, survey data, extents of the model, modelled time periods and matrix development methodology is described in sections 1 to 4.

At the initial stage of the project, the following three design options were assessed in VISSIM:

- Option 1 – Introduction of a segregated cycleway on the east side of the road along the whole route from George Street to Lauriston Place and closure of Forrest Road to general traffic. Due to the closure of Forrest Road, Bristo Place becomes two-way with one lane in each direction for general traffic. Further changes to traffic operations include the closure of the road between Market Street and Chambers Street for general traffic, closure of Victoria Street, the introduction of shuttle working on Bank Street, the introduction of a signalised junction at George IV Bridge / Chambers Street and a new signalised crossing at the northern extent of Forrest Road, and introduction of a separate cycling stage at every signalised junction along the route.
- Option 2 – As Option 1, including all changes to traffic management and introduction of a segregated cycleway on the east side of the road. However, unlike in Option 1, in Option 2 there is no dedicated cycle stage for cyclists at each junction, therefore the left turn for all traffic at each junction is prohibited and the green aspect for cyclists appears during the same stage as that for north / south traffic.
- Option 3 – In contrast to Option 1 and Option 2, Option 3 includes the introduction of a segregated cycleway on the west side of the road. Option 3 is based on Option 2 and hence includes all changes to traffic management as in Option 2, with the exception that right turns for general traffic are prohibited at certain junctions.

The initial modelling results described in section 7, have shown that Option 1 displays the worst journey time results for both cyclists and buses, due to the dedicated stage for cyclists at each junction and an increased traffic demand from Market Street, as a result of the road closure for general traffic between Chambers Street and Market Street.

Option 2 and Option 3 performed better in comparison to Option 1, due to the longer stages for traffic at signalised junctions along the route. However, the introduction of traffic signals at the junction of George IV Bridge and Chambers Street and the signalised crossing at Forrest Road / Bristo Place cause additional delay, meaning bus journey times for Option 2 and Option 3 were slower than in the base model.

After initial assessment of the modelling results for all three options, further road closures were included in the option models, which were proposed by City of Edinburgh Council. Namely, Option 1 was modelled with Market Street, Waverley Bridge and Cockburn Street closed to general traffic.

Further modelling results for Option 1 (Market Street closed) have shown a significant reduction in bus journey times in comparison to Option 1 (Market Street open) results. For example, bus journey times in Option 1 (Market Street closed) in the northbound direction was around 12 minutes and 27 minutes faster in the AM and PM peaks respectively against the Option 1 (Market Street Open). For the southbound direction the difference in journey time was around 2 minutes and 5 minutes for the AM and PM peak respectively. These improved journey times in Option 1 (Market Street closed) are reflected in the traffic conditions on The Mound, where there are smaller queues and generally less congestion when Market Street is closed.

Based on the modelling results of options 1, 2 and 3, the initial conclusions of the undertaken modelling work were summarised in section 8. The initial assessment of the proposed options showed that, when Market Street is open, Option 2 is the preferred option as it causes less delay to cyclists and buses in comparison to Option 1. However, further modelling of Option 1 has shown that closing Market Street to general traffic significantly improves bus journey times in comparison to Option 1 (Market Street Open), which makes Option 1 a feasible option.

Appendix D describes the additional modelling tests which were carried out after discussions with City of Edinburgh Council about the modelling results of options 1, 2 and 3, which is described in sections 7 and 8.

In order to increase the effectiveness of the proposed options, CEC asked AECOM to make the following key changes to the Option 2 (Market Street Closed) and Option 3 (Market Street Closed) models:

1. Modification of the signal settings at the High Street / George IV Bridge junction to implement a second pedestrian stage; and
2. Testing of alterations to the shuttle work between High Street and Market Street.

Furthermore, as part of the additional modelling, a new “Hybrid” option design was created. This option is a synthesis of the Option 1 and Option 2 designs. Option 2 Hybrid includes all of the changes to traffic management / operations as contained in Option 2, and a dedicated cycling stage at the George IV Bridge / High Street junction, The Mound / Market Street junction and The Mound / Princes Street junction as in Option 1. The segregated cycleway in Option 2 Hybrid is on the east side of the road from the bottom of Forrest Road to The Mound / Princes Street junction and on the west side of the road from Princes Street to George Street.

In order to improve the operation of the shuttle work between High Street and Market Street, two sets of signal timings (Option A and Option B) were created in LinSig for the High Street / George IV Bridge junction. The main difference between the Option A and Option B signal settings is that Option A has a dedicated stage for cyclists, whereas in Option B cyclists run at the same time with traffic on Bank Street.

Additional modelling results for Option 2, Option 2 Hybrid and sub test options (Option A and Option B) are described in sections D.3 and D.5. According to the obtained results, the Option A and Option B signal settings slightly reduce the end-to-end journey time for cyclists in both directions, in both the AM and PM peak periods, in comparison to the Option 2 Hybrid model. For example, in the AM peak, Option A and Option B were 23 to 25 seconds faster in the northbound direction and 6 to 8 seconds faster in the southbound direction than Option 2 Hybrid. Similarly, in the PM peak, Option A and Option B were 34 to 36 faster in the northbound direction and 4 to 13 seconds faster in the southbound direction in comparison to Option 2 Hybrid.

Furthermore, both Option A and Option B significantly reduce bus journey times in the northbound direction for both the AM and PM peak periods in comparison to the Option 2 Hybrid model. Bus journey times in Option A and Option B were 65 to 69 seconds faster in the AM peak and 64 to 92 seconds faster in the PM peak. In the southbound direction both options show a marginal reduction in bus journey time in comparison to the northbound direction.

Overall, this report evaluates various traffic management and cycling infrastructure design options for the corridor from Middle Meadow Walk to George Street. The initial modelling results for Option 1 Option 2 and Option 3 are described in section 7, whereas the additional modelling results for Option 2, Option 2 Hybrid and Option 2 Hybrid sub-test options (Option A and Option B) are described in Appendix D.

Considering all of the modelling results, it can be concluded that Option 2 Hybrid with the Option B signal settings at the George IV Bridge / High Street junction can be considered to be the preferred design option, as it provides the best combination of safety for cyclists and journey time results for both cyclists and buses.

1. Introduction

In 2016 AECOM created calibrated and validated VISSIM model, which covered Forrest Road / Bristo Place / Teviot Place / George IV Bridge area in Edinburgh as part of Transport Scotland Community Links Plus programme.

In 2019 AECOM were commissioned by the City of Edinburgh Council to extend the existing VISSIM model to cover a corridor from George Street to Lauriston Place. The extended VISSIM model will be used to define and assess traffic management and cycle infrastructure options in Edinburgh city centre as part of Transport Scotland and Sustrans' Community Links Plus programme. The project, Meadows to George Street, aims to improve walking and cycling infrastructure along the corridor, as well as enhance the public realm.

This report describes development of the extended base model as well as development of the option models and analysis of obtained results.

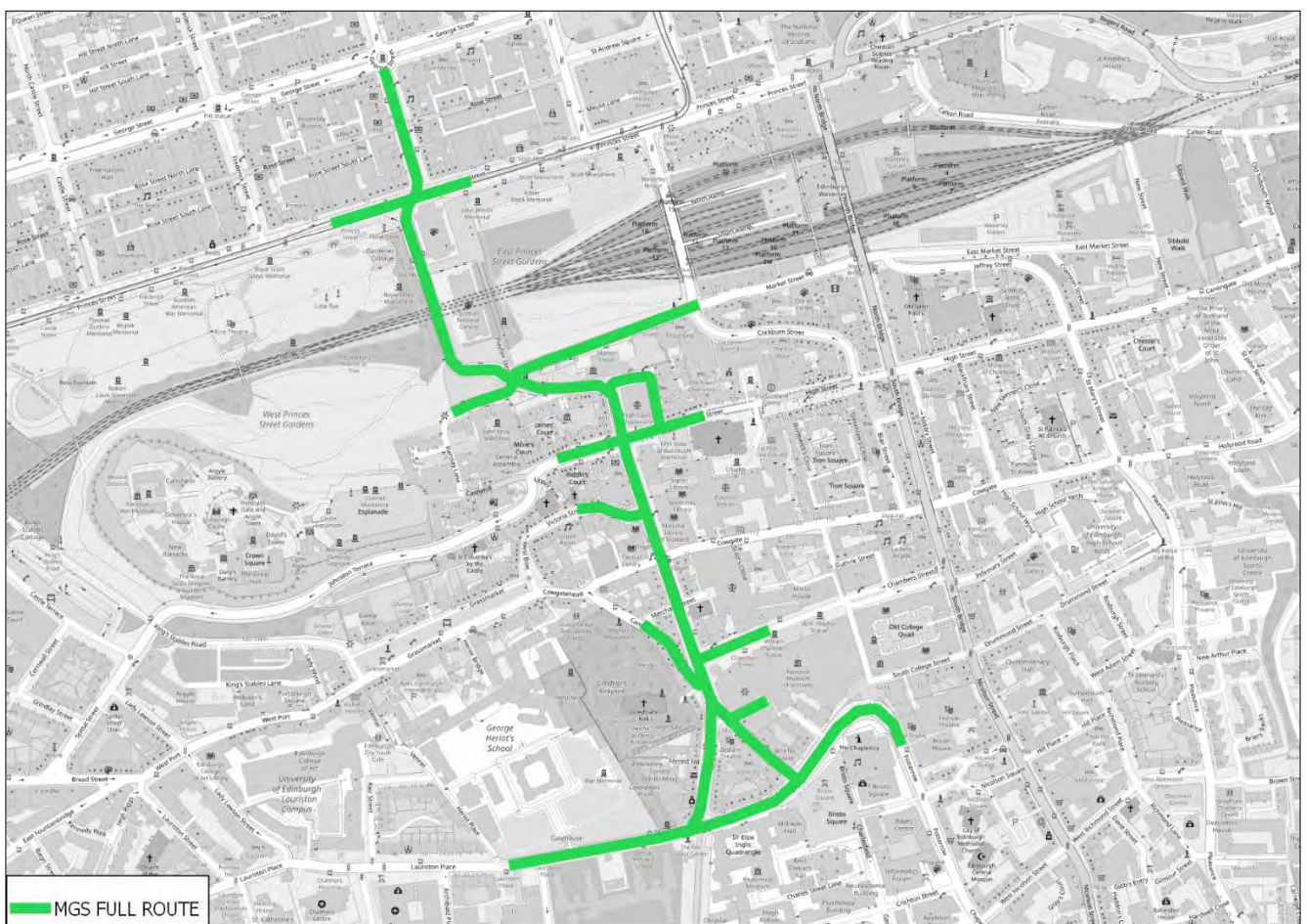


Figure 1: George Street to Lauriston Place Corridor map

1.1 Background

The area is in an urban environment, with retail outlets, restaurants and cafes, and private residences, as well as educational institutions. All of the streets in the area are subject to a speed limit of 20mph. The area is a key public transport corridor, linking the town centre to the north with areas to the south-east and south-west.

The proposals include the following changes:

- Teviot Place becomes two-way (currently one-way westbound);
- General traffic is removed from Forrest Road, with the road being accessible to cyclists, pedestrians, servicing vehicles (during certain time periods only) and for local access (e.g. to Forrest Hill);
- New traffic signals at the Lothian Street / Teviot Place / Bristo Place junction;
- Bristo Place becomes two-way (currently one-way south-eastbound);
- A new crossing at the northern extent of Forrest Road;
- New traffic signals at the Chambers Street / George IV Bridge junction;
- An improved crossing for cyclists at the junction of Princes Street, The Mound and Hanover Street;
- Bi-directional segregated cycleways on Teviot Place, Forrest Road, Lothian Street, George IV Bridge, and Bank Street; and
- New segregated cycle infrastructure on The Mound and Hanover Street, although the exact nature of this remains to be decided.

1.2 Task Objectives

The primary aim of this exercise was to assess the proposed traffic management and cycle infrastructure options, which are being considered for implementation as part of the “Community Links Plus” project.

1.3 Report Structure

The remainder of this report is structured as follows:

- Section 2 – Survey Data
The survey data that was used in the construction of the models is detailed.
- Section 3 – Base Model Development
The parameters, assumptions and limitations associated with the base model are described.
- Section 4 – Calibration and Validation
Level of calibration and validation achieved for the AM and PM base models.
- Section 5 – Proposed Option
This section describes each option in detail, presenting figures to illustrate the proposals.
- Section 6 – Sensitivity Tests
This section describes the sensitivity tests that were carried out.
- Section 7 – Modelling Results
The modelling results from each option are presented, highlighting their strengths and weaknesses.
- Section 8 – Conclusions and Recommendations
The conclusions and recommendations that have been drawn from the modelling outputs are detailed.

2. Data

2.1 Traffic Survey Data

Traffic survey was undertaken by Tracsis Ltd on Tuesday 15th March 2016 and Tuesday 13th and Wednesday 14th of November 2018. However, further manual counts were undertaken to assess the flows from Victoria Street. These dates avoid local school holiday periods and any other days where flows are unrepresentative of normal conditions. The conducted traffic surveys cover an area from George Street to Teviot Place. The following junctions were surveyed for Manual Junction Turning Counts and Queue Length Surveys

15th March 2016

- George IV Bridge / Chambers Street / Candlemaker Row Staggered Priority Junction.
- George IV Bridge / Forrest Road / Bristo Place Traffic Signal Junction;
- Bristo Place / Lothian Street / Teviot Place Traffic Signal Junction; and
- Forrest Road / Lauriston Place / Teviot Place Traffic Signal Junction.

13th and 14th November 2018

- Hanover Street / Princes Street Signalised Junction
- Mound Place / The Mound / Market Street Signalised Junction
- St Giles Street / The Mound / Bank Street Priority Junction
- Royal Mile / Bank Street / George IV Bridge Signalised Junction

As previously mentioned, the Victoria Street / George IV Bridge junction was subject to a separate manual count following the completion of the surveys listed above.

It should be noted that a review of the 2016 and 2018 survey data was undertaken to assess any difference in the flow along George IV Bridge. The results indicated negligible differences therefore no adjustments were made to the 2016 data.

During the day of the survey, classified turning count and queue lengths was collected over the following time periods:

- AM period: 07:00-10:00
- PM peak: 14:30-18:30

2.2 Signal Data

Within the modelled network there are a number of signalised junctions and signalised pedestrian crossings. To accurately model these junctions / crossings, signal data was requested from City of Edinburgh Council for the following junctions;

- George IV Bridge / Forrest Road / Bristo Place Traffic Signal Junction;
- Bristo Place / Lothian Street / Teviot Place Traffic Signal Junction;
- Forrest Road / Lauriston Place / Teviot Place Traffic Signal Junction;
- Mound Place / The Mound / Market Street Signalised Junction; and
- Royal Mile / Bank Street / George IV Bridge Signalised Junction.

Signals timings at Hanover Street / Princes Street Signalised Junction were extracted from the CEC's VISUM model.

2.2.1 Public Transport

Using detailed online timetables and routing from Lothian buses, public transport information was gathered to be inputted in the models.

2.2.2 Additional Data

Multiple site visits were undertaken to understand current traffic conditions and driving behaviour in the area.

The key points highlighted from the site visit are below:

- Steep gradient on The Mound southbound direction reduces saturation flow at The Mound/Market Street junction, especially when buses stop at the bus stop before the stop line.
- Vehicles turning right from North Bank Street onto Market Street form informal second lane at the junction and do not block the northbound movement.
- Surveyed queue lengths on North Bank Street and Bank Street are in reality forming one long queue.
- In addition, cycle time and stage lengths were recorded for Hanover/George street junction, Hanover Street / Rose Street pedestrian crossing and Hanover Street / Princes Street junction.
- Delays along Lauriston Place occur in the AM peak due to children drops off at George Heriot's School
- Parking along Forrest Road, Teviot Place and Bristo Place reduce through capacity

The above have all been included to enhance the model's realism.

3. Base Model Development

3.1 Background

The following section describes the development of the base model. The model has been calibrated and validated in VISSIM version 10.00-02. The modelled network was developed based on 2018 site visits, survey footage and conducted Google scoping exercise. Driving behaviour was adjusted based on the survey footage and observations from the site visit.

3.2 Modelled Area

Figure 2 below shows the full extent of the modelled area, where yellow rectangle highlights model area built in 2016 VISSIM (Original Model) model and green rectangle highlights model extension created in 2019.

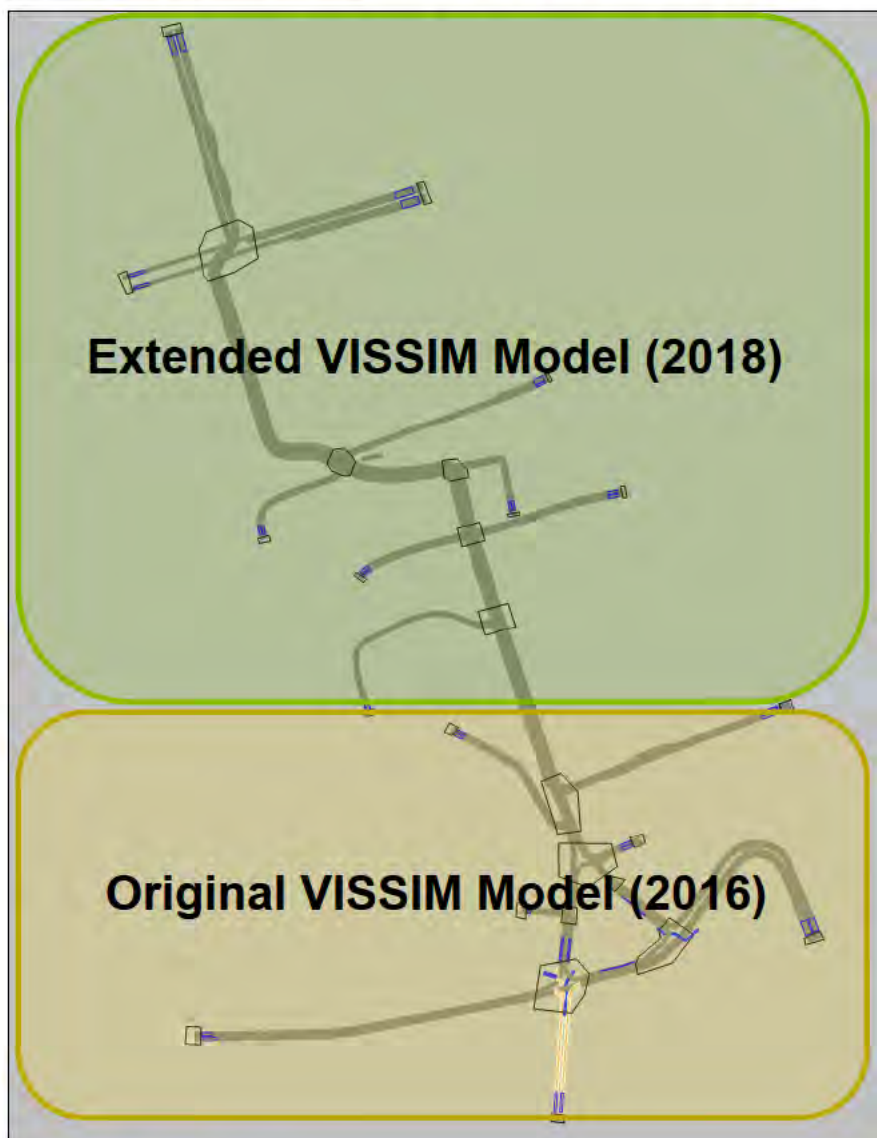


Figure 2: Modelled area

The corridor section from Hanover Street to Bristo Place has one lane for general traffic in each direction. Bristo Place, Teviot Place and Forrest Road are one-way roads with two lanes for general traffic.

An advisory cycle lane is currently available on the sections from The Mound / Princes Street to Lawnmarket / George IV Bridge and from George IV Bridge / Chambers Street to the Bristo Port / Teviot Place junction on the

east side of the road. On George IV Bridge there is one lane for general traffic and one bus lane in each direction.

The following turns from the main corridor are banned:

- No left or right turn movements from Hanover Street and The Mound onto Princes Street; and
- No right turn movement from George IV Bridge onto Victoria Street.

3.3 Driver Behaviour and Specific Site Characteristics

The following information was collected and incorporated into the model to achieve realistic driving behaviour, based on the observations on site and from the video survey footage:

- Lane usage and gradients, use of lanes, weaving manoeuvres, impacts on larger vehicles when starting on a steep gradient etc;
- Speed limits and adherence to the 20mph speed limits; and
- Driver behaviour at signalised and priority junctions, such as courteous driving behaviours, reactions to lights changing, etc.

3.3.1 Modelled Periods

Based on the survey data analysis, the following peak hours were identified for the AM and PM periods:

- AM Weekday 08:00 to 09:00 (with a 30 minute build up period); and
- AM Weekday 16:45 to 17:45 (with a 30 minute build up period).

3.3.2 Vehicle Types

Seven vehicle types are represented within the model:

- Car;
- Light Goods Vehicle (LGV);
- Other Goods Vehicle 1 (OGV1);
- Other Goods Vehicle 1 (OGV2);
- Cyclists;
- Taxis; and
- Local Access Vehicles.

3.4 Public Transport

As discussed, online timetables and routing from Lothian buses was used to develop the public transport within the traffic model. Details such as behaviour at bus stops were examined especially along Forrest Road.

3.5 Matrix Development

3.5.1 Overview

This section describes development of the base demand matrices and profiles for the base VISSIM model. Separate matrices were created to represent the AM peak (08:00 – 09:00) and the PM peak (16:45 – 17:45), with light vehicle, heavy vehicle and cycle matrices created for each period.

3.5.2 Demand Matrices

The same methodology was used to estimate demand matrices for **light vehicles**, **heavy vehicles**, and **cycles**. The 2018 demand matrices were estimated using classified junction turning counts.

The matrix development used the following methodology:

1. The demand movements from the original VISSIM model of the Teviot Place / Forrest Road / Bristol Place area remain unchanged (with the exception of trips to George IV Bridge).
2. The demand movements from the original VISSIM model to George IV Bridge were distributed between the new zones north of Victoria Street, with this distribution being based on the 2018 classified turning counts.
3. The demand movements from the new extended area were distributed based on the 2018 classified turning counts (with the exception of trips to George IV Bridge).
4. The demand movements from the new extended area to George IV Bridge were distributed between the original zones south of Victoria Street, this distribution was based on the 2016 classified turning counts.

Trips from Victoria Street were distributed using both the 2016 and 2018 survey data.

3.5.3 Profiling

It is essential that demand profiles are modelled since fluctuation in demands can result in spikes in queuing and could have an impact on the operation of the network. To this end, 2016 and 2018 classified turning count data was used to derive the demand profiles for the original and extended sections of the model.

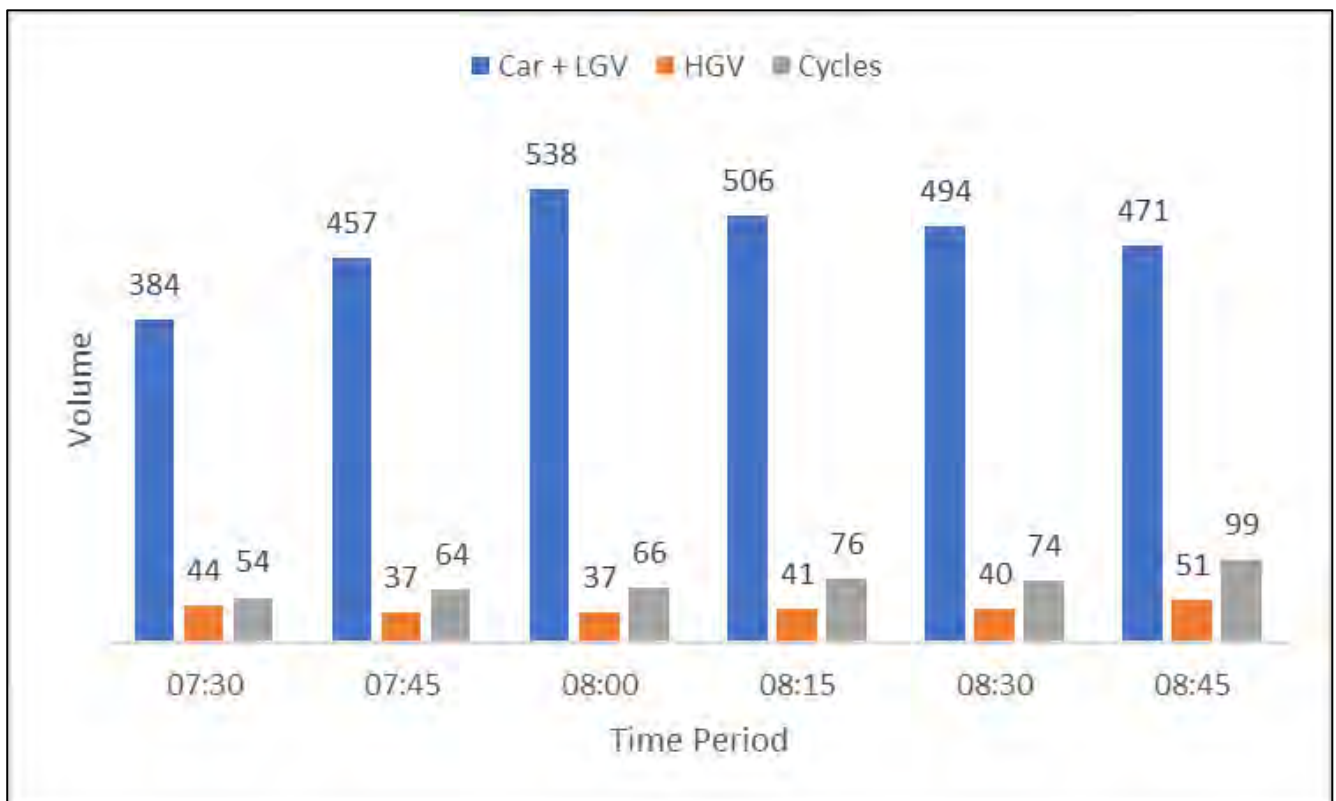


Figure 3: AM Profiles

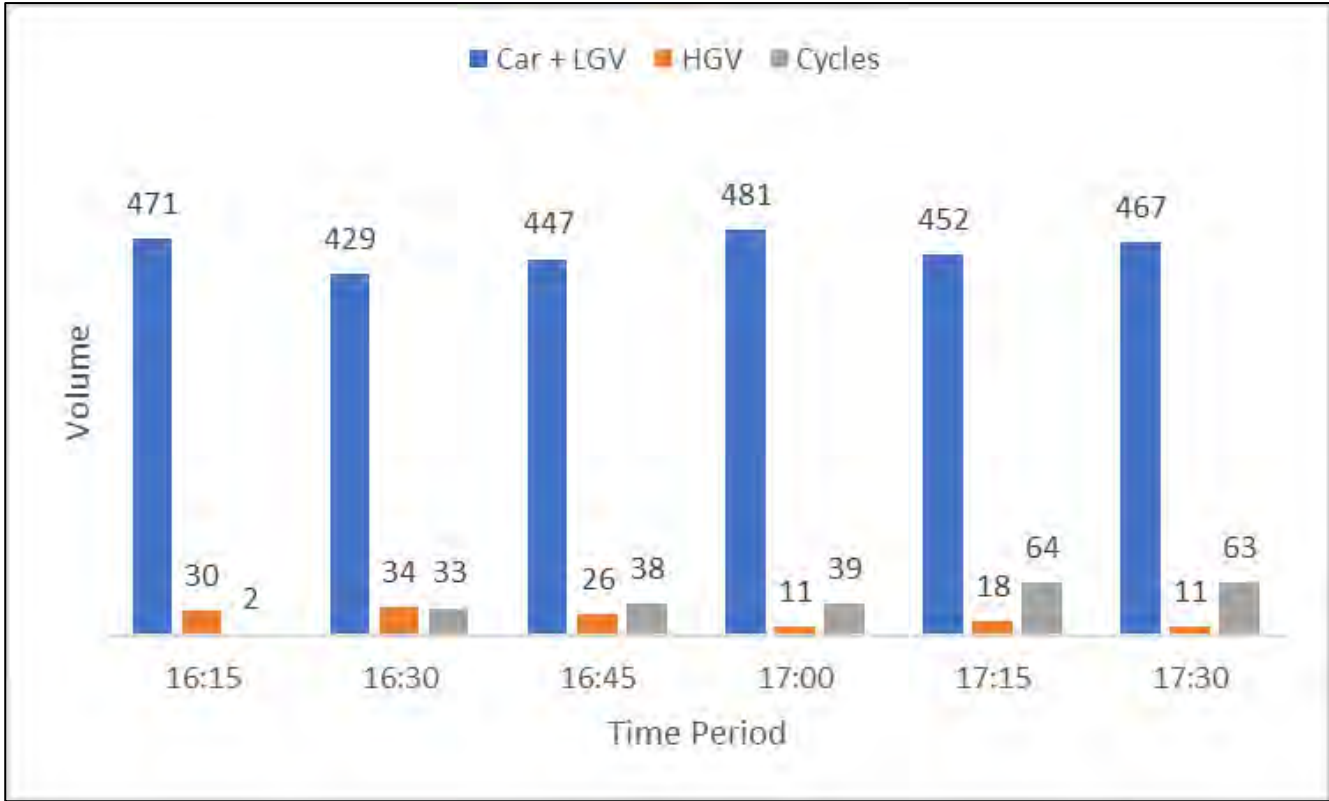


Figure 4: PM Profiles

4. Calibration and Validation

This section describes the calibration and validation TAG criteria and provides evidence of the calibration and validation of the developed base model. AM and PM calibration summary tables and queue graphs are provided to demonstrate that the AM and PM base models have been calibrated and validated.

4.1 Overview

Calibration

The calibration of the model was undertaken by comparing modelled turn counts to the observed data set.

The criteria used for the calibration and validation of the model are detailed in the advice given in the WebTAG 3.1. A total of 10 seed runs were carried out for each peak. A seed alters the distributions within the model creating variation. It is essential that the model is tested with varying seeds to ensure the model results are robust. Turning movement calibration has followed TAG 3.1 guidance using the GEH statistic, which is a form of the Chi-squared statistic that incorporates both relative and absolute errors, and is defined as follows:

$$GEH = \sqrt{\frac{(M - C)^2}{(M + C)/2}}$$

Where: GEH is the GEH statistic;

M is the modelled flow; and

C is the observed flow.

Individual flow criteria which depends on the level of flow:

- The difference between modelled and surveyed flows must be <100 vehicles for flows <700 vehicles;
- The difference between modelled and surveyed flows must be <15% for flows between 700 and 2,700 vehicles; and
- The difference between modelled and surveyed flows must be <400 vehicles from flows >2,700 vehicles.

The model is seen to be calibrated once 85% of the turning flows meet the GEH criteria or individual criteria.

Validation

In TAG 3.1 there are no criteria for queue length validation due to the dynamic nature of the queue and human interpretation of what a “queue” is. Therefore, according to TAG 3.1, the queue length comparison should only be seen as supporting evidence.

However, due to the extent of the modelled area in the models being small (less than 3 kilometres long), the comparison of the corresponding observed and modelled queue lengths has been chosen to validate the base model.

4.2 Calibration – Turning Count Results

The results for the AM peak show a high level of calibration, as shown in Table 1.

Table 1: Turning Count Calibration - AM Peak

	Results
Number	56
Average GEH	0.99
Maximum GEH	3.27
GEH < 5	100%
Difference <100	100%

The results for the PM peak also show a high level of calibration, as shown in Table 2.

Table 2: Turning Count Calibration - PM Peak

	Results
Number	56
Average GEH	1.1
Maximum GEH	4.41
GEH < 5	100%
Difference <100	100%

4.3 Validation – Queue Length comparison AM and PM Peaks

Examples of the queue length comparison graphs that have been used to determine and demonstrate that the AM and PM base models are validated are shown in Figure 5 and Figure 6.

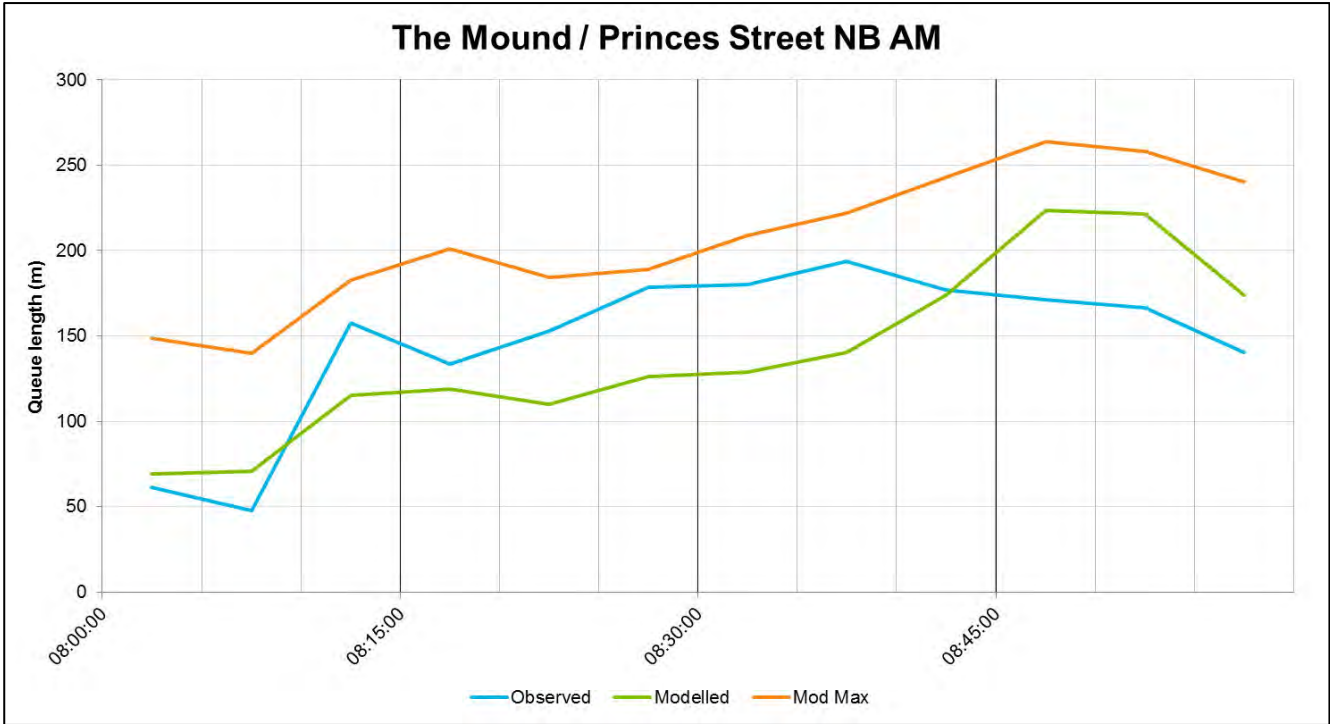


Figure 5: Queue Length Comparison – The Mound / Princes Street NB AM

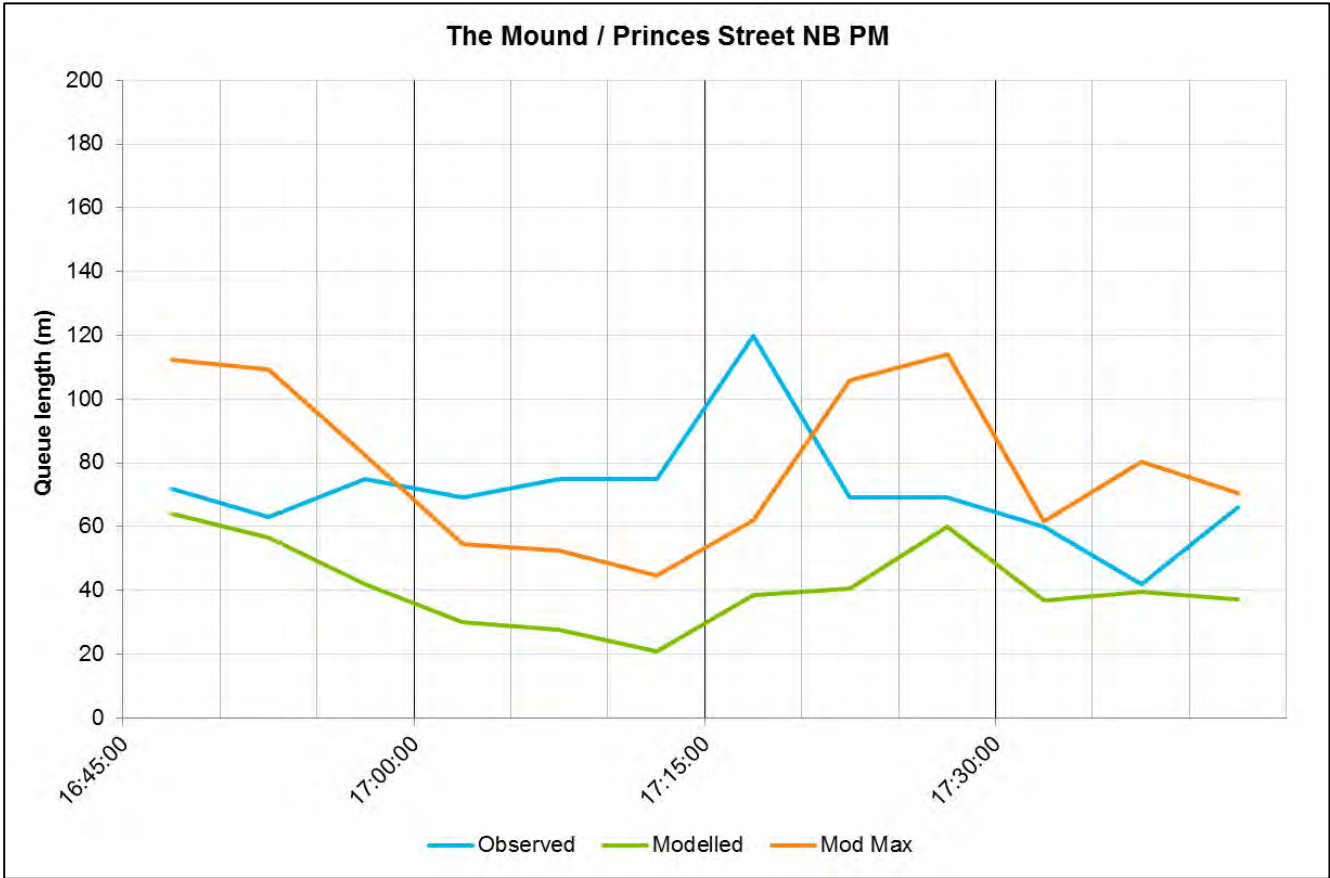


Figure 6: Queue Length Comparison – The Mound / Princes Street NB PM

5. Option Modelling

This section describes the development of the 3 options that were modelled. Option models were created in VISSIM 10 to test traffic management and cycle infrastructure options, designed by the AECOM Streets team to improve walking and cycling infrastructure along the corridor.

The three options that were modelled were as follows:

- Option 1
Segregated cycleway on the east side of George IV Bridge, Bank Street and The Mound; segregated cycleway on the west side of Hanover Street; dedicated cycle stages would be provided to allow the cycleway to cross junctions; St Giles Street would be open.
- Option 2
Segregated cycleway on the east side of George IV Bridge, Bank Street, The Mound and Hanover Street; St Giles Street closed at Bank Street (with access only permitted from Lawnmarket or from George IV Bridge); cycleway runs with general traffic where possible (including at Princes Street, High Street and Chambers Street).
- Option 3
As Option 2, but with the segregated cycleway on the west side of George IV Bridge, Bank Street, The Mound and Hanover Street.

These three options are described in sections 5.1 to 5.3.

5.1 Option 1

5.1.1 Option 1 Traffic Operations

Option 1 includes the introduction of a segregated cycleway on the east side of the road along the whole route from George Street to Lauriston Place, and closure of Forrest Road for general traffic. Due to the closure of Forrest Road, Bristo Place becomes two-way with one lane in each direction for general traffic. Further changes to traffic operations include the closure of the road between Market Street and Chambers Street for general traffic, closure of Victoria Street, shuttle working is introduced on Bank Street, the introduction of a signalised junction at George IV Bridge / Chambers Street, and a new signalised crossing at the northern extent of Forrest Road.

The shuttle working on Bank Street severs the north-south corridor for general traffic, meaning that there is a reduction in demand between Chambers Street and Market Street. The signal timings at the George IV Bridge / High Street and Market Street / The Mound junctions were adjusted to match the reduced demand. **In addition to the previous changes, a separate stage for cyclists is introduced at each signalised junction along the route.**

The signalised crossing at the northern extent of Forrest Road aims to provide safe crossing of Bristo Place / George IV Bridge to transition between Forrest Road and the cycleway on the east side of George IV Bridge. The crossing is demand dependant and the crossing is synchronised with the traffic signals at the George IV Bridge / Chambers Street junction to provide a green wave and to reduce queueing on George IV Bridge and Bristo Place. The separate stage for cyclists at every signalised junction should improve cyclist's safety and provide a sense of priority for cyclists.

Figure 7 shows the Option 1 VISSIM network with the segregated cycleway (in WHITE), which is predominantly positioned on the east side of the corridor.

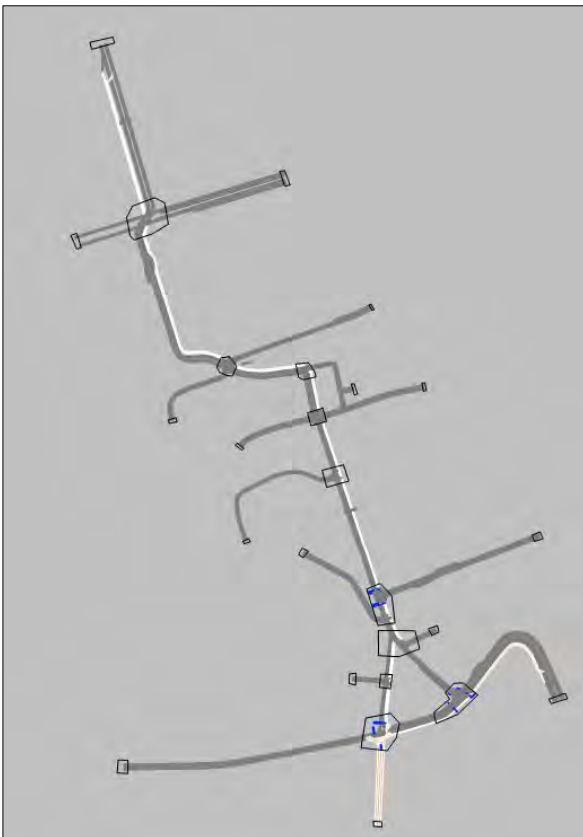


Figure 7: Option 1 VISSIM Layout

5.3 Option 3

5.3.1 Option 3 Traffic Operations

Option 3 is based on Option 2 and was developed in order to determine the potential benefits of positioning the cycleway on the west side of Forrest Road, George IV Bridge, Bank Street, The Mound and Hanover Street. By positioning the cycleway on the west of the carriageway, the junctions at George IV Bridge / Forrest Road, Chambers Street, St Giles' Street and Market Street are simplified as there is no conflict between traffic travelling to and from the side roads and the cycleway.

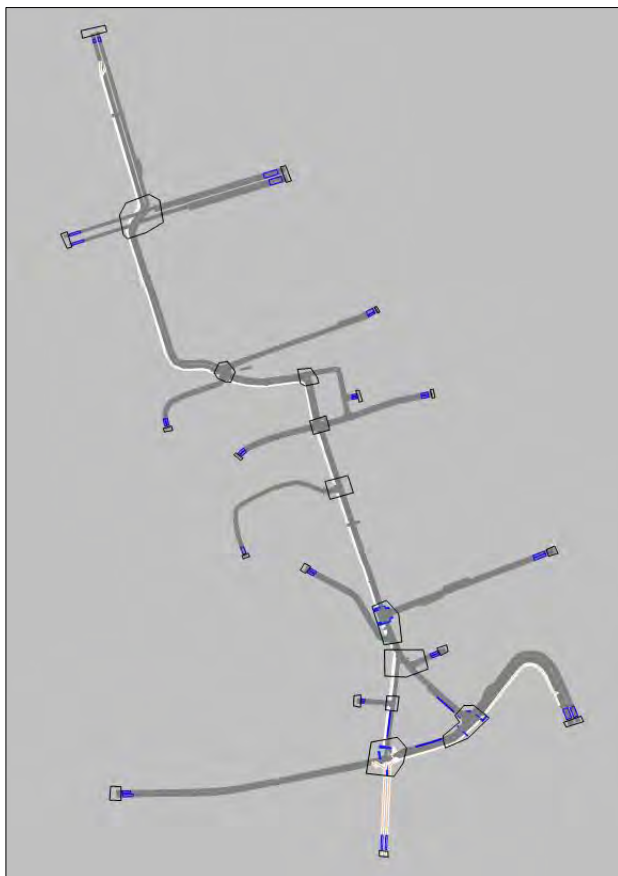
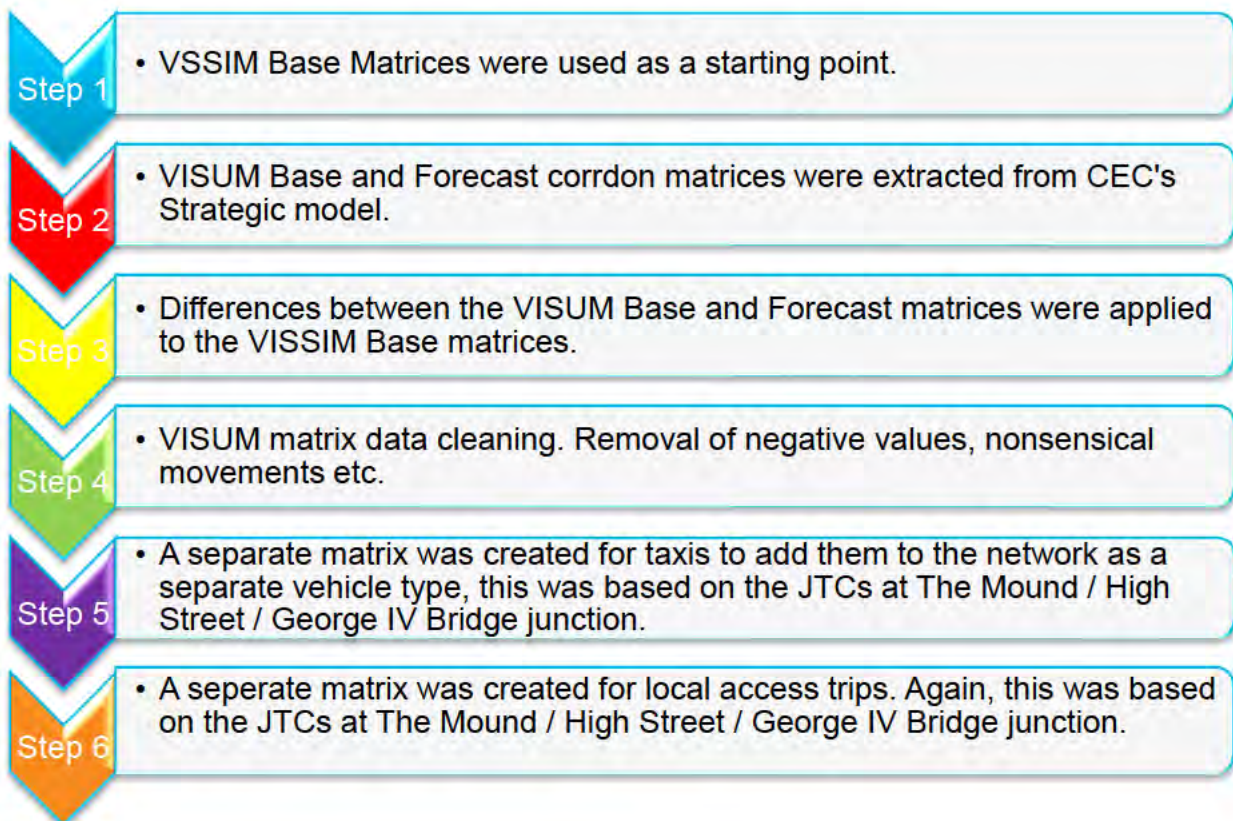


Figure 9: Option 3 Traffic Management

5.3.2 Matrix Development

A full description of how the demand matrices were developed is discussed within the appendices of this report, however a summary is provided below:



5.3.3 Additional Matrix Development Notes

- According to current timescales the proposed traffic management changes will be implemented by 2023.
- The future year demand matrices included the closure for general traffic between Market Street and Chambers Street.
- For Option 2, there is no left turn from Bank Street to High Street, thus these trips were reassigned to southern zones, for both the taxi and local access demand matrices.

6. Further Option Modelling

Section 6 describes further modelling tests, which were carried out after the final session of public consultations in May 2019 and discussions of initial modelling results with City of Edinburgh Council.

Since the completion of the previous modelling options, as described in section 4, CEC have updated their wider traffic management plans, which include the closure of Market Street and Waverley Bridge. These additional closures will have a significant impact on the demands to and from The Mound / Hanover Street.

The paragraph below summarises further changes to traffic management and describes the series of sensitivity tests that were carried out.

6.1 Market Street Closure

In terms of safety for cyclists, Option 1 is the preferred option, however as section 7 will highlight, Option 1 presents significant delays to the network. However, given the expected reduction in traffic due to the closures highlighted below, Option 1 is expected to perform satisfactorily therefore has been used to test a variety of sensitivity tests.

The following closures are being proposed for the sensitivity test.

- Closure of Waverley Bridge;
- Closure of East Market Street; and
- Closure of Cockburn Street.

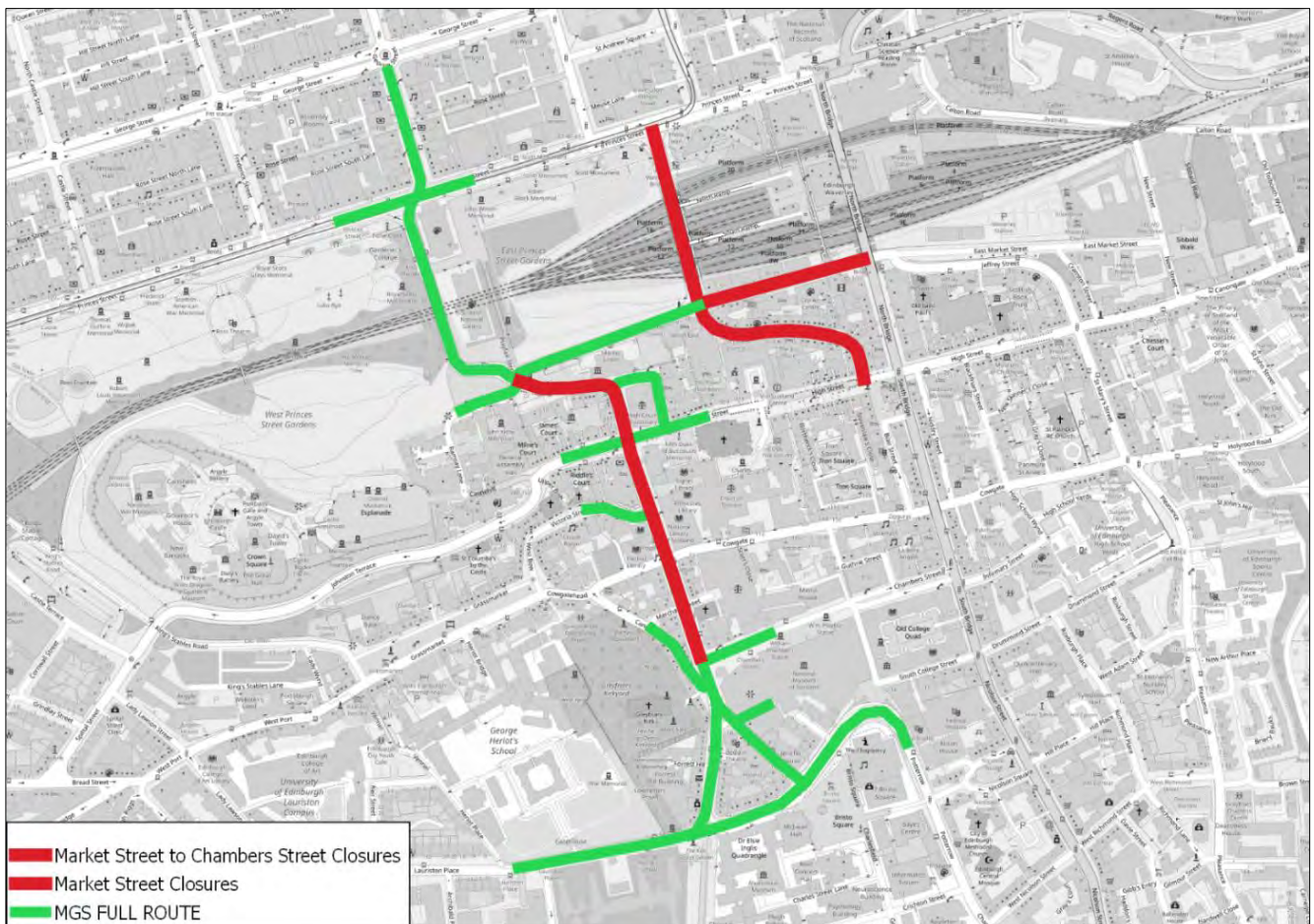


Figure 10: Closures on Market Street Map

6.2 Sensitivity Tests

The purpose of the sensitivity tests is to provide a safety margin in which Option 1 could operate without undue disruption to the network. The demand estimates have come from CEC's strategic model, which does not have sufficient base data to accurately forecast the expected traffic volumes if the proposed closures were in place. Therefore, these sensitivity tests are being used to provide CEC some comfort if the estimates were to be found inaccurate.

6.2.1 Option 1 Demand

As part of further modelling work on Option 1, sensitivity tests were carried out to determine a maximum level of traffic that can pass through Market Street / The Mound junction without blocking key junctions such as Princes Street/ The Mound / Hanover Street during AM and PM peak periods.

The following methodology was used to perform sensitivity tests:

- New set of VISSIM matrices for "Light" and "Heavy" vehicles were estimated using VISUM OPTION matrices with closed Market Street. **The estimated demand was used as a base scenario for the sensitivity testing.**
- For both AM and PM peak hours, the "Light" vehicle demands from Hanover Street to Market Street and from Market Street to Hanover Street was proportionally increased by 5%, 10%, 20%, 30% and 35%.
- Finally, the inflated AM and PM peak hour matrices for "Light" vehicles were profiled into 15 minutes' matrices. **The same profiles were used for the sensitivity tests as were used for the base model and initial option testing.**

6.2.2 Option 1 Cyclists Green Time

Further tests were carried out to estimate the maximum stage length for cyclists at the Princes Street / The Mound junction. In the initial Option 1 model, signal timings at the Princes Street / The Mound junction were fixed and consisted of 3 stages:

- Stage 1 - Princes Street traffic movement
- Stage 2 – Cyclists movement
- Stage 3 - The Mound / Hanover Street traffic movement

In the initial Option 1 model, the length of the cyclist's stage is minimal: 7 seconds of green time (+intergreen), while the stage length of The Mound / Hanover Street traffic stage is 21 seconds of green time (+intergreen). As traffic demand to / from Hanover Street has reduced, due to the closure of Market Street, the length of the cyclist's stage can be extended. The length of the Princes Street stage must remain consistent with current timings, due to the tram and bus services on Princes Street.

6.3 Assumptions

- **For the Option 1 sensitivity tests, it was assumed that light vehicles (Taxis) going to / from Market Street are travelling to / from Waverley station to pick up / drop off passengers.**
- **It was assumed that there is a constant demand of passengers travelling to / from Waverley station, thus the total number of vehicles going from Hanover Street to Market Street and from Market Street to Hanover Street must be the same.**

7. Modelling Results

The following chapter describes the modelling results. The results consider the following performance indicators:

- Journey times;
- Network Statistic (average delay per vehicle etc); and
- Queue Length.

7.1 Initial Options Modelling Journey Times

Journey time data was obtained for the base model and for each of the option models, in order to assess the various options.

In total, journey time data was obtained for 3 main routes, as shown in Figure 11 below:

- Southbound from George Street to Potterrow – **Route 1**
- Northbound from Potterrow to George Street – **Route 1**
- Southbound from George Street to Lauriston Place – **Route 2**
- Northbound from Lauriston Place to George Street – **Route 2**
- Northbound from Lauriston / Potterrow to George Street through Forrest Road (cyclists only) – **Route 3**

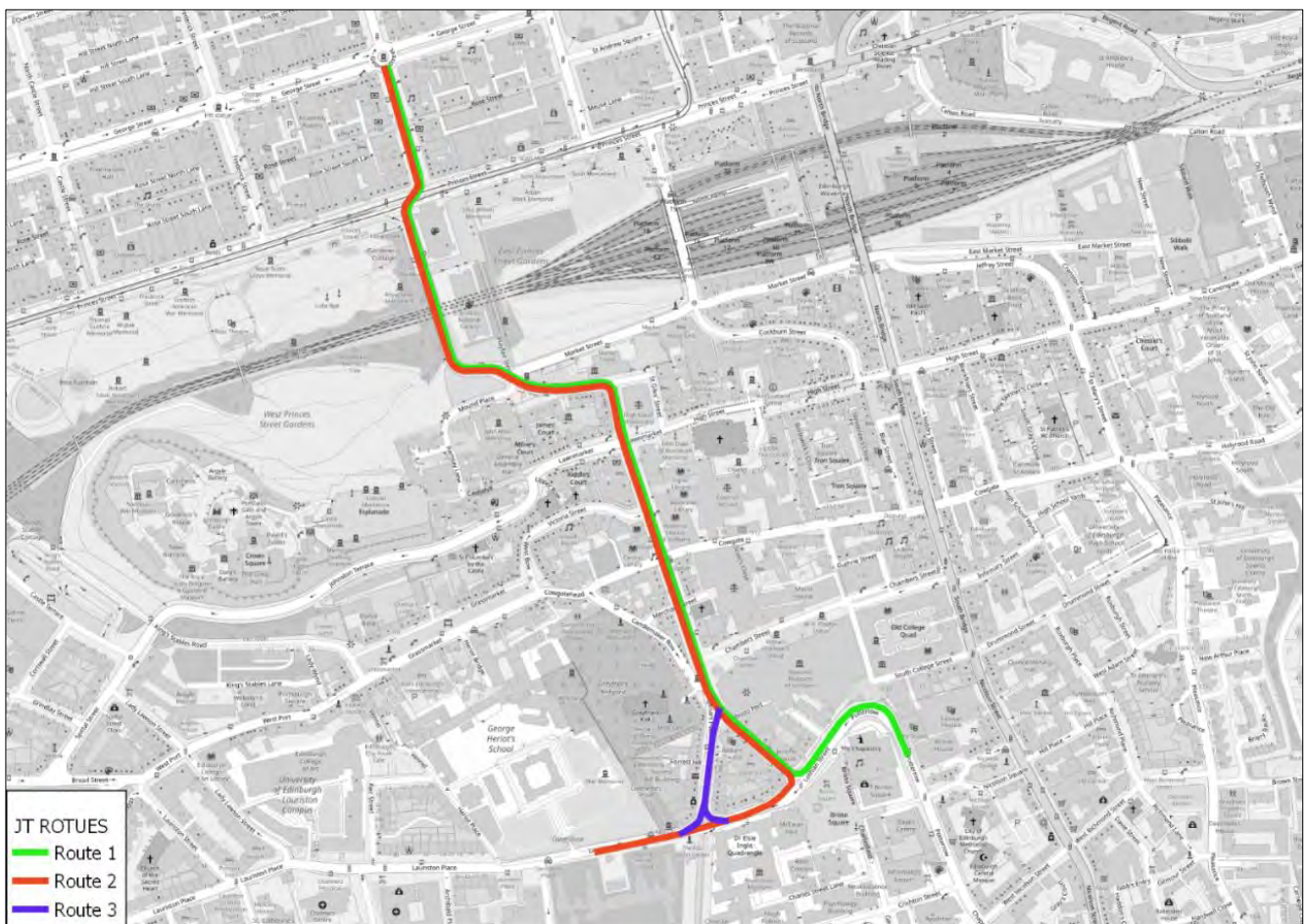


Figure 11: Journey Time Routes

It should be noted that only Route 1 has been used to illustrate the expected journey times for cyclists and buses, however a comprehensive journey time review is presented in the appendices.

7.1.1 Network Performance

The network performance indicators which have been analysed are; average delay and latent demand. The latent demand is the number of vehicles that cannot be processed by the network and are still yet to enter the modelled network at the end of the recorded simulation.

Table 3 summarises the average delay for cyclists.

Table 3: Average Delay for Cyclists (seconds)

	AM	PM	Weighted Average
Base	53.91	45.39	50.30
OPT 1	111.85	95.88	105.35
OPT 2	110.23	80.57	97.61
OPT 3	102.83	105.3	104.04

As shown in Table 3, the three options display approximately twice as much delay as that of the base model, in both AM and PM peaks. Option 1 has the worst delays in the AM, while Option 3 has the highest delays in the PM.

The weighted average highlights option 2 as the preferred option in terms of delays for cyclists.

Table 4 presents the average delay for buses.

Table 4: Average Delay for Buses (seconds)

	AM	PM	Weighted Average
Base	213.07	217.96	215.47
OPT 1	497.45	631.71	561.94
OPT 2	247.55	267.35	257.31
OPT 3	255.1	310.75	282.35

Table 4 shows that Option 1 has the highest delays for buses in both the AM and the PM peaks. Similar to the model outputs for Cyclists, Option 2 is highlighted as the preferred option with a weighted average delay of 257 seconds, around 40 seconds higher than that of the base scenario.

In terms of private vehicles, the average delays are presented in Table 5 below.

Table 5: Average Delay for Private Vehicles (seconds)

	AM	PM	Weighted Average
Base	115.04	108.96	112.12
OPT 1	252.82	316.60	282.98
OPT 2	149.68	174.12	161.77
OPT 3	151.13	156.97	154.02

For private vehicles, Option 1 has the highest delays for light vehicles for both the AM and PM peaks. Option 2 and 3 shows similar delays between the AM and PM peaks, albeit Option 3 has a marginally lower weighted average delay.

Table 6 summarises the latent demand for the Base and Option models.

Table 6: Latent Demand

	AM	PM
Base	12.3	32.9
OPT 1	148.1	254.8
OPT 2	32.9	29.1
OPT 3	17.7	0.6

Again Option 1 has the worst latent demand figures with 148 vehicles and 255 vehicles being held off the network in the AM and PM peaks respectively. Option 3 has the least latent demand and performs marginally better than both Base and Option 2.

7.1.2 Cyclists

Table 7 summarises the journey times for cyclists along Route 1 for the base and the three options.

Table 7: Cycle Journey Time (Market Street Open)

Direction	Route Name	Modelling Option	JT Route	AM Journey Time	PM Journey Time
NB	Bristo Place – George Street	Base	Route 1	00:06:24	00:07:07
		Option 1	Route 1	00:07:13	00:07:08
		Option 2	Route 1	00:08:41	00:08:05
		Option 3	Route 1	00:07:18	00:07:12
SB	George Street - Potterrow	Base	Route 1	00:06:05	00:06:16
		Option 1	Route 1	00:08:08	00:08:14
		Option 2	Route 1	00:08:00	00:07:52
		Option 3	Route 1	00:07:47	00:06:20

Table 7 shows that the base option presents the best journey times for cyclists travelling from George Street to Potterrow in both directions for both AM and PM peak periods. This is due to the signalisation of the George IV Bridge / Chambers Street and Forrest Road / Bristo Place junctions in each of the options.

Figure 12 and Figure 15 present the journey time profiles for the north and southbound routes during the AM and PM peaks.

Figure 12 shows the Route 1 northbound journey times for each section during the AM peak period. It can be clearly seen that for all options it takes much longer to pass through the section from Bristo Place to Chambers Street, due to additional stops at signalised junctions as described above.

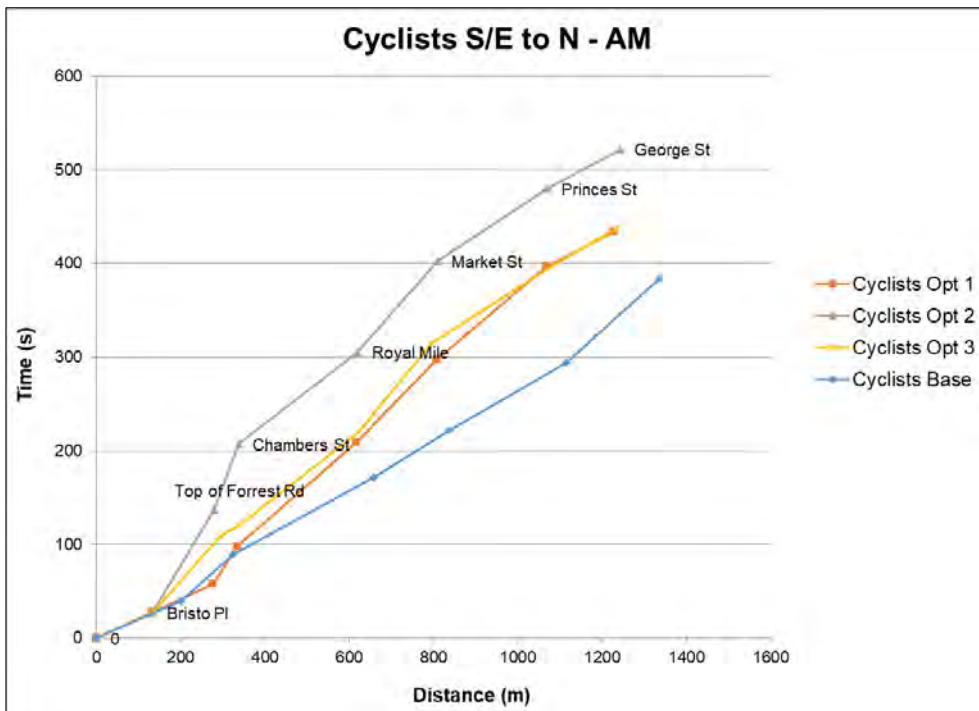


Figure 12: Journey Time Cyclists NB (AM Peak)

Figure 13 shows the Route 1 southbound journey times for each section during the AM peak period. The main delay is experienced between Princes Street and the Royal Mile. This delay is caused by introduction of separate stage for cyclists at the Market Street / The Mound junction, as well as the shuttle working on Bank Street.

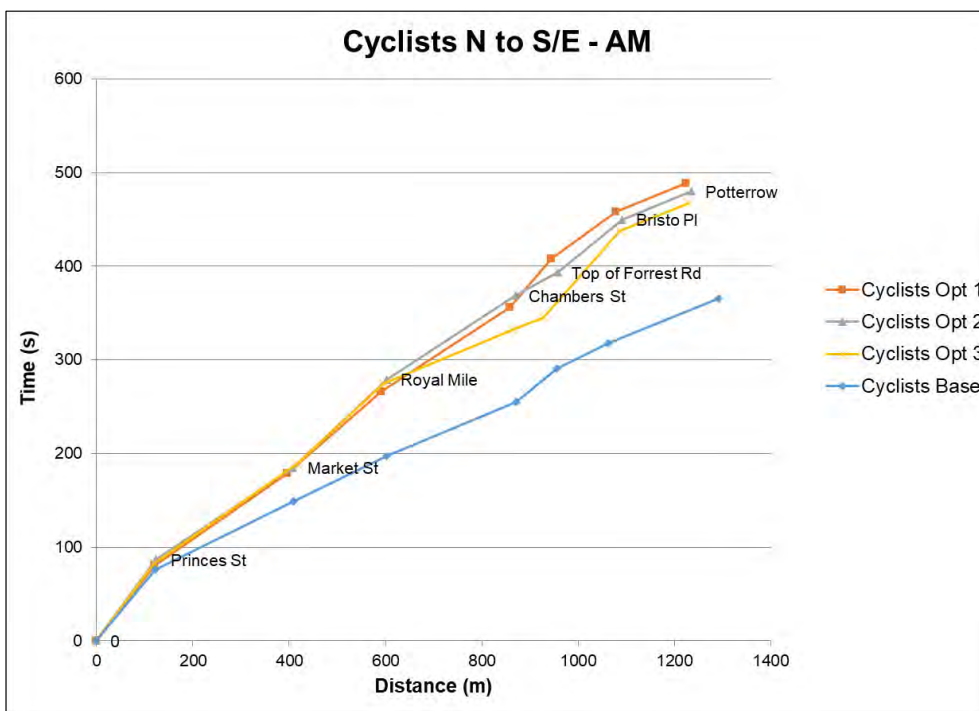


Figure 13: Journey Time Cyclists SB (AM Peak)

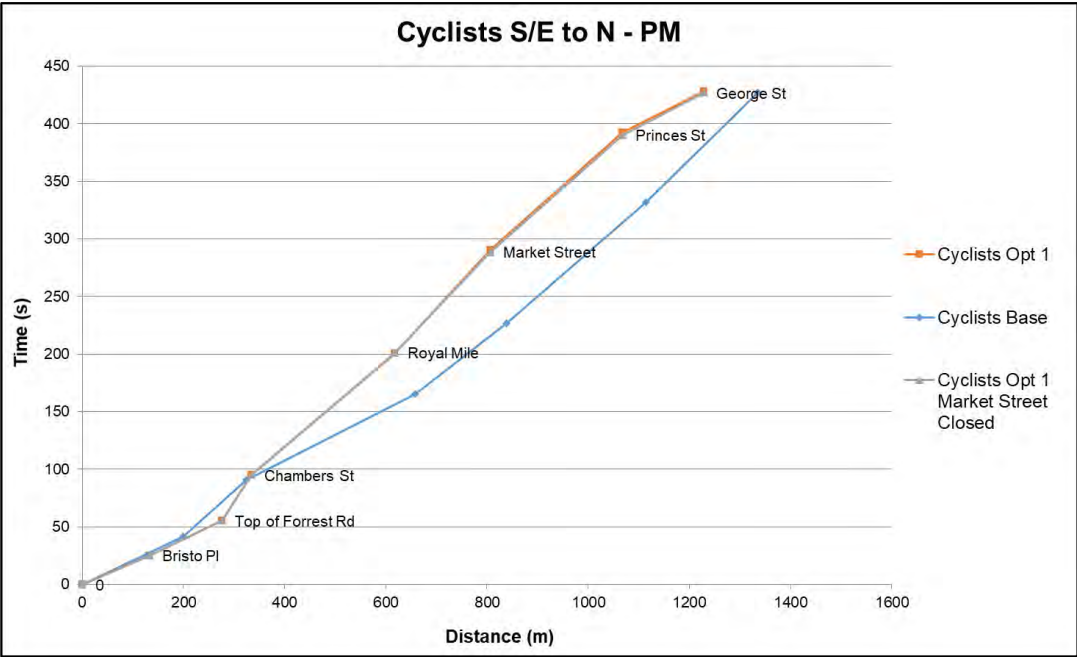


Figure 14: Journey Time Cyclists NB (PM Peak)

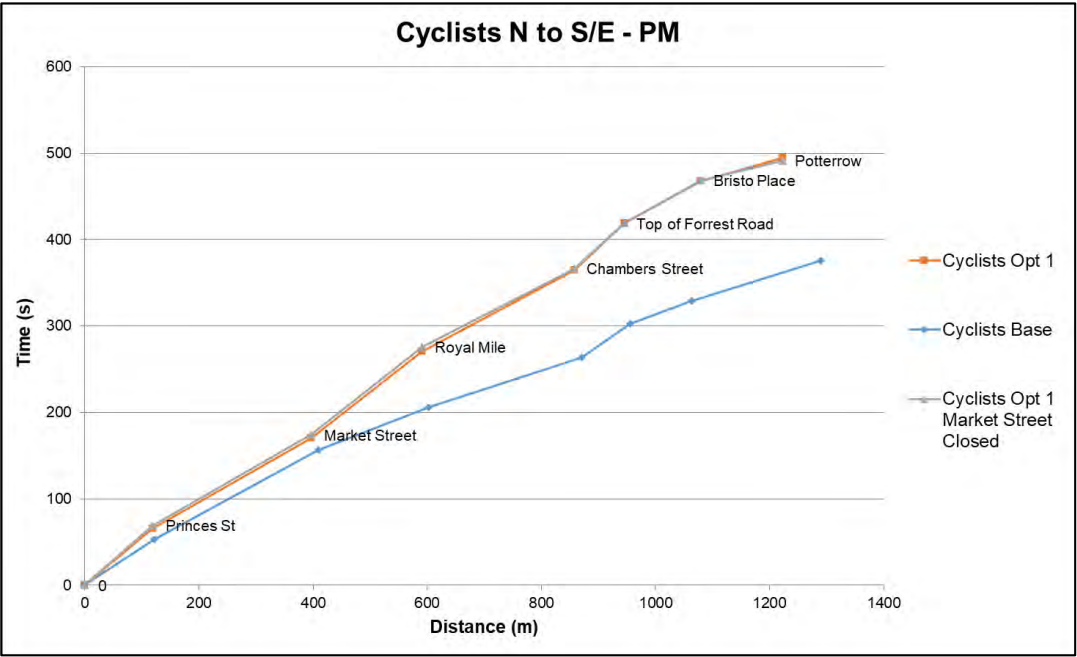


Figure 15: Journey Time Cyclists SB (PM Peak)

7.1.3 Buses

Table 8 summarises the journey times for buses along Route 1 for the base and the three options.

Table 8: Bus Journey Time (Market Street Open)

Direction	Route Name	Modelling Option	AM Journey Time	PM Journey Time
NB	Bristo Place – George Street	Base	00:12:39	00:09:24
		Option 1	00:23:35	00:39:42
		Option 2	00:09:46	00:10:12
		Option 3	00:10:19	00:11:59
SB	George Street - Potterrow	Base	00:07:29	00:08:02
		Option 1	00:13:39	00:15:19
		Option 2	00:08:51	00:09:34
		Option 3	00:08:52	00:10:20

Table 8 highlights that the base option shows the best journey time for buses to travel from George Street to Potterrow in both directions during the PM peak and southbound during the AM peak period. Option 2 shows the shortest journey time for buses to go northbound in the AM peak.

Option 1 is the slowest option for buses in both directions for both AM and PM peak periods. This is because of the introduction of the separate stage for cyclists at all signalised junctions in Option 1. Apart from Option 2 travelling northbound during the AM peak hour, overall Option 2 and Option 3 display slower bus journey times in both directions for both AM and PM peak periods compared to the base model.

Figure 16 to Figure 19 below show bus journey times for each section of Route 1 going northbound and southbound for the two peaks.

In both directions Option 1 is the slowest option for buses, specifically between Princes Street and the Royal Mile. This additional delay is caused by the changes to the signal settings, especially at the Market Street / The Mound junction. This has a significant impact on private vehicles, which in turn impacts buses as there is no bus segregation within this section of the corridor.

Option 2 and Option 3 perform better in comparison to Option 1, due to the longer stages for traffic at signalised junctions along the route, however the introduction of the signalised junction at George IV Bridge / Chambers Street and the signalised crossing at Forrest Road / Bristo Place cause additional delay, thus bus journey times for Option 2 and Option 3 are slower than for the base option.

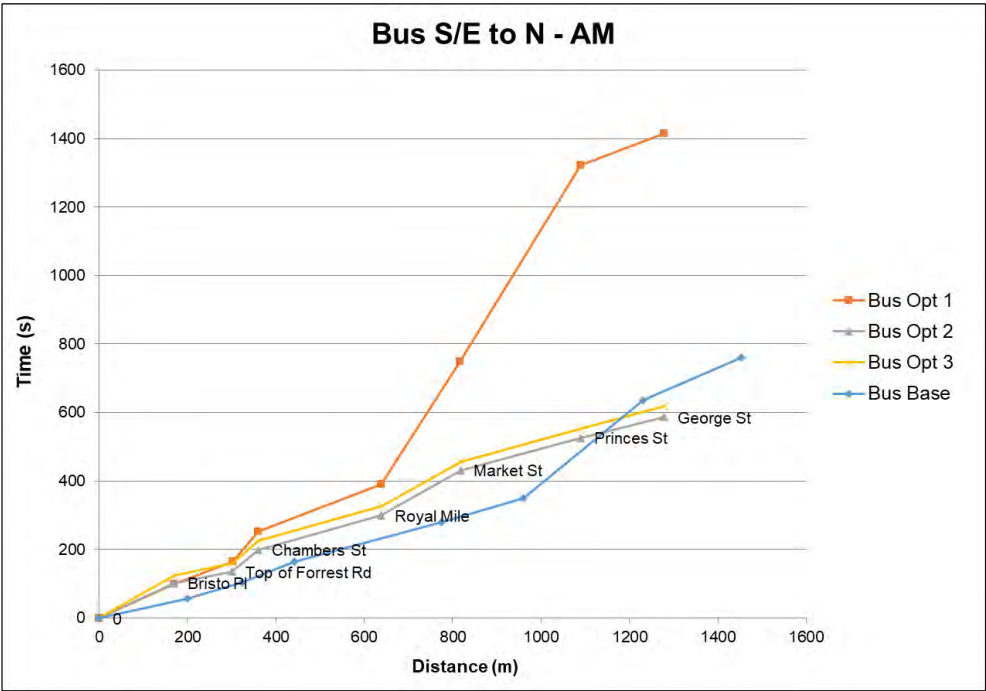


Figure 16: Journey Time Buses NB (AM Peak)

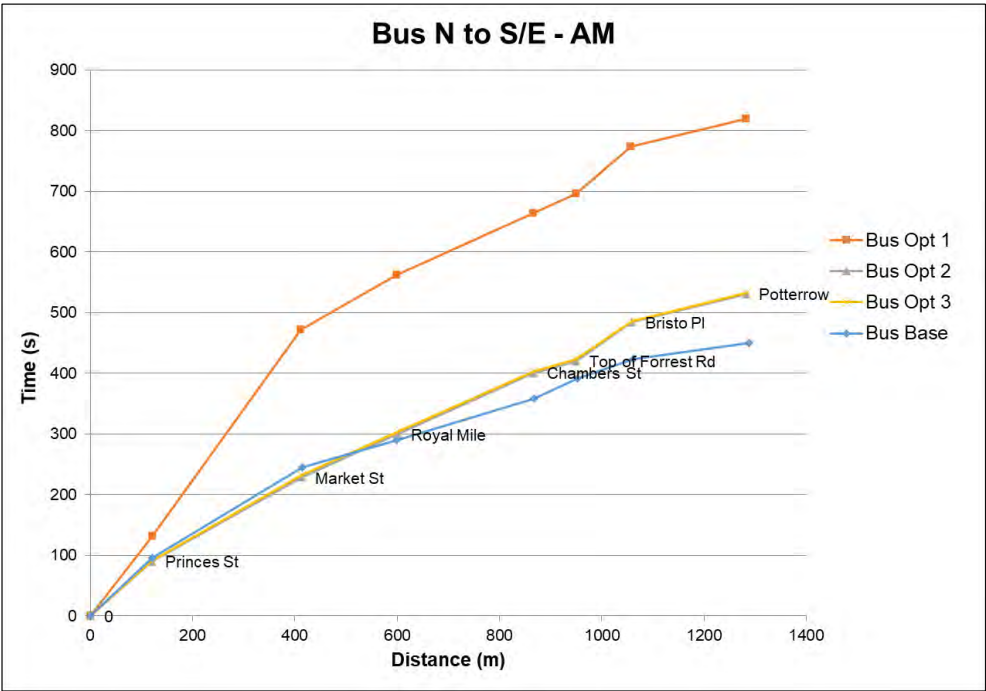


Figure 17 Journey Time Buses SB (AM Peak)

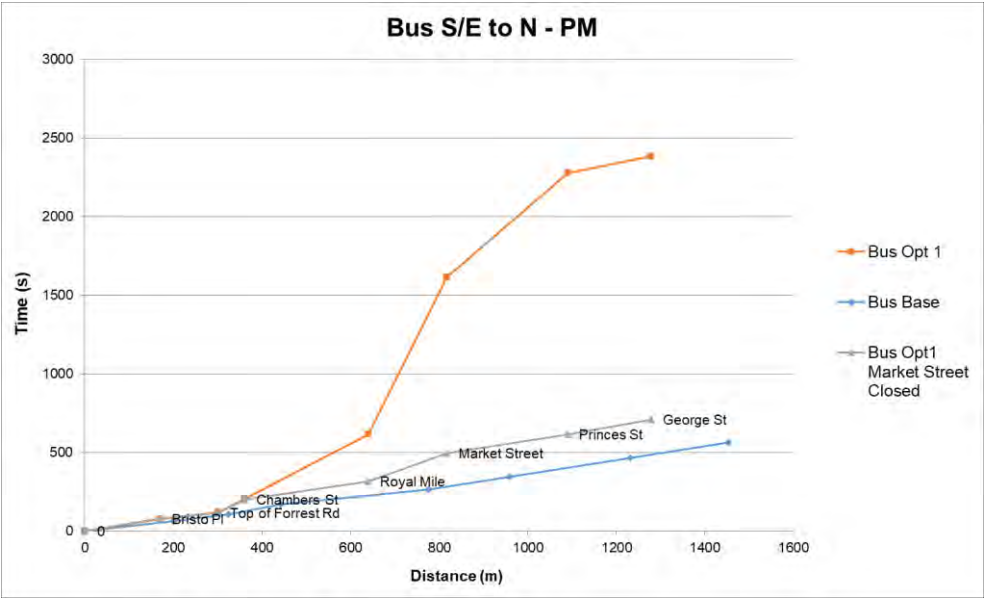


Figure 18 Journey Time Buses NB (PM Peak)

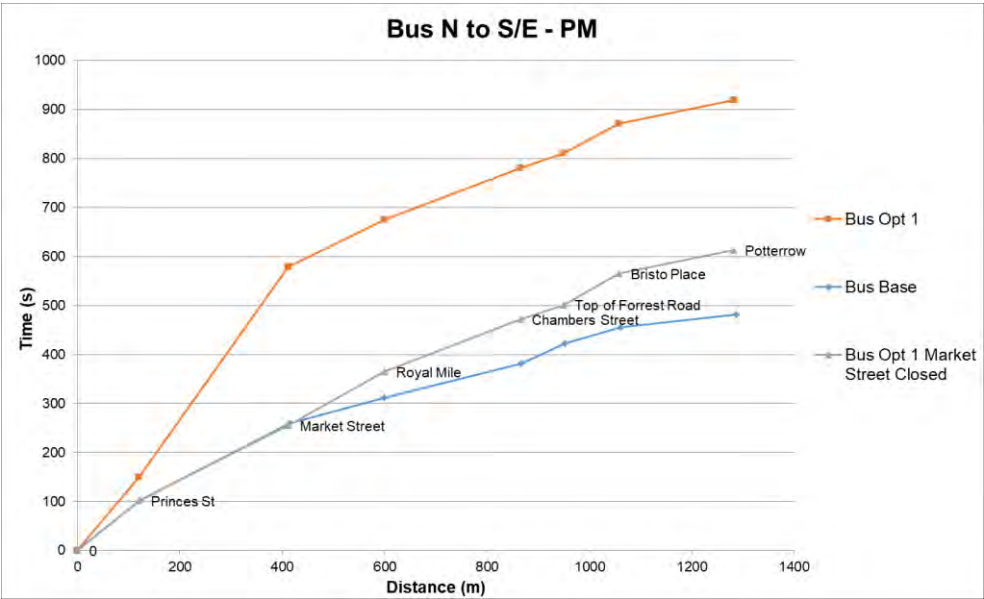


Figure 19 Journey Time Buses SB (PM Peak)

7.2 Sensitivity Tests - Option 1

The following section considers the impact on Option 1 due to the proposed additional closures, namely Market Street, Waverley Bridge and Cockburn Street. The analysis considers the following tests:

1. The impact of the proposed closures against the original scenarios;
2. The impact if the demand to and from Market Street were to increase; and
3. The maximum increase in green time for cyclists crossing Princes Street based on the expected demands.

7.2.1 Market Street Closed Journey Time (Test 1)

The following analysis considers the impact of the proposed additional closures and whether the resulting reduction in traffic between Market Street and Hanover Street is such that Option 1 would be feasible.

7.2.1.1 Cyclists

Table 9 summarises the journey times for cyclists along Route 1 for the following options.

- Base;
- Option 1 (Market Street open); and
- Option 1 (Market Street closed).

Table 9: Cyclists Journey Time – Sensitivity Test 1

Direction	Route Name	Modelling Option	JT Route	AM Journey Time	PM Journey Time
NB	Bristo Place – George Street	Base	Route 1	00:06:24	00:07:07
		Option 1 (Market Street open);	Route 1	00:07:13	00:07:08
		Option 1 (Market Street Closed)	Route 1	00:07:11	00:07:06
SB	George Street - Potterrow	Base	Route 1	00:06:05	00:06:16
		Option 1 (Market Street open);	Route 1	00:08:08	00:08:14
		Option 1 (Market Street Closed)	Route 1	00:07:51	00:08:11

Table 9 Table 7 shows that Market street closure has a minor impact on cyclists. Cycle journey times for Option 1 (Market Street closed) are 2 seconds less than for Option 1 (Market Street open). The journey time for cyclists to travel along Route 1 in both directions for both AM and PM peak periods is shorter in the Base model, with the exception of northbound in the PM peak.

Figure 20 and Figure 21 show that there is minimal difference between cyclists' journey time for Option 1 (Market Street closed) and Option 1 (Market Street open). Given the segregation of cyclists from other vehicles these results are sensible, since congestion will rarely impact the movement of bicycles, especially if cycle infrastructure is provided.

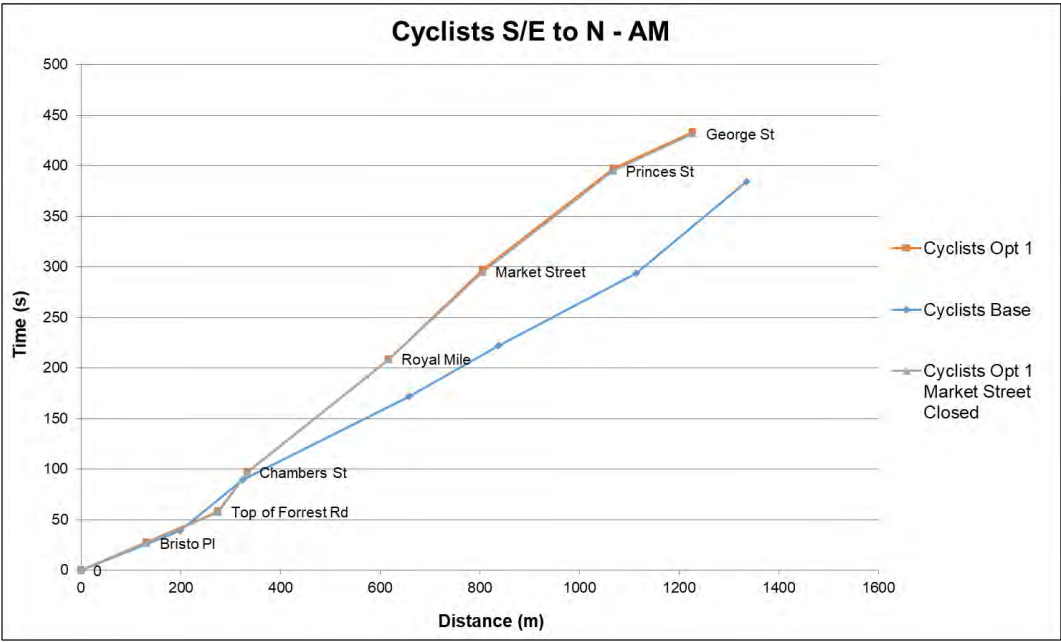


Figure 20: AM Cyclists Journey Time NB (Sensitivity Test 1)

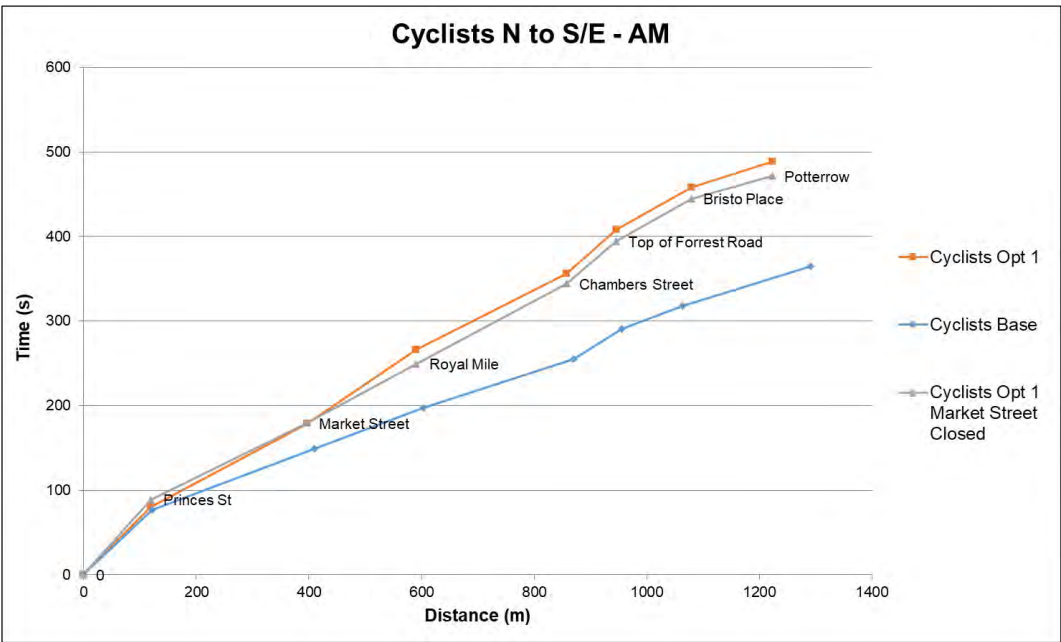


Figure 21: AM Cyclists Journey Time SB (Sensitivity Test 1)

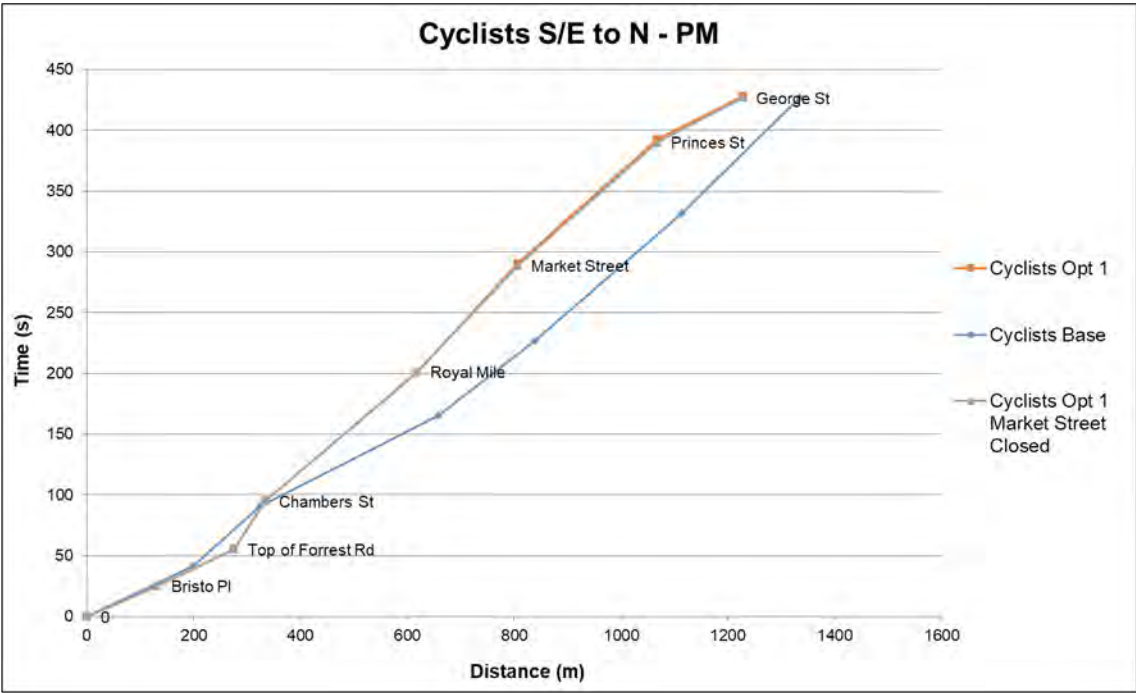


Figure 22: PM Cyclists Journey Time NB (Sensitivity Test 1)

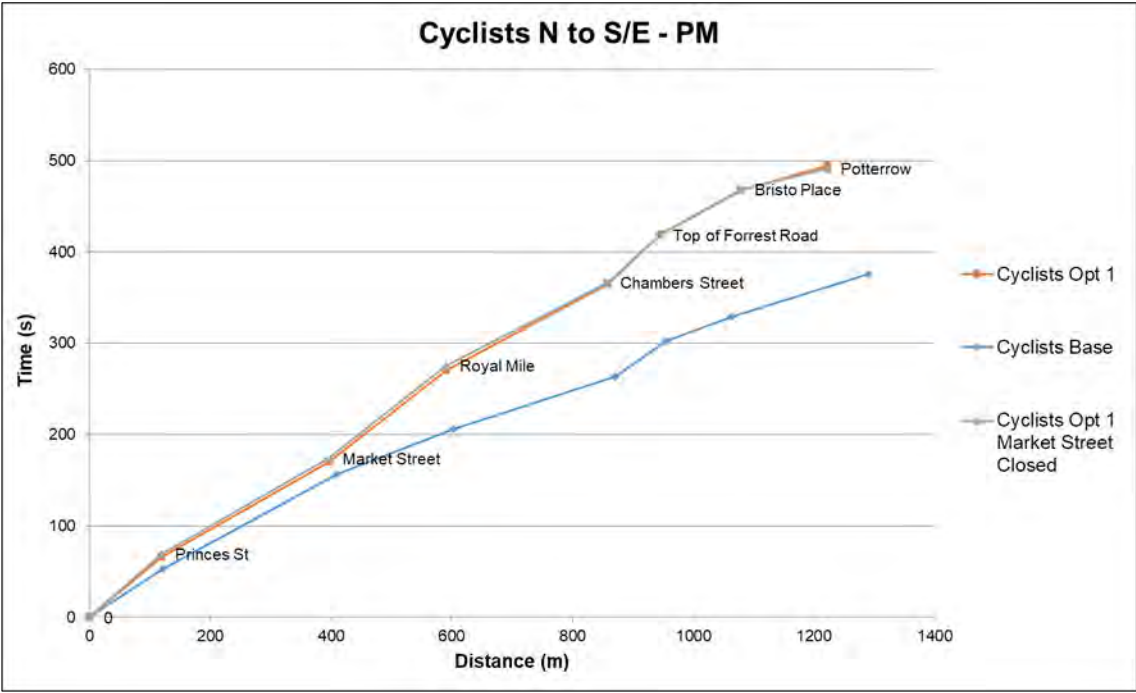


Figure 23: PM Cyclists Journey Time SB (Sensitivity Test 1)

7.2.1.2 Buses

Table 10 summarises the journey times for buses along Route 1 for the following options.

- Base;
- Option 1 (Market Street open); and
- Option 1 (Market Street closed).

Table 10: Bus Journey Time – Sensitivity Test 1

Direction	Route Name	Modelling Option	JT Route	AM Journey Time	PM Journey Time
NB	Bristo Place – George Street	Base	Route 1	00:10:37	00:07:45
		Option 1 (Market Street open);	Route 1	00:23:35	00:39:42
		Option 1 (Market Street Closed)	Route 1	00:10:51	00:11:50
SB	George Street - Potterrow	Base	Route 1	00:07:29	00:08:02
		Option 1 (Market Street open);	Route 1	00:13:39	00:15:19
		Option 1 (Market Street Closed)	Route 1	00:11:33	00:10:12

Table 10 shows that the closure of Market Street, Waverley Bridge and Cockburn Street significantly improves bus journey times in both directions for both the AM and PM peak periods, however they remain higher than those in the base model, with the exception of the northbound movement in the AM peak period, which sees only a 14 second increase in journey times.

Journey times for buses in Option 1 (Market Street closure) travelling northbound from Potterrow to Hanover Street is around 12 minutes and 27 minutes faster in the AM and PM peaks respectively against the Option 1 (Market Street Open). For the southbound direction the difference in journey time is around 2 minutes and 5 minutes for the AM and PM peak respectively. These improved journey times in Option 1 (Market Street closed) reflect the traffic conditions on The Mound, which present relatively low levels of flows / congestion. Based on these demands it can be said that Option 1 (Market Street closed) is now a feasible option.

Figure 24 to Figure 27 display the bus journey time profiles which highlight the significant improvement to journey times once Market Street is closed.

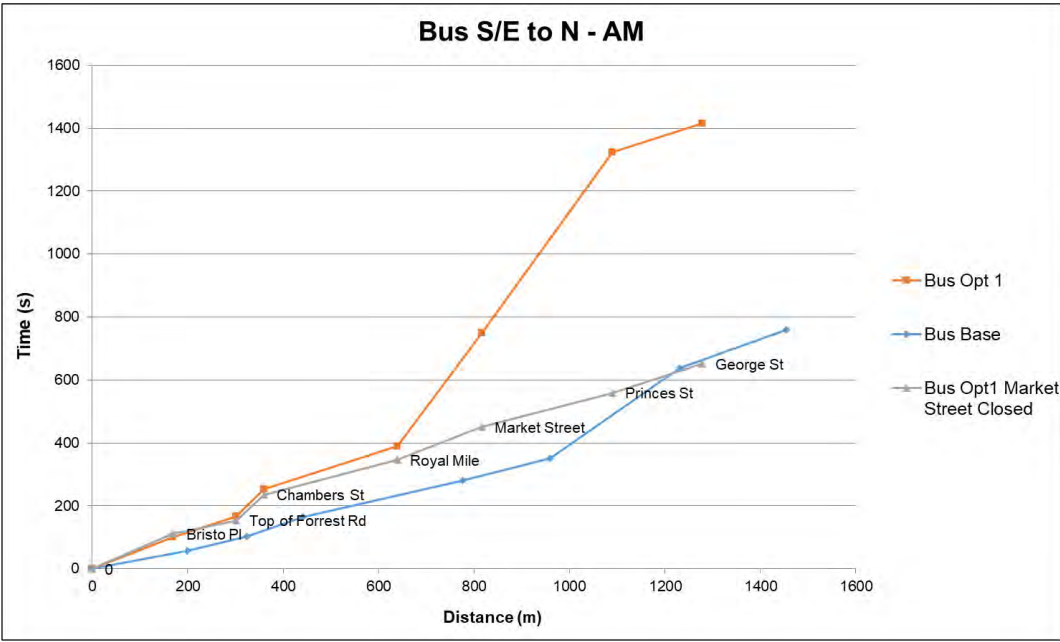


Figure 24: Bus Journey Time NB (Sensitivity Test 1)

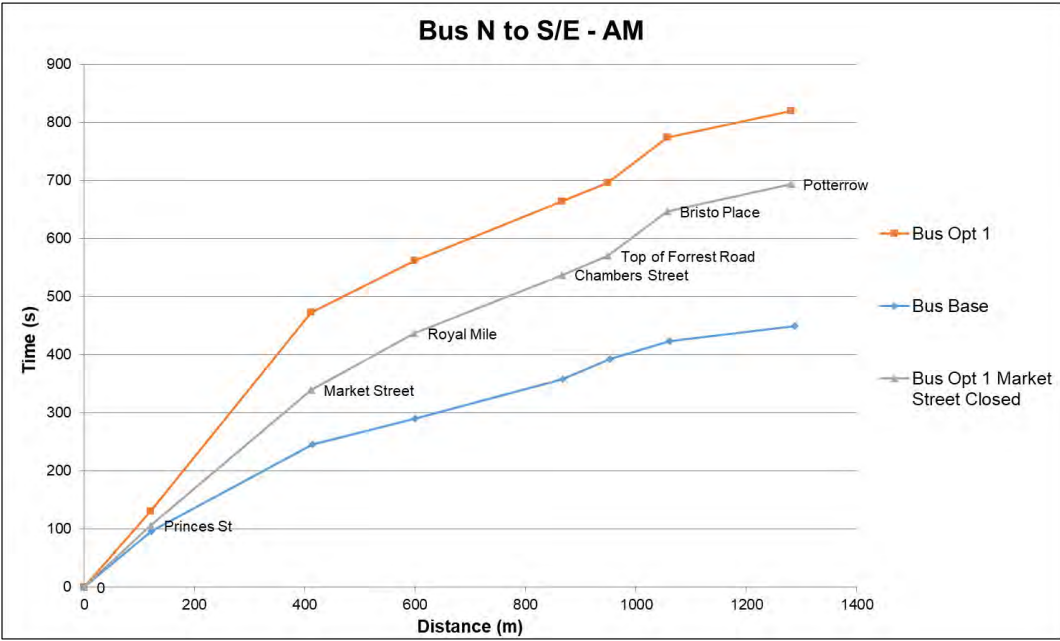


Figure 25: Bus Journey Time SB (Sensitivity Test 1)

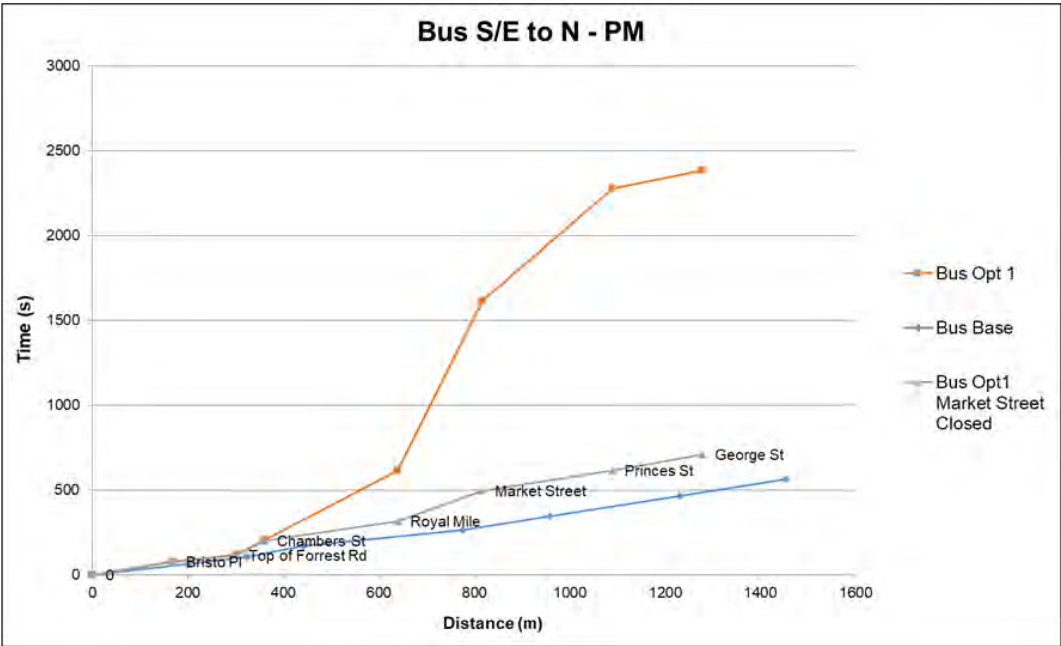


Figure 26: PM Bus Journey Time NB (Sensitivity Test 1)

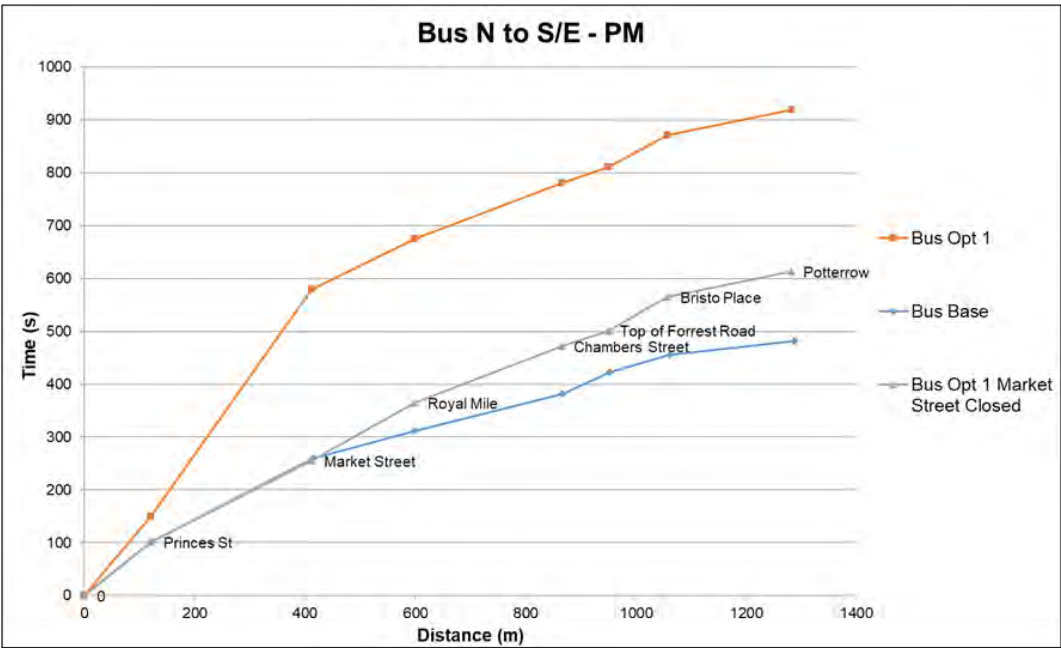


Figure 27: PM Bus Journey Time SB (Sensitivity Test 1)

7.2.2 Demand Sensitivity test (Test 2)

The following sensitivity test highlights how much traffic can be added to the movements between Hanover Street and Market Street. Table 11 presents each of the sensitivity tests and highlights in **red** at which point the demand resulted in a detriment to either the Market Street / The Mound Junction or the Princes Street / The Mound / Hanover Street Junction.

Table 11: Demand Sensitivity test

Test Scenario	AM	PM
	Hanover Street to Market Street; Market Street to Hanover Street	Hanover Street to Market Street; Market Street to Hanover Street
Base	169	178
5% increase	178	186
10% increase	186	195
20% increase	203	213
30% increase	220	231
35% increase	228	240

The critical demand for AM and PM peak periods is 228 vehicles and 240 vehicles respectively. At these demands the queue on The Mound extends from Princes Street to Market Street resulting in difficulty when exiting either Market Street or Bank Street.

During the PM peak period, at the maximum demand of 240 vehicles, the queue on The Mound extends on to Princes Street and blocks movements across Princes Street. Furthermore, there is no capacity on The Mound for vehicles travelling from North Bank Street.

Based on the above, the forecast demand could be underestimated by around 30% before the demand becomes detrimental to the operation of Market Street / The Mound junction or the Princes Street / The Mound / Hanover Street junction.

Figure 28 below shows a screenshot of the traffic conditions at 08:55 on The Mound using an increase of 35% above estimated demand. As shown, the queue on The Mound extends towards Princes Street and blocks movements from Hanover Street onto The Mound.

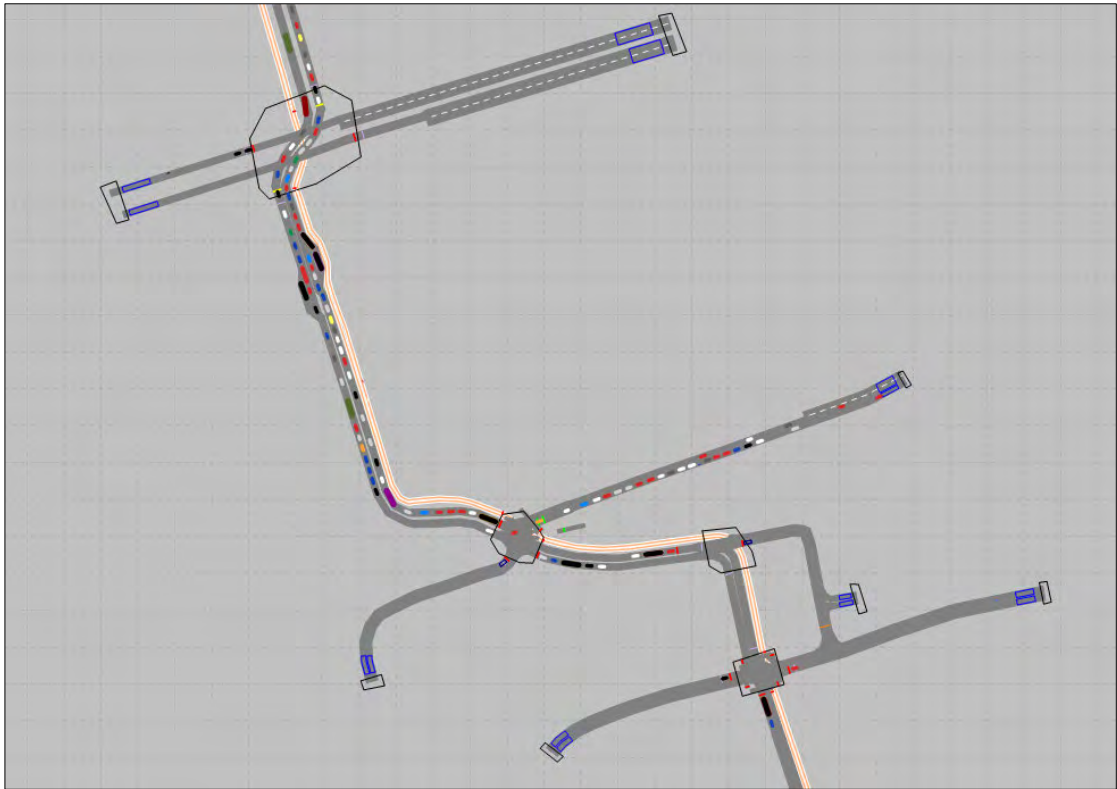


Figure 28: AM Queue on The Mound 35% increase in demand

Figure 29 below shows the maximum queue lengths for each sensitivity test scenario for the AM peak. Options that remain within a queue length of 250 metres will not impact the operation of the junction on The Mound.

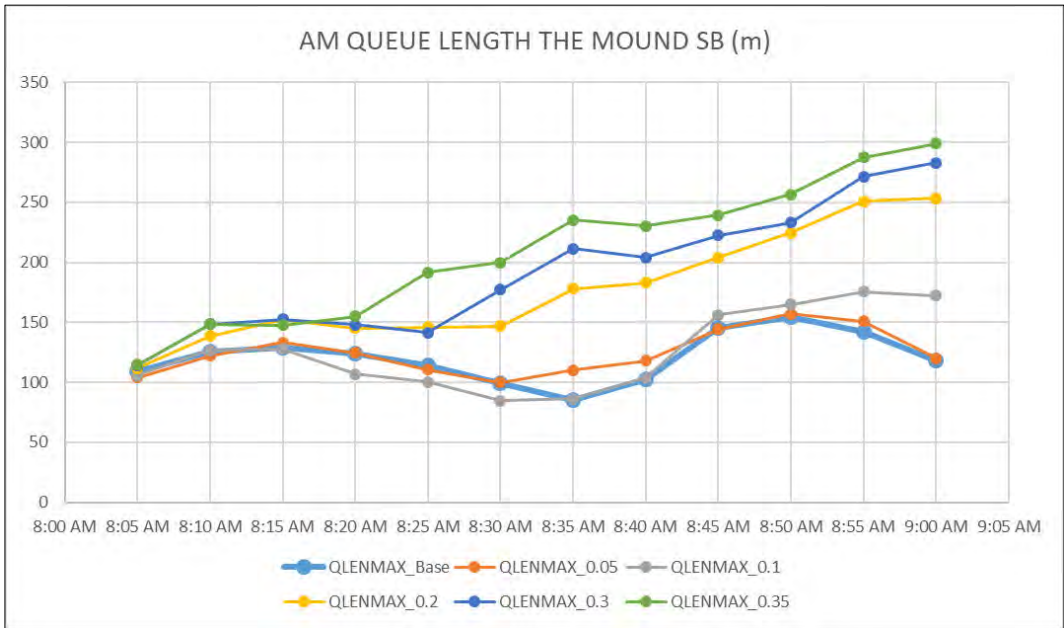


Figure 29: AM Queue Lengths SB (Sensitivity Test 2)

Figure 30 below shows a screenshot of the traffic queue at 17:44 on The Mound using a 35% increase over the estimated demand.



Figure 30: PM Queue on The Mound 35% increase in demand

Figure 31 and Figure 32 shows the queue length gradually growing through the PM Peak, with a maximum queue length of 250m, which is the approximate distance between the Market Street / The Mound junction and the Princes Street / The Mound / Hanover Street junction. It should be highlighted that demands drop down after 17:45, however this is beyond the modelled period and cannot be presented.

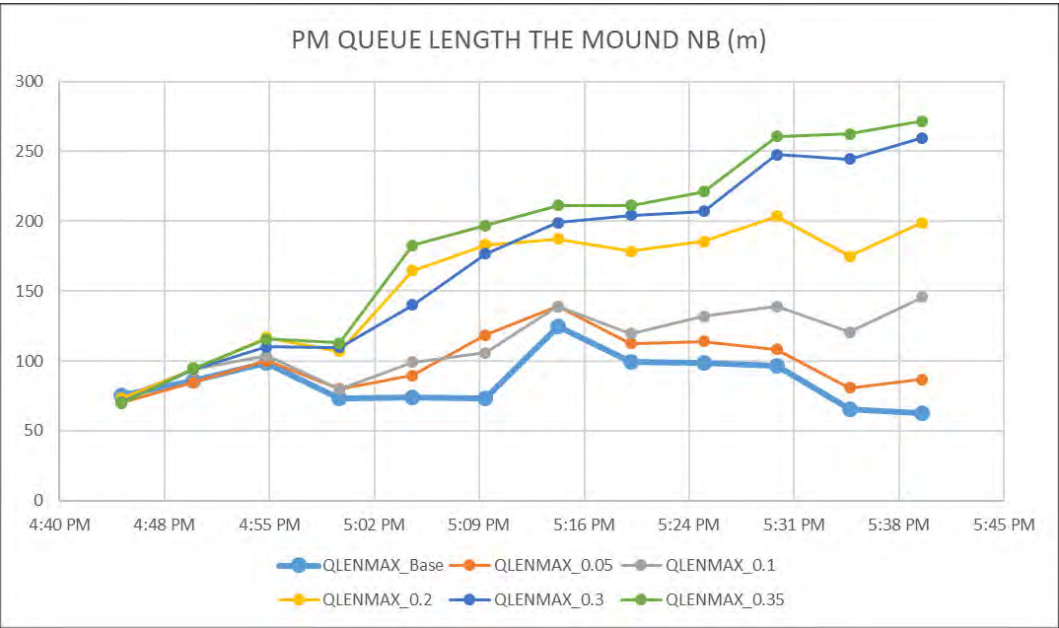


Figure 31: Queue Length PM NB (Sensitivity Test 2)

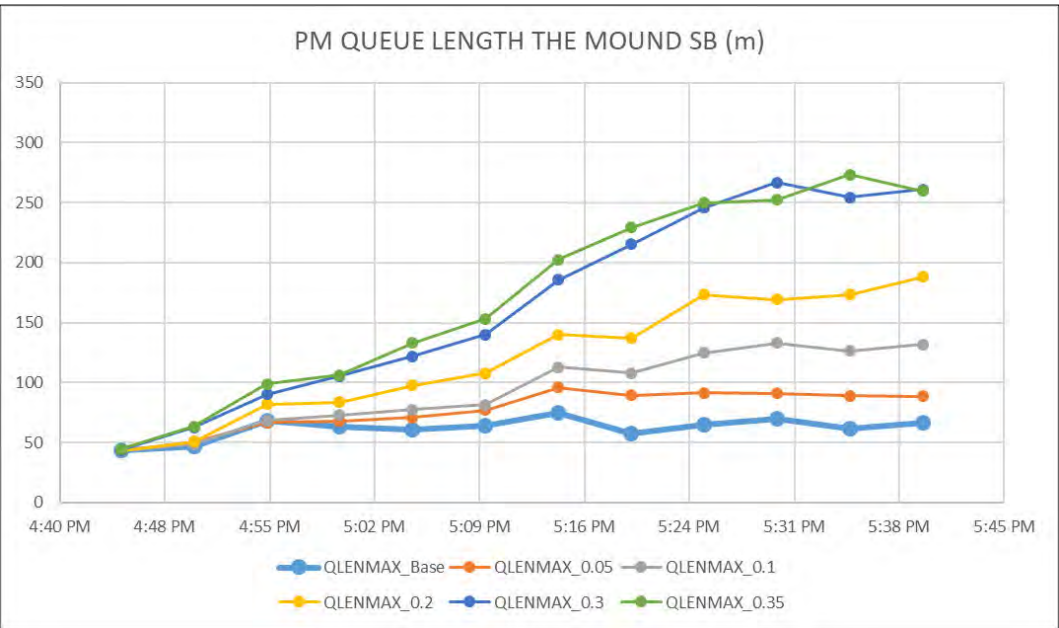


Figure 32: Queue Length PM SB (Sensitivity Test 2)

7.2.3 Maximum Green time for Cyclists Stage (Test 3)

Table 12 below summarises stage lengths for the Princes Street / The Mound / Hanover Street junction from the initial Option 1 model and from the sensitivity tests.

Table 12: Original Green Time for each Stage at the Princes Street / The Mound / Hanover Street Junction

Stage Name	Initial Option 1 Green Time AM / PM
Princes Street	67 seconds
Cyclists	7 seconds
Hanover Street / The Mound	21 seconds

The above dedicated cycle stage was gradually increased to the detriment of the Hanover Street / The Mound stage to maintain the overall cycle length. The criteria for “failure” was the same as for Sensitivity Test 2, which was a queue length that extends back to the upstream junction causing its operation to be compromised.

A one second increase on the dedicated cycle stage in the AM and PM peak was introduced until the queue lengths reached the upstream junction. The maximum green time for cyclists was estimated at 13 seconds, an increase of 6 seconds on the original settings, as shown in the table below.

Table 13: Revised Green Time for each Stage at the Princes Street / The Mound / Hanover Street Junction

Stage Name	Maximum Option 1 Green Time AM / PM
Princes Street	67 seconds
Cyclists	13 seconds
Hanover Street / The Mound	15 seconds

Figure 33 and Figure 34 illustrate the queue lengths from Princes Street along The Mound using the timings in Table 13 above. It can be seen that the queue length are approximately 250 metres, the maximum queue length before the queue impacts the Market Street / The Mound junction.

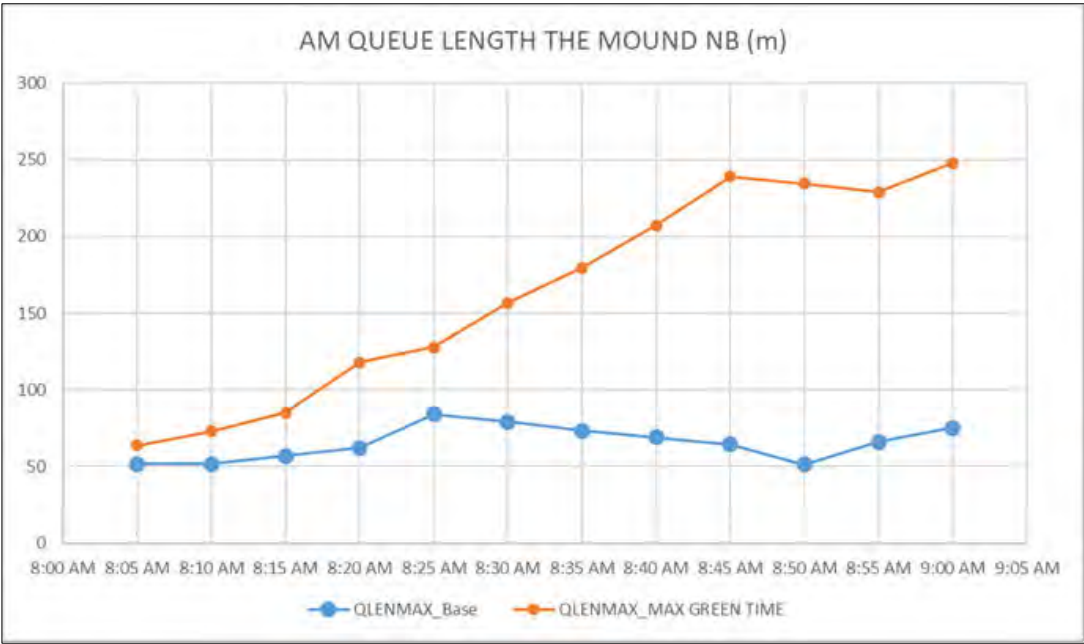


Figure 33: AM NB Queue Lengths (Sensitivity Test 3)

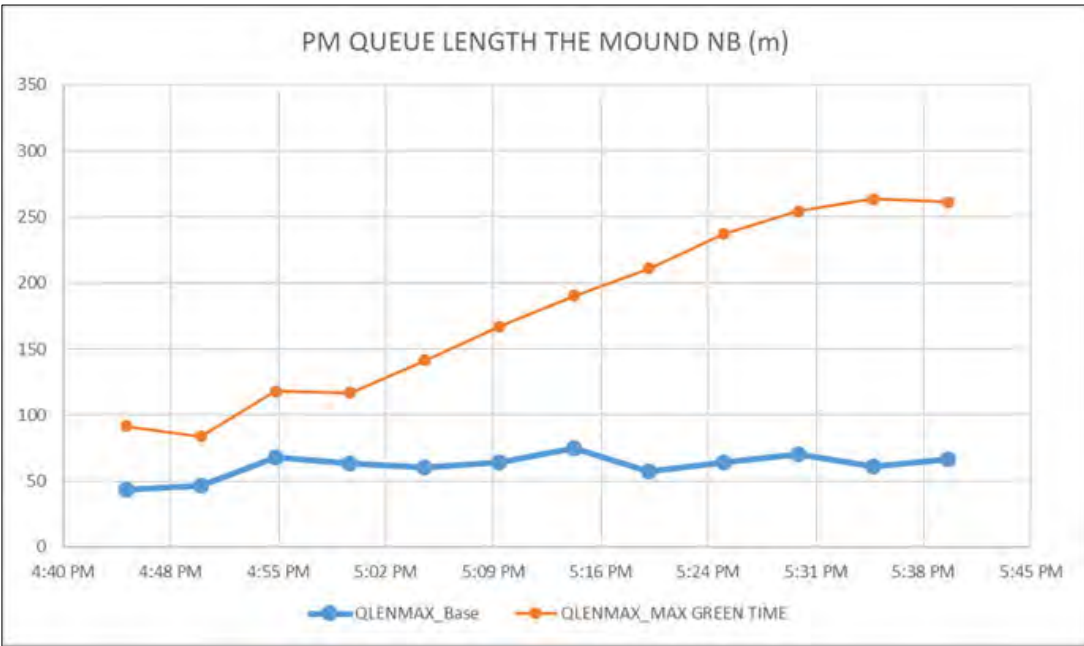


Figure 34: PM NB Queue Lengths (Sensitivity Test 3)

8. Summary and Recommendations

8.1 Base Model

The base model has been calibrated using turning counts and validated using queue lengths and has been acknowledged as a good representation of the current conditions along the Meadows to George Street corridor.

The model replicates vehicle activated signals along the corridor to ensure the model represents the varied nature of the signal staging. The model also incorporated site specific behaviour such as buses taking off slowly on The Mound due to the gradient.

Based on the high level of detail and calibration achieved (100% for all turns), the model is suitable for its purpose.

8.2 Original Option Test

Three options were originally considered, which have the following key features.

- Option 1
Segregated cycleway on the east side of George IV Bridge, Bank Street and The Mound; segregated cycleway on the west side of Hanover Street; dedicated cycle stages would be provided to allow the cycleway to cross junctions; St Giles Street would be open.
- Option 2
Segregated cycleway on the east side of George IV Bridge, Bank Street, The Mound and Hanover Street; St Giles Street closed at Bank Street (with access only permitted from Lawnmarket or from George IV Bridge); cycleway runs with general traffic where possible (including at Princes Street, High Street and Chambers Street).
- Option 3
As Option 2, but with the segregated cycleway on the west side of George IV Bridge, Bank Street, The Mound and Hanover Street.

These options were compared against the base scenario and each other to identify the preferred option for cyclists, buses and private vehicles. Table 14 summarises the performance of each option.

Table 14: Summary Table – Initial Options (Weighted Average delay)

	Baseline	Preferred Option	Second Preference	Least Preferred Option
Cyclists	50 sec	Option 2 (97 sec)	Option 3 (104 sec)	Option 1 (105 sec)
Buses	215 sec	Option 2 (257 sec)	Option 3 (282 sec)	Option 1 (561 sec)
Private Vehicles	112 sec	Option 3 (154 sec)	Option 2 (161 sec)	Option 1 (282 sec)

Based on the table above and the focus on improving cyclists and bus operation, Option 2 is the preferred option.

8.3 Sensitivity Testing

Once the original models had been tested, CEC considered further road closures, namely the closures on Market Street, Waverley Bridge and Cockburn Street. These changes have a significant impact in lowering the demand volumes between Market Street (Waverley Station) and Hanover Street. As such, Option 1, which is the

only option that included a dedicated cycle stage for cyclists at all junctions, was revisited as it was anticipated that Option 1 could operate within capacity based on the lower demand volumes.

The forecast matrices from the strategic model were deemed unreliable given that the model did not have specific details on the movements to and from Waverley Station. Therefore, it was proposed that a range of sensitivity tests should be undertaken to provide CEC with some comfort on whether the Option could cope with higher than estimated demands. Furthermore, the option was tested to see if further green time could be provided to cyclists at The Mound / Princes Street junction.

The following comments are based on the outputs from these sensitivity tests:

- Option 1 is able to cope with the revised demands, however bus journey times would still be adversely affected with respect to the base model.
- The estimated demand between Market Street and Hanover Street could increase by around 30% and still operate satisfactory in the AM and PM peaks.
- Based on the estimated demands, additional green time could be allocated to the cycle stage at The Mound / Princes Street junction. A maximum of 6 seconds could be redistributed to the cycle stage.

In terms of network performance, the weighted average delay is highlighted in Table 15.

Table 15: Base Option 1 with Closures (Weighted Average delay)

	Baseline	Option 1 (Scenario Test 1, With Closures)	Option 1 (Without Closures)
Cyclists	50 sec	96 sec	105 sec
Buses	215 sec	306 sec	562 sec
Private Vehicles	112 sec	139 sec	283 sec

The result show that cyclists will experience an increase in delay of 46 seconds, whereas buses will experience a delay of 109 seconds when compared to the base model. Private vehicles will see an increase of 27 seconds delay against the baseline. This highlights the benefit of reducing demand within this area.

8.4 Recommendations

Based on the performance criteria, which is reducing journey times for buses and cyclists, Option 2 is the preferred option. However, although Option 2 provides additional safety measures for cyclists, these measures come at a cost with journey time for cyclists increasing by 47 seconds against the base scenario. Buses see an increase of 40 seconds delay against the base scenario. Private vehicles see a similar increase in delays.

It is clear that the additional closures would enable Option 1 to be reconsidered as a feasible option as the network can cope with the lower demands. Sensitivity testing highlights that there is reserve capacity within the Option 1 network, however this is limited. Option 2 and 3 have not been tested with the revised demands, however it is anticipated that they too would see a reduction in journey times and delays with respect to the results with Waverley Bridge, Market Street, and Cockburn Street.

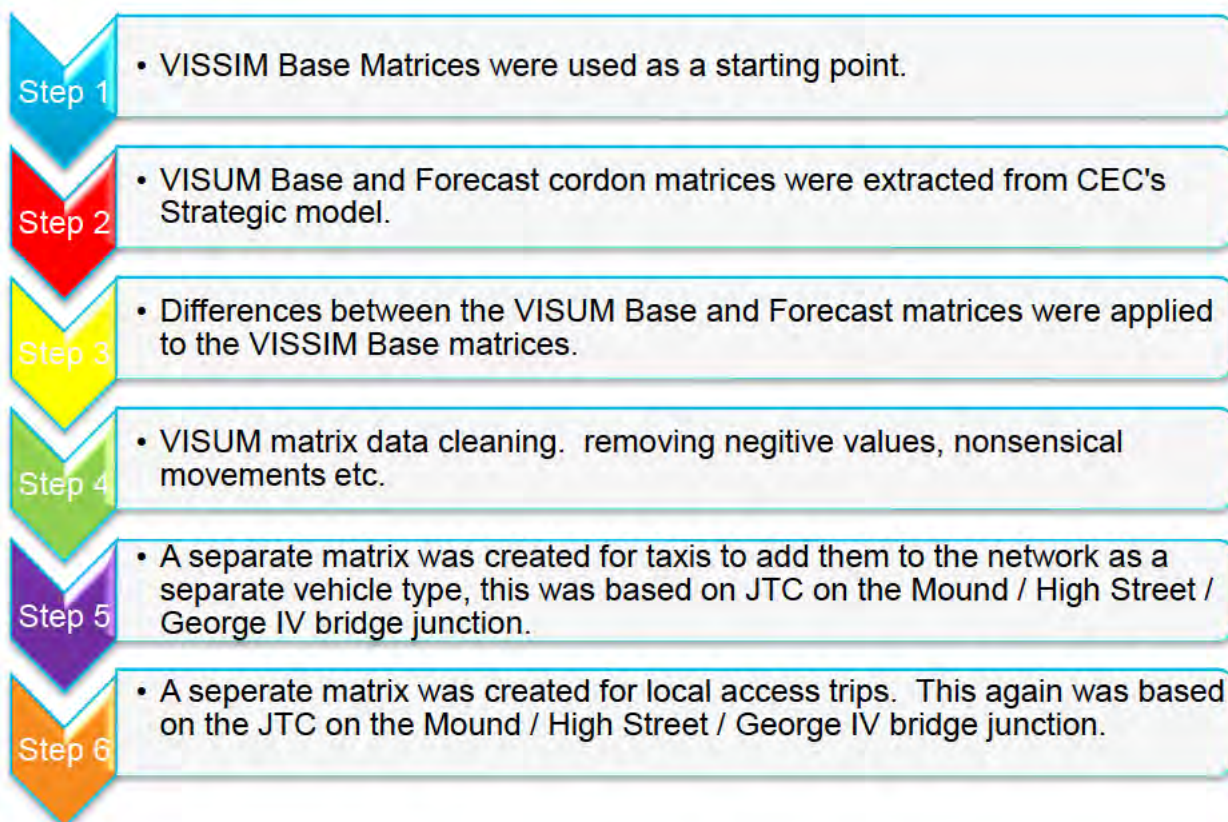
It should be noted that additional modelling tests were carried out after discussions with CEC about the modelling results of options 1, 2 and 3. In order to increase the effectiveness of the proposed options, CEC asked AECOM to make the following key changes to the Option 2 (Market Street Closed) and Option 3 (Market Street Closed) models:

1. Modification of the signal settings at the High Street / George IV Bridge junction to implement a second pedestrian stage; and
2. Testing of alterations to the shuttle work between High Street and Market Street.

Furthermore, as part of the additional modelling, a new “Hybrid” option design was created. The results of this additional modelling are detailed in Appendix D.

Appendix A : Forecast Matrix Development

AECOM received VISUM demand matrices from Jacobs. Two demand matrices were provided for the AM and PM peaks, these demand matrices were the validated base models and the proposed closure models. The flow chart below explain the procedures which were taken to clean and apply these demand matrices onto our current base models.



Based on the above the following tables present the demand matrices at each step.

Table 16: Step 1 – VISSIM Base totals

Peak	Model	Total
AM	VISSIM Base	2011
PM	VISSIM Base	1821

Table 17: Step 2 - VISUM Base and Forecast cordon matrices were extracted from CEC's Strategic model.

Peak	Model	Total
AM	VISUM Base	2011
AM	VISUM Forecast	2076
PM	VISUM Base	2100
PM	VISUM Forecast	2096

Table 18: Step 3 - Differences between the VISUM Base and Forecast matrices were applied to the VISSIM Base matrices.

Peak	Model	Total
AM	VISUM Base	65
PM	VISUM Base	4

Step 4 – Negative Numbers were Removed

Table 19: Step 5 – Adjusted Taxi Matrix

Peak	Model	Total
AM	VISSIM Taxi	77
PM	VISSIM Taxi	93

Table 20: Step 6 – Adjusted Local Traffic

Peak	Model	Total
AM	VISSIM Taxi	250
PM	VISSIM Taxi	180

Table 21: Total VISSIM forecast demands (including Cars) comparison against VISUM forecast demands

Peak	Model	Total
AM	VISSIM Forecast	1999
AM	VISUM Forecast	2076
PM	VISSIM Forecast	1932
PM	VISUM Forecast	2096

Appendix B : Queue Lengths

B.1 AM Peak Period

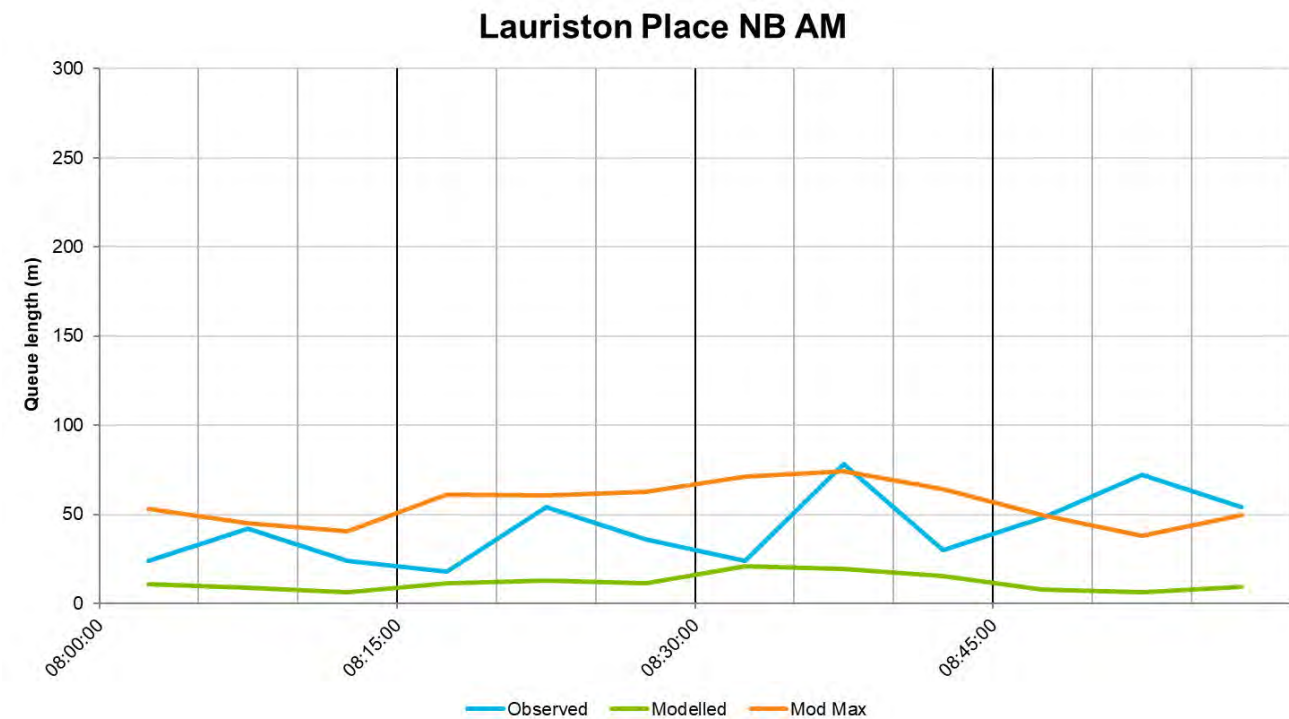


Figure 35: Queue Length Comparison – Lauriston Place/ Forrest Road NB AM

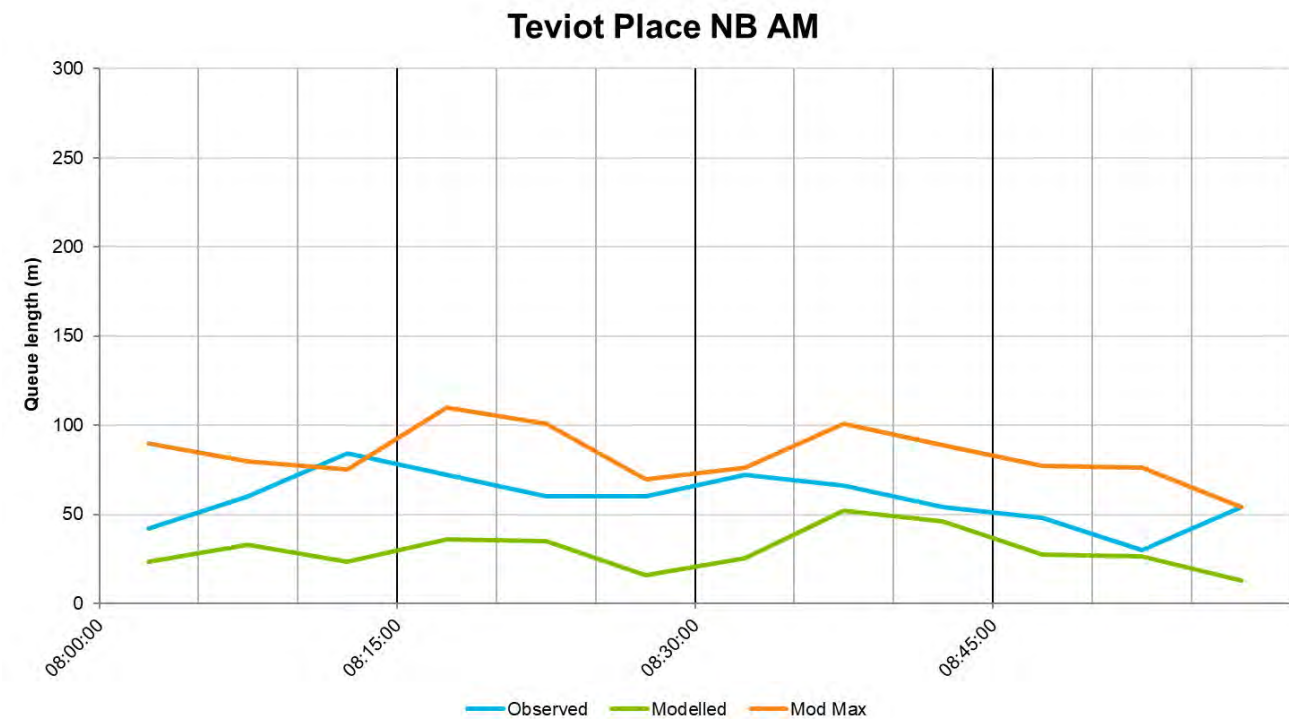


Figure 36: Queue Length Comparison – Teviot Place / Forrest Road NB AM

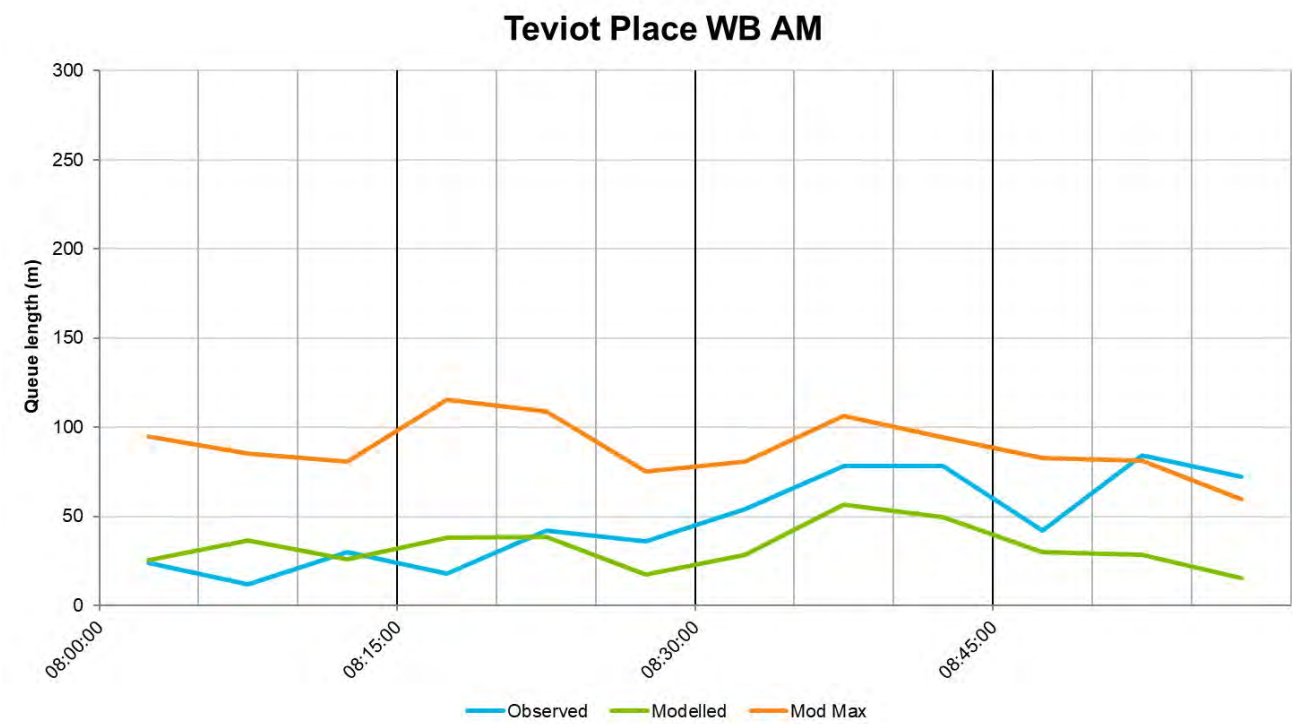


Figure 37: Queue Length Comparison – Teviot Place / Forrest Road WB AM

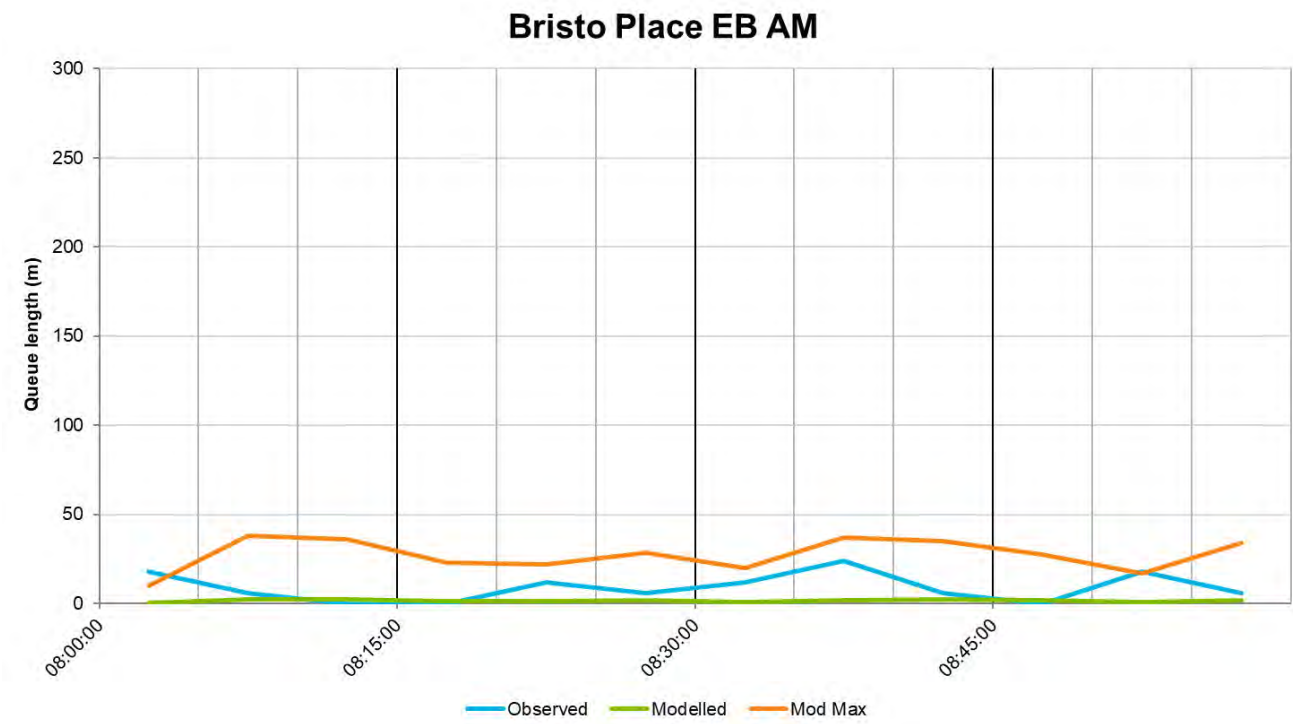


Figure 38: Queue Length Comparison – Bristo Place / Potterrow EB AM



Figure 39: Queue Length Comparison – Bristo Place / Teviot Place WB AM

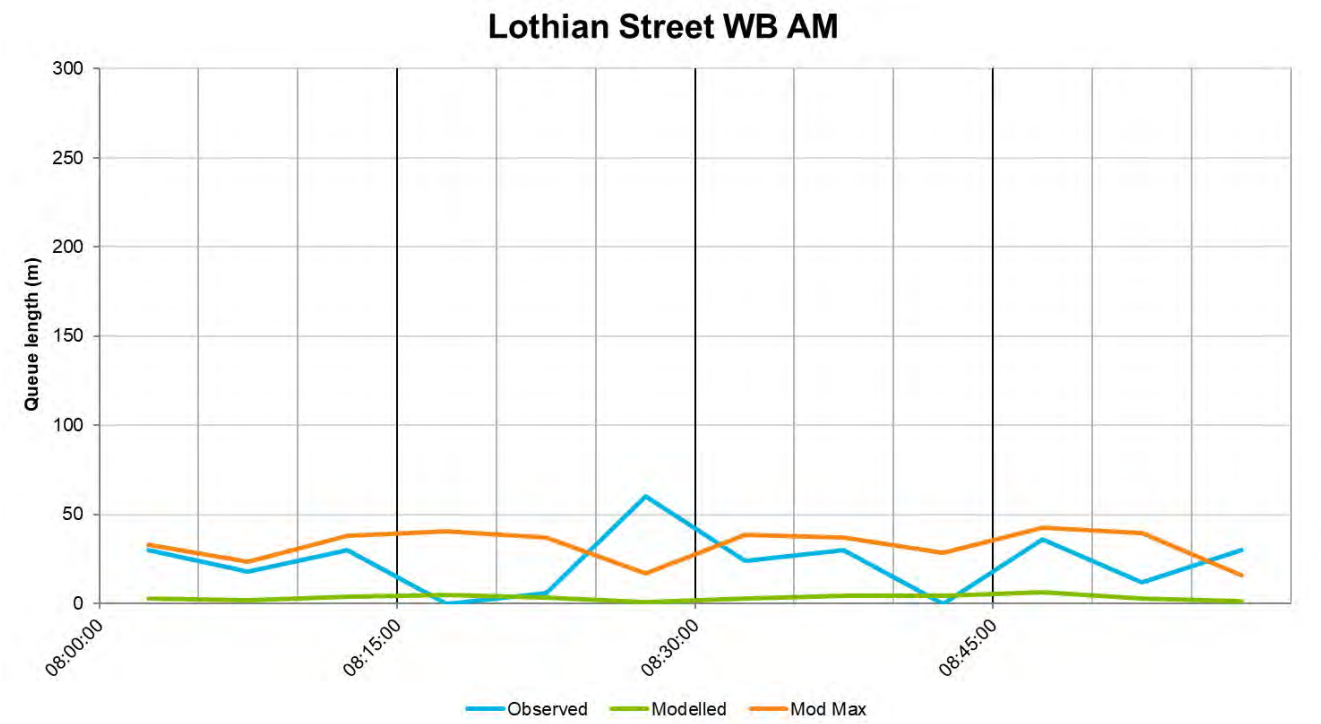


Figure 40: Queue Length Comparison – Lothian Street / Teviot Place WB AM

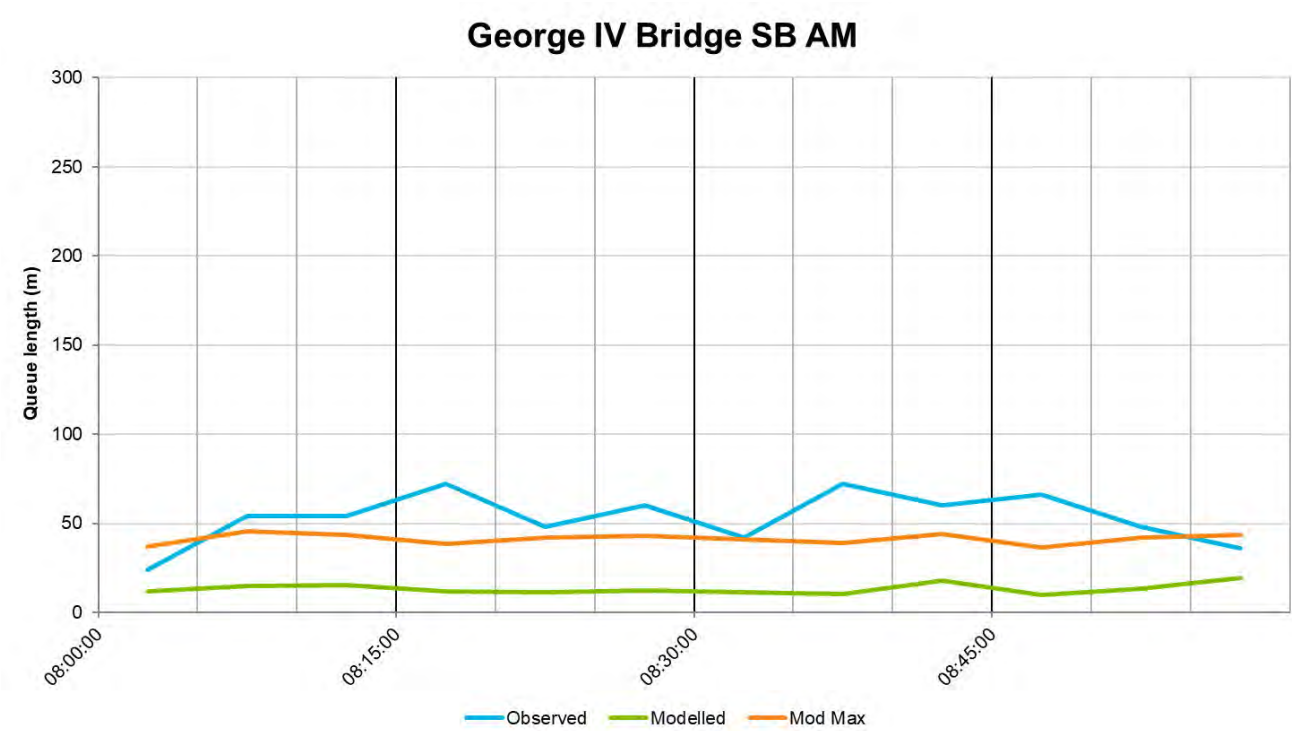


Figure 41: Queue Length Comparison – George IV Bridge / Bristo Port SB AM

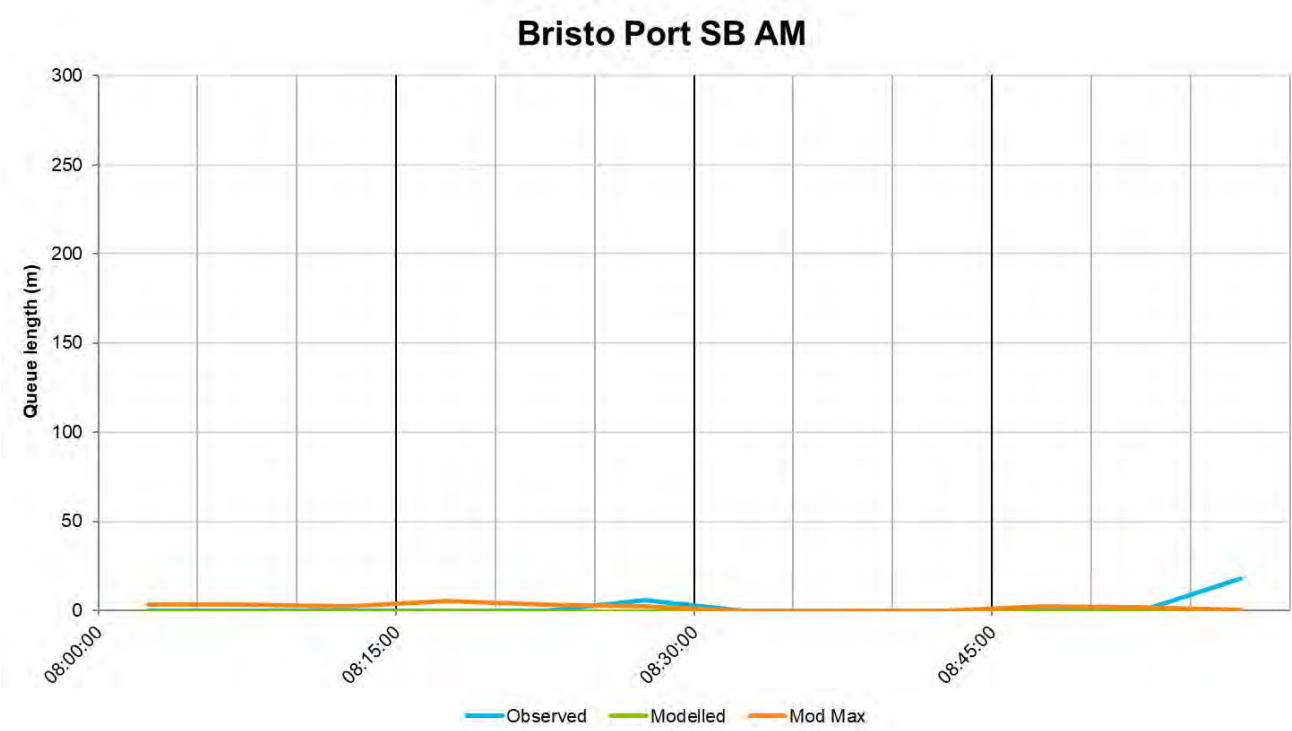


Figure 42: Queue Length Comparison – Bristo Port / George IV Bridge SB AM

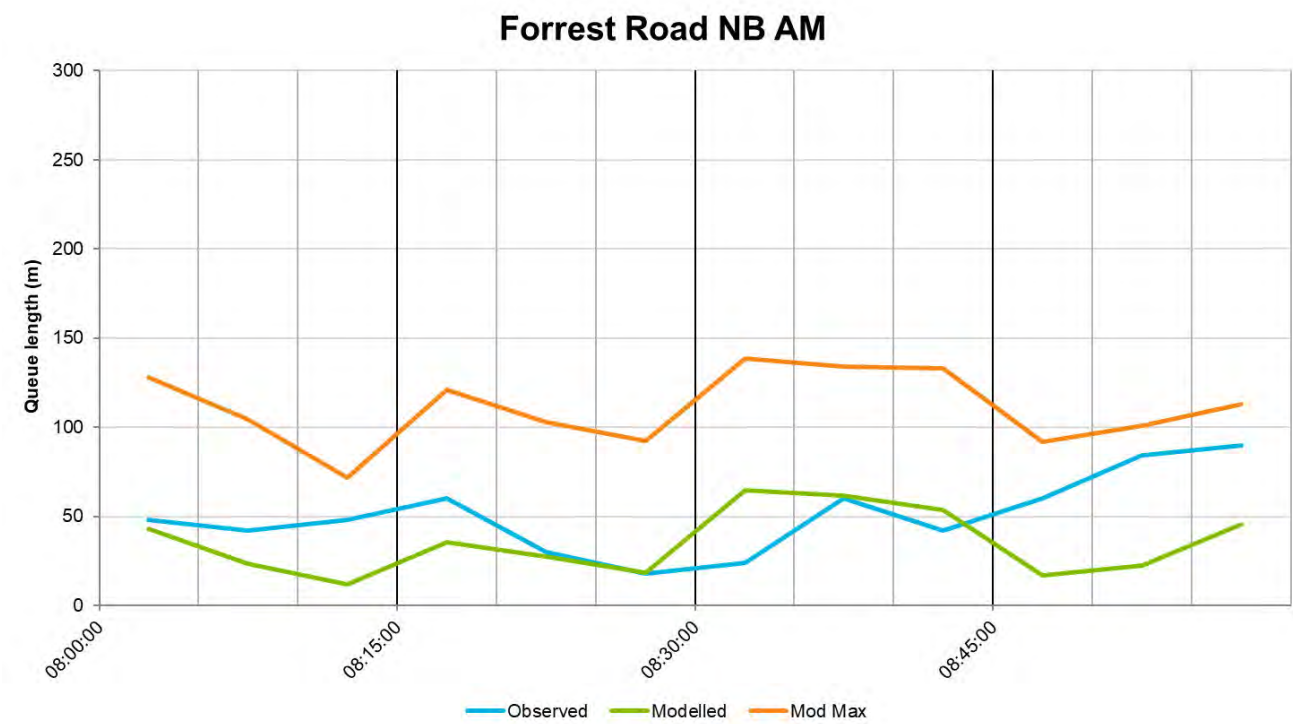


Figure 43: Queue Length Comparison – Forrest Road / Bristo Place NB AM

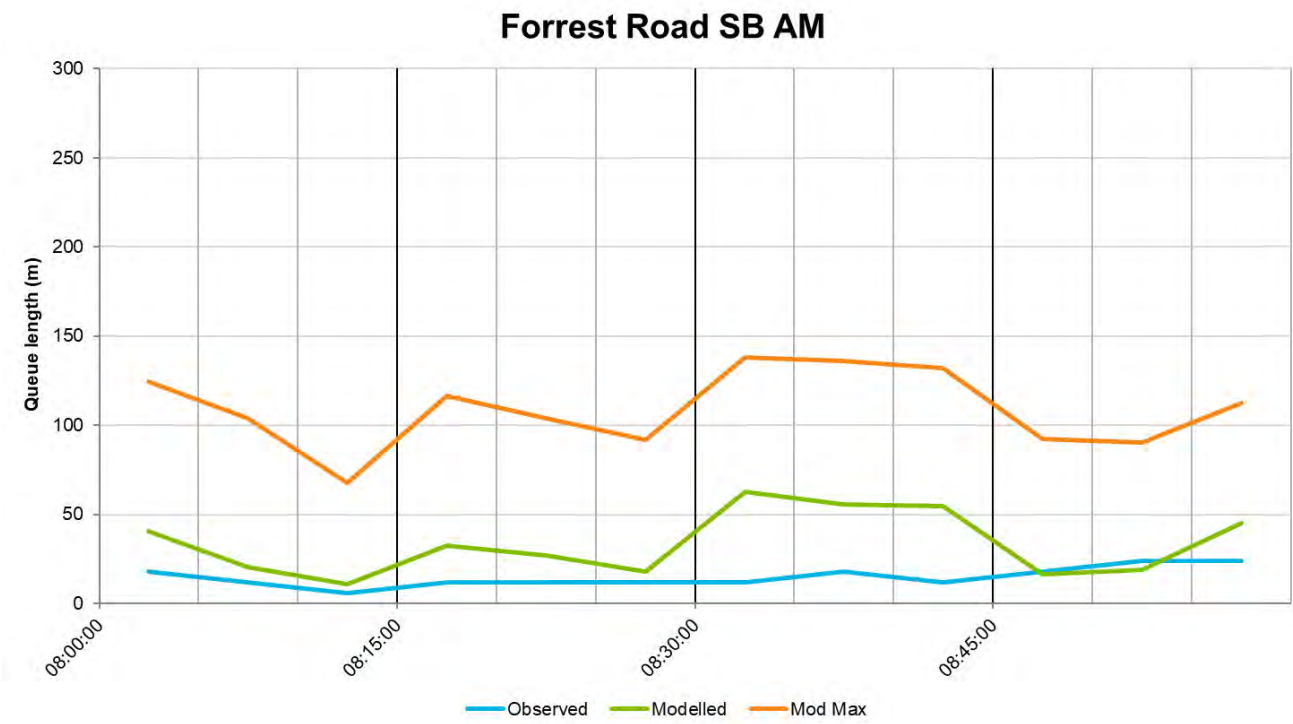


Figure 44: Queue Length Comparison – Forrest Road / Bristo Place SB AM

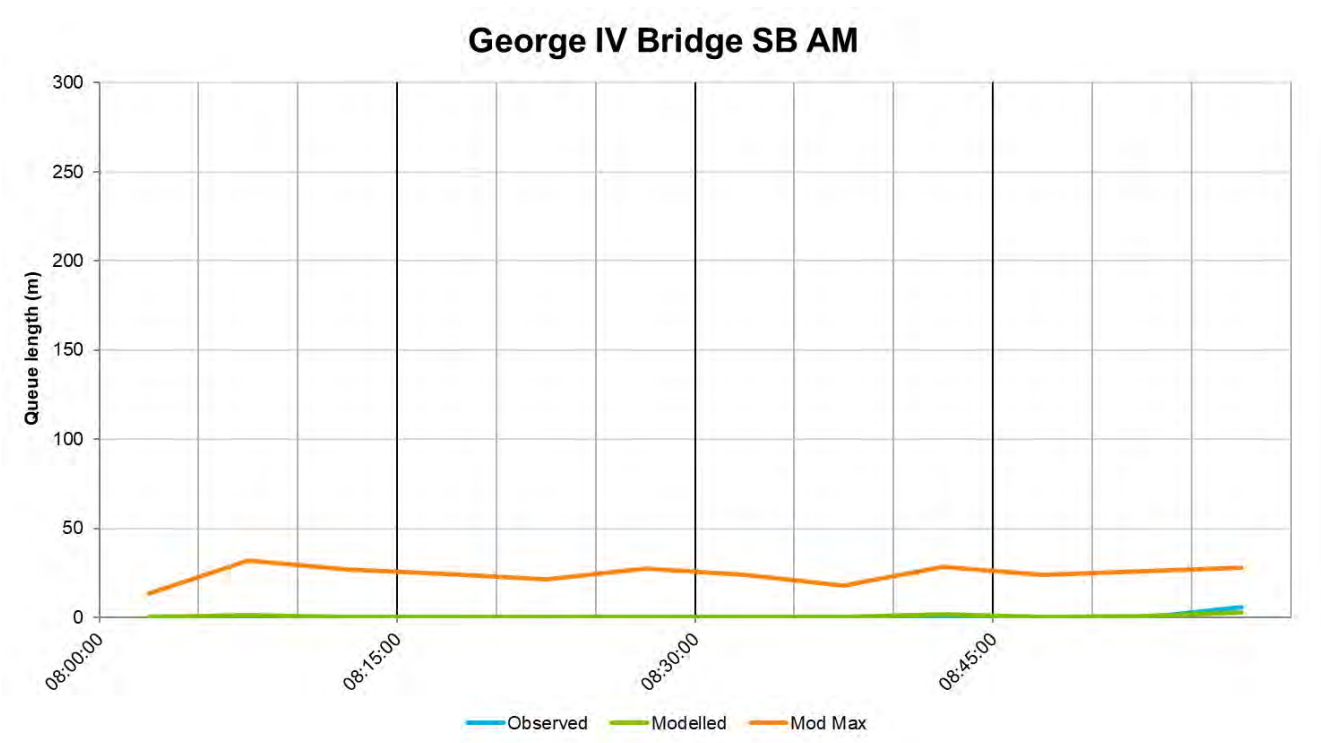


Figure 45: Queue Length Comparison – George IV Bridge / Candlemaker Row SB AM

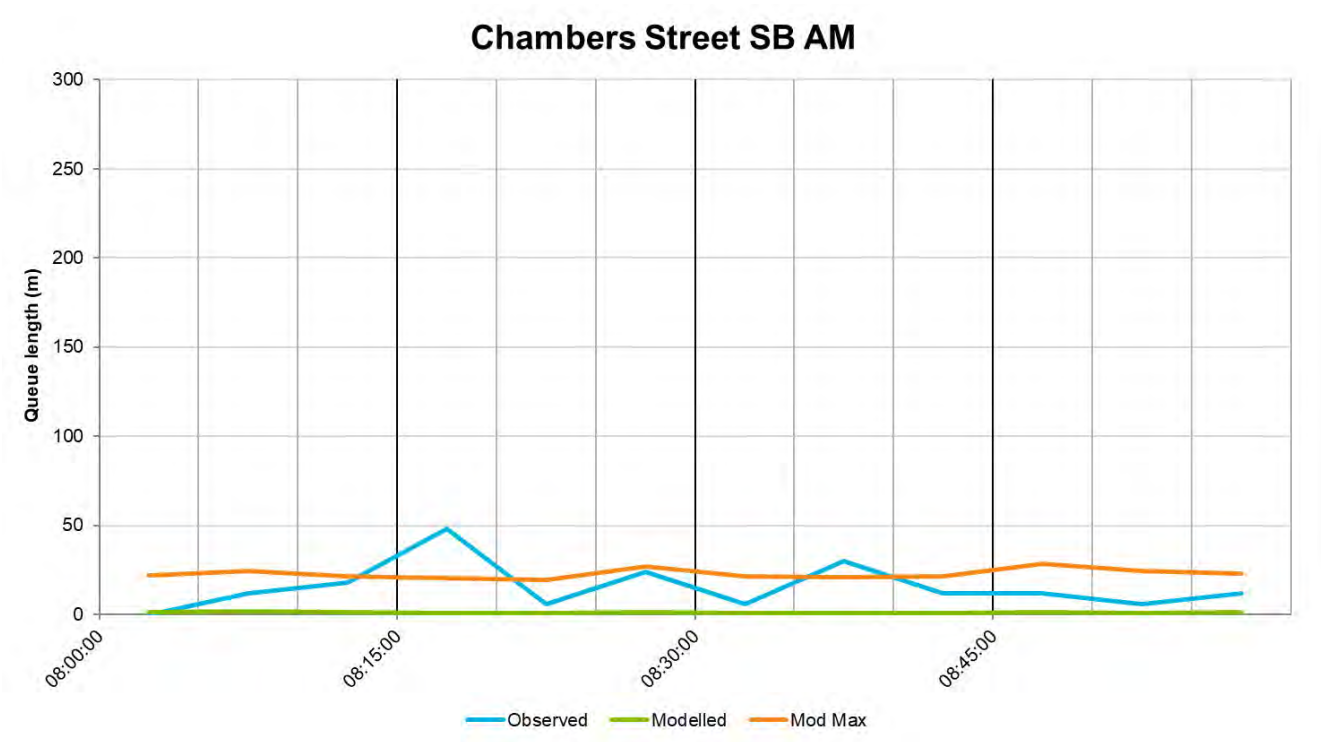


Figure 46: Queue Length Comparison – Chambers Street / George IV Bridge SB AM

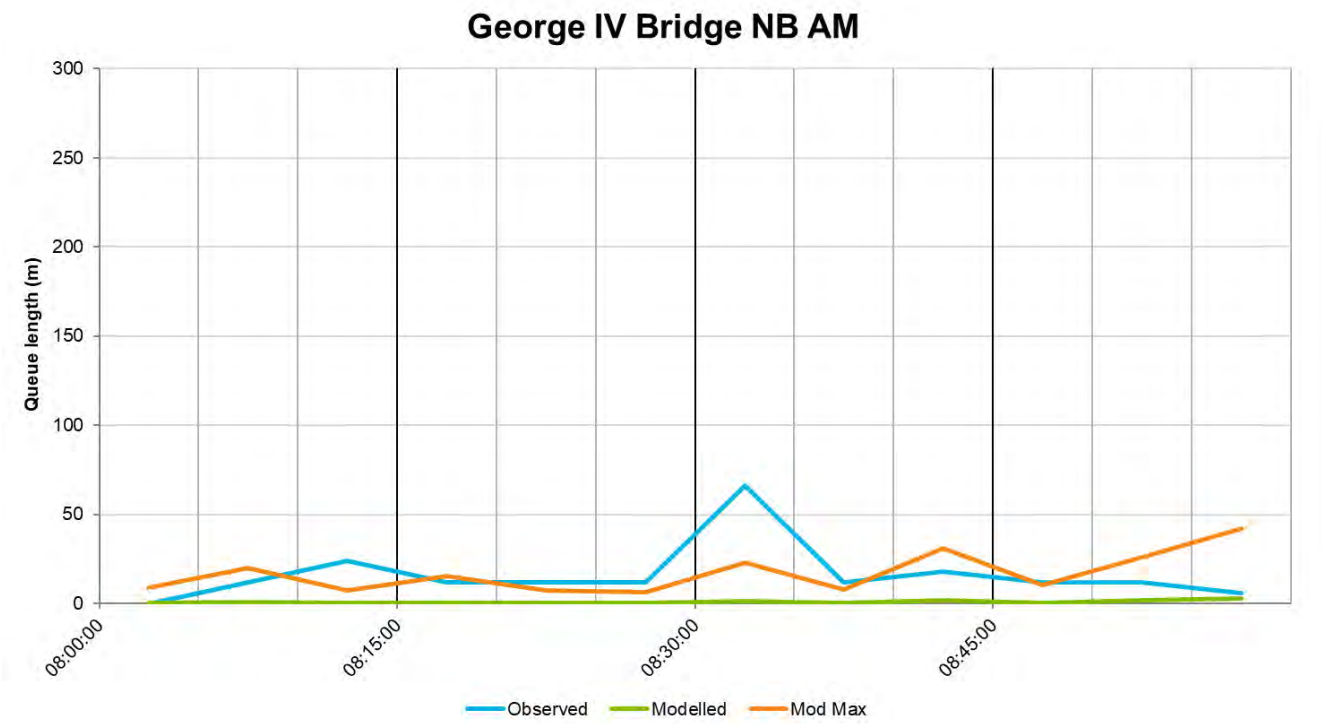


Figure 47: Queue Length Comparison – George IV Bridge / Chambers Street NB AM

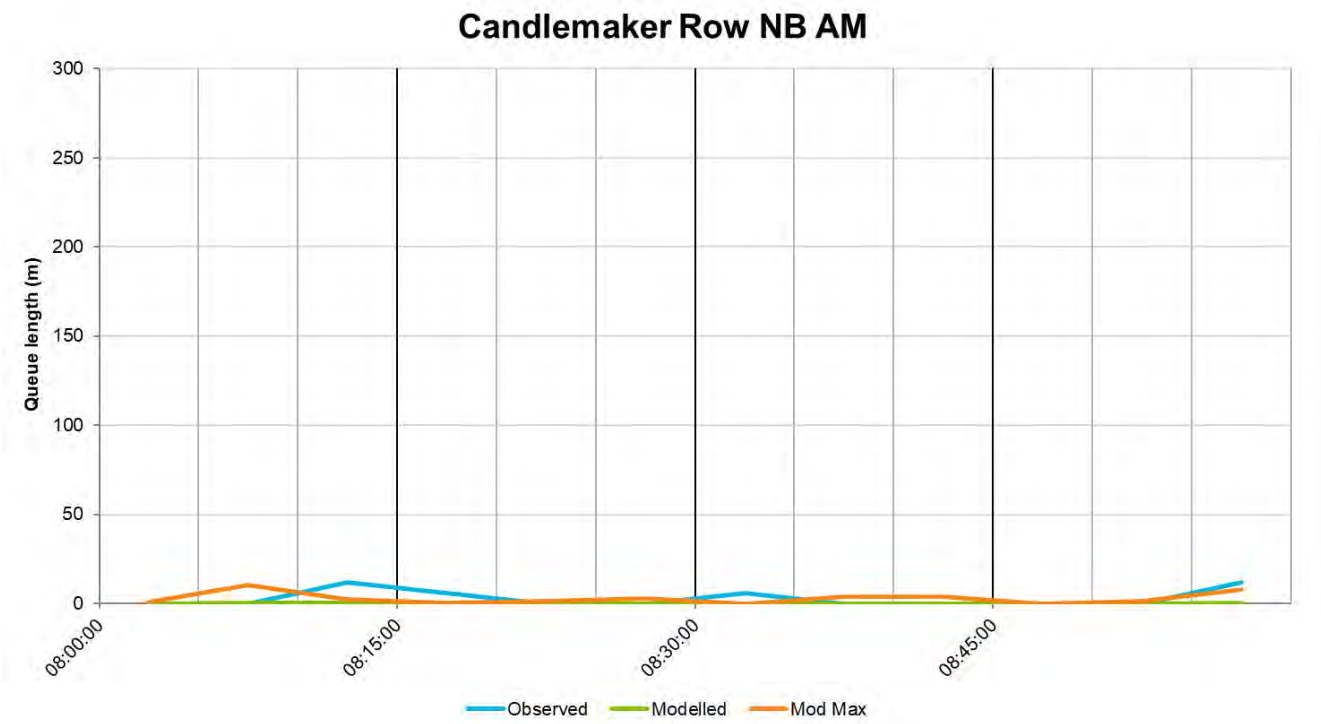


Figure 48: Queue Length Comparison – Candlemaker Row / George IV Bridge NB AM

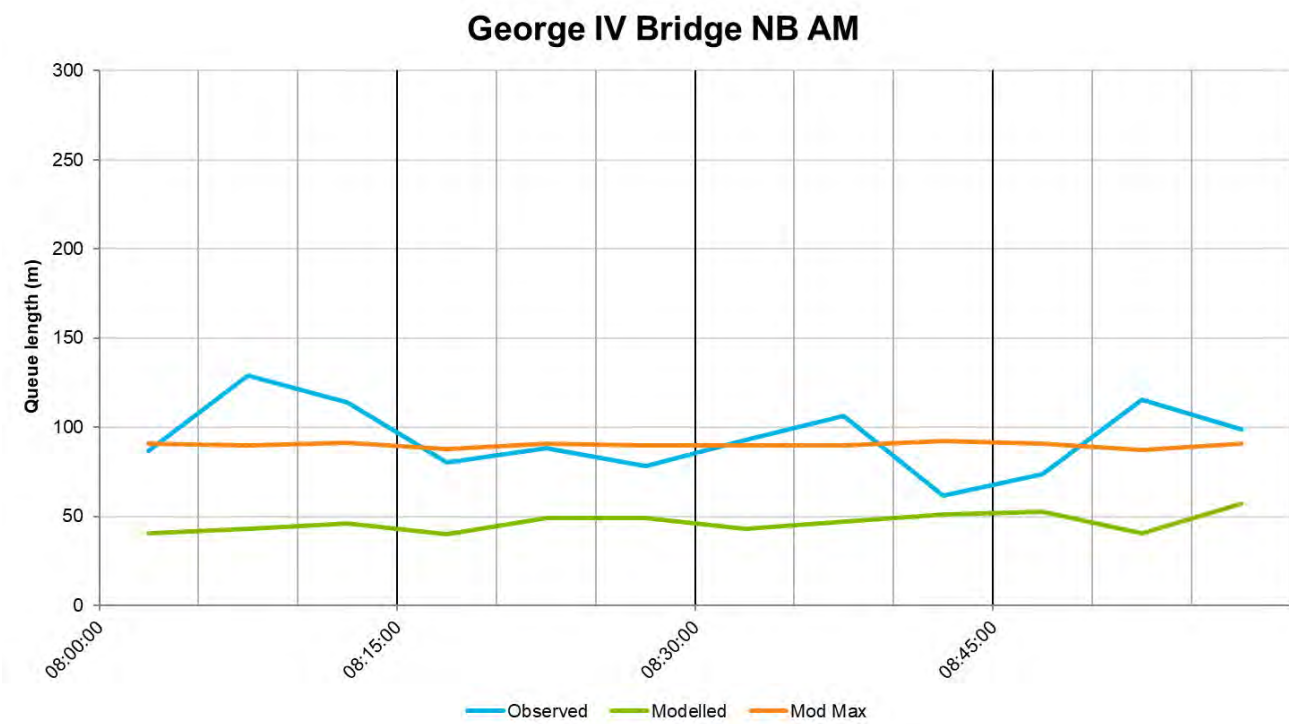


Figure 49: Queue Length Comparison –George IV Bridge / Royal Mile NB AM

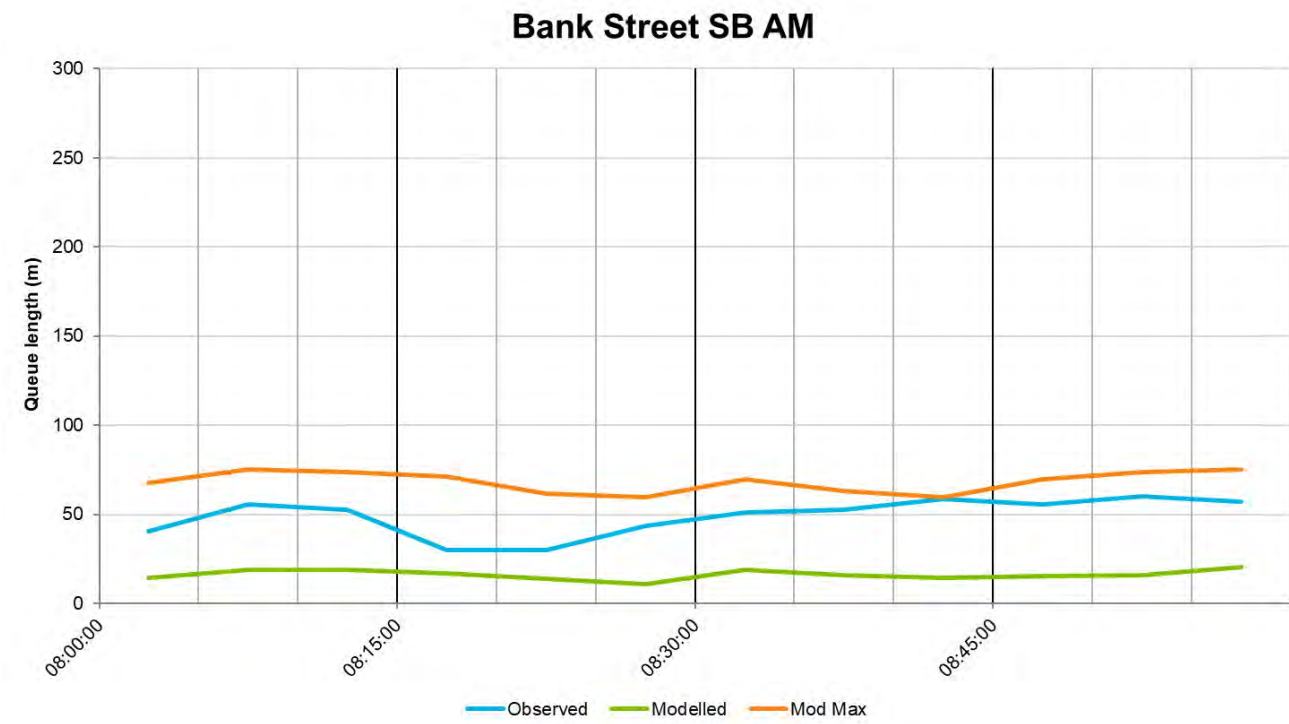


Figure 50: Queue Length Comparison –Bank Street / Royal Mile SB AM

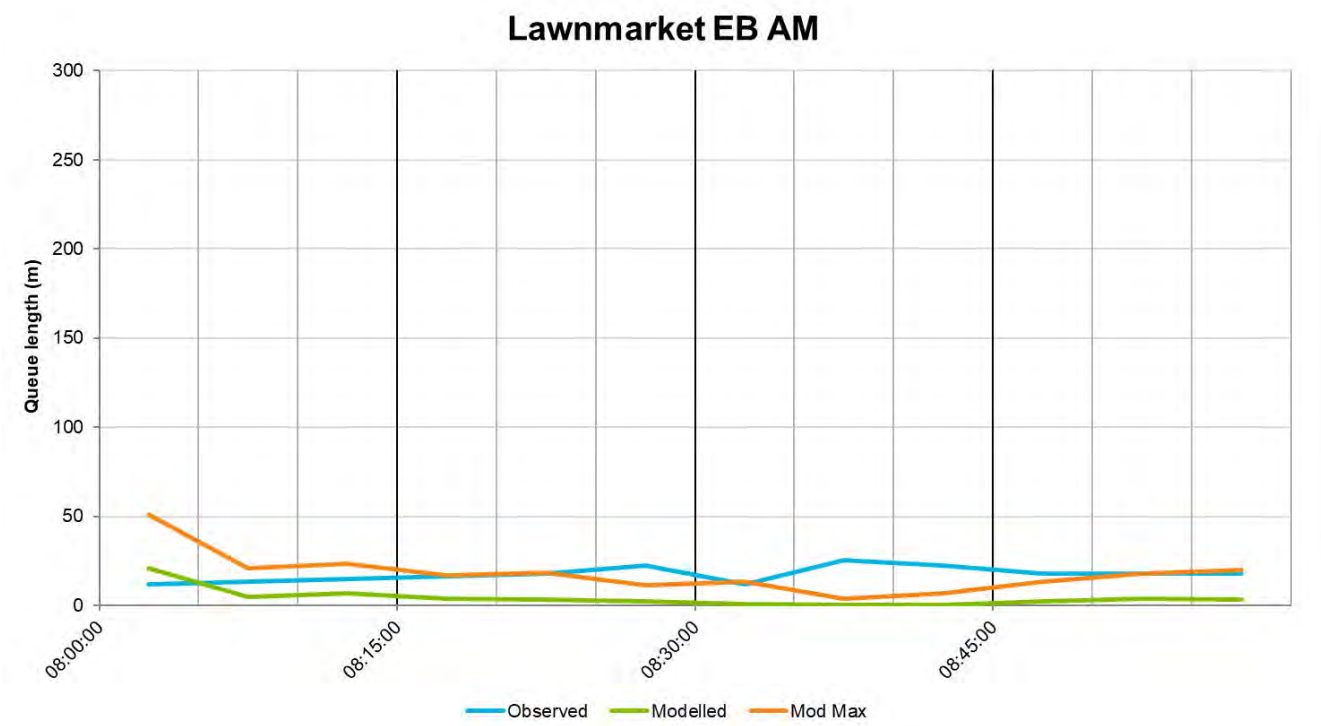


Figure 51: Queue Length Comparison –Lawnmarket / George IV Bridge EB AM

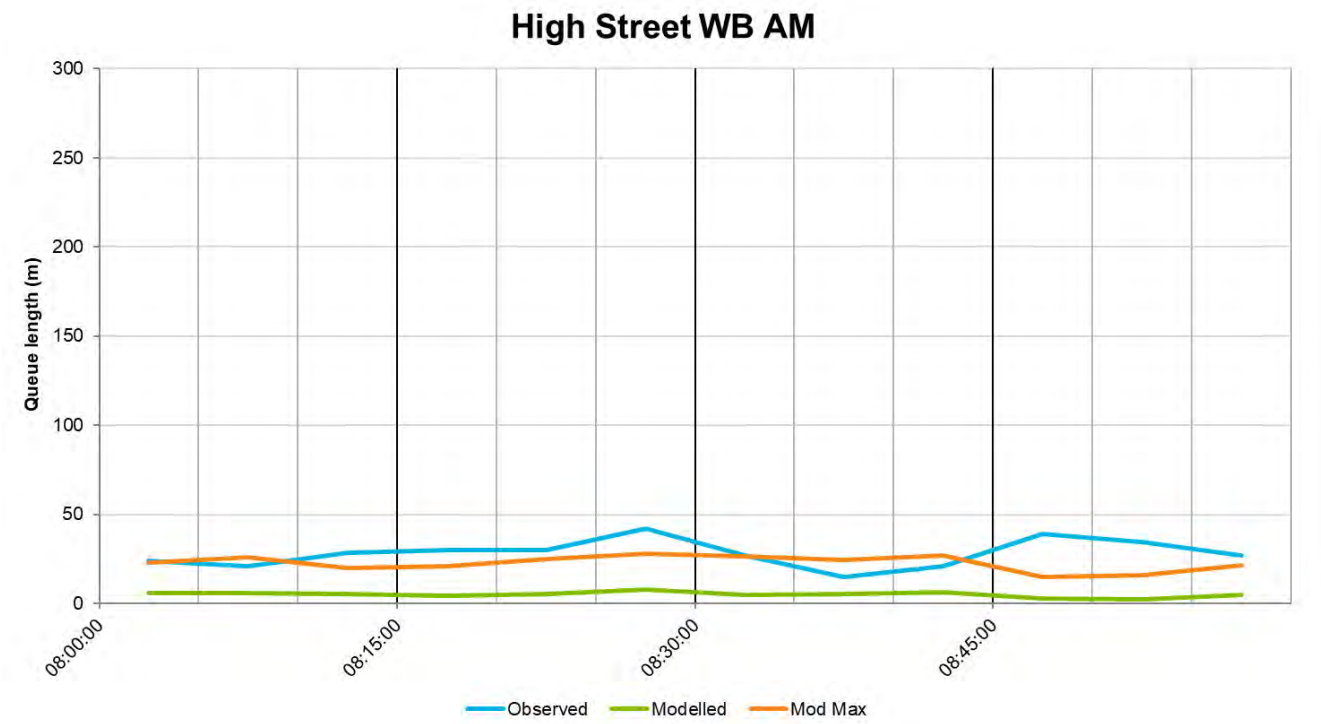


Figure 52: Queue Length Comparison –High Street / George IV Bridge WB AM

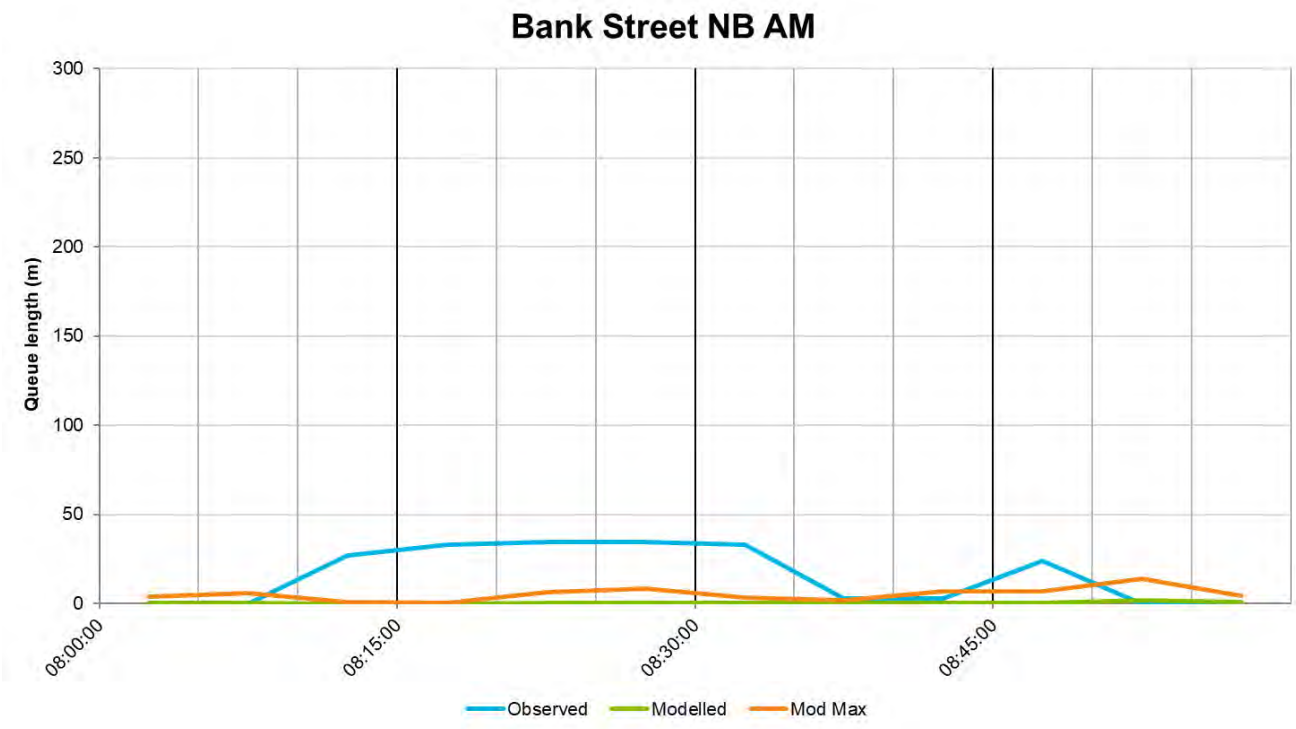


Figure 53: Queue Length Comparison –Bank Street / St Giles Street NB AM

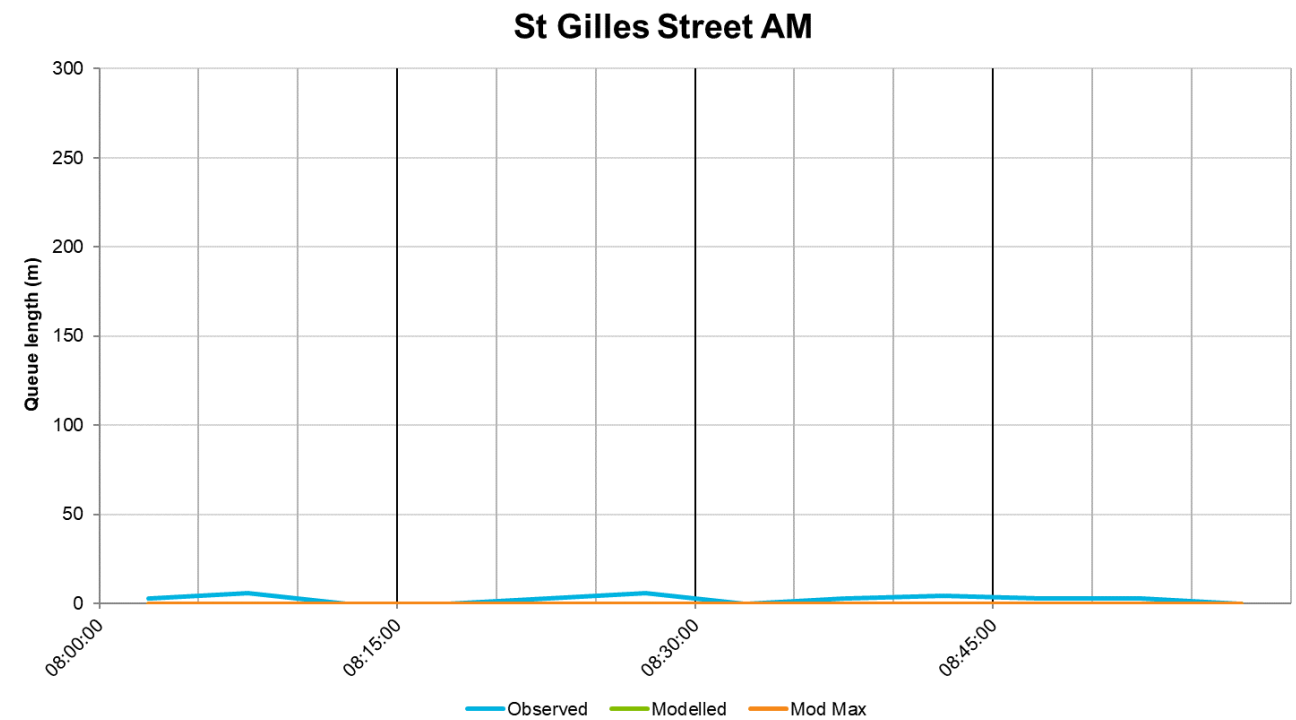


Figure 54: Queue Length Comparison –St Giles Street / Bank Street AM

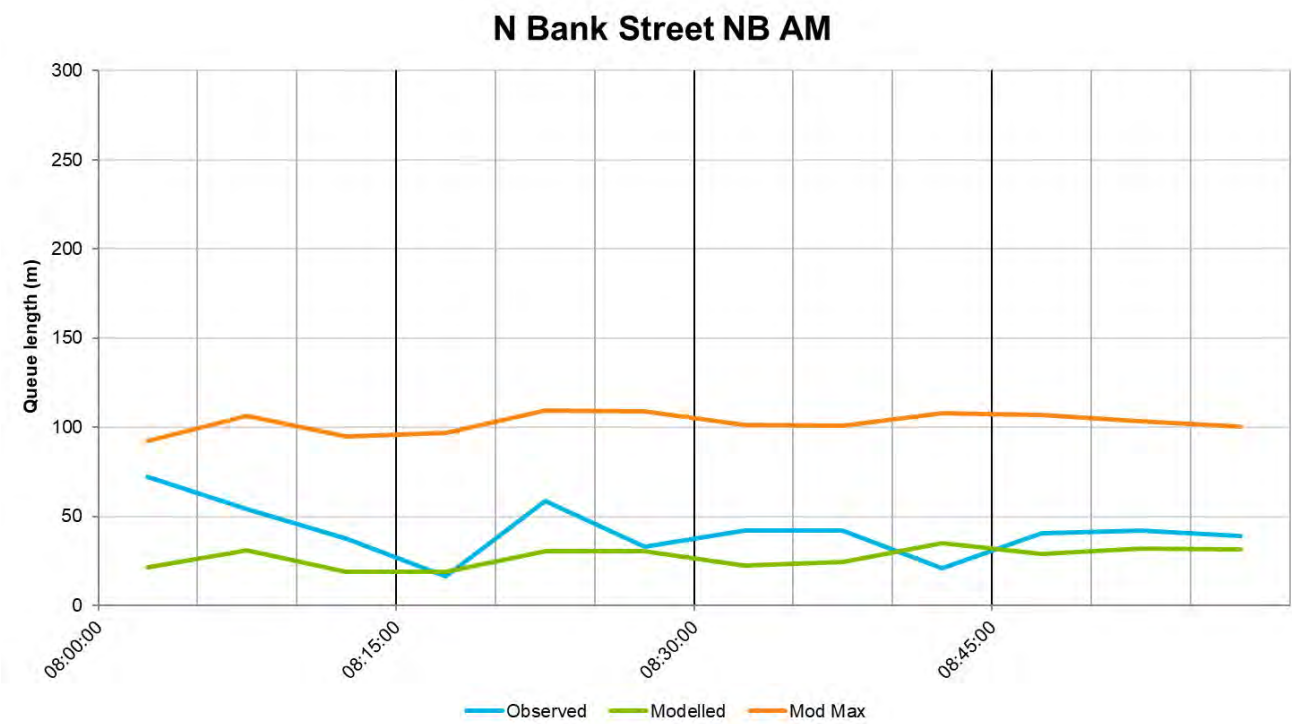


Figure 55: Queue Length Comparison –N Bank Street / Market Street NB AM

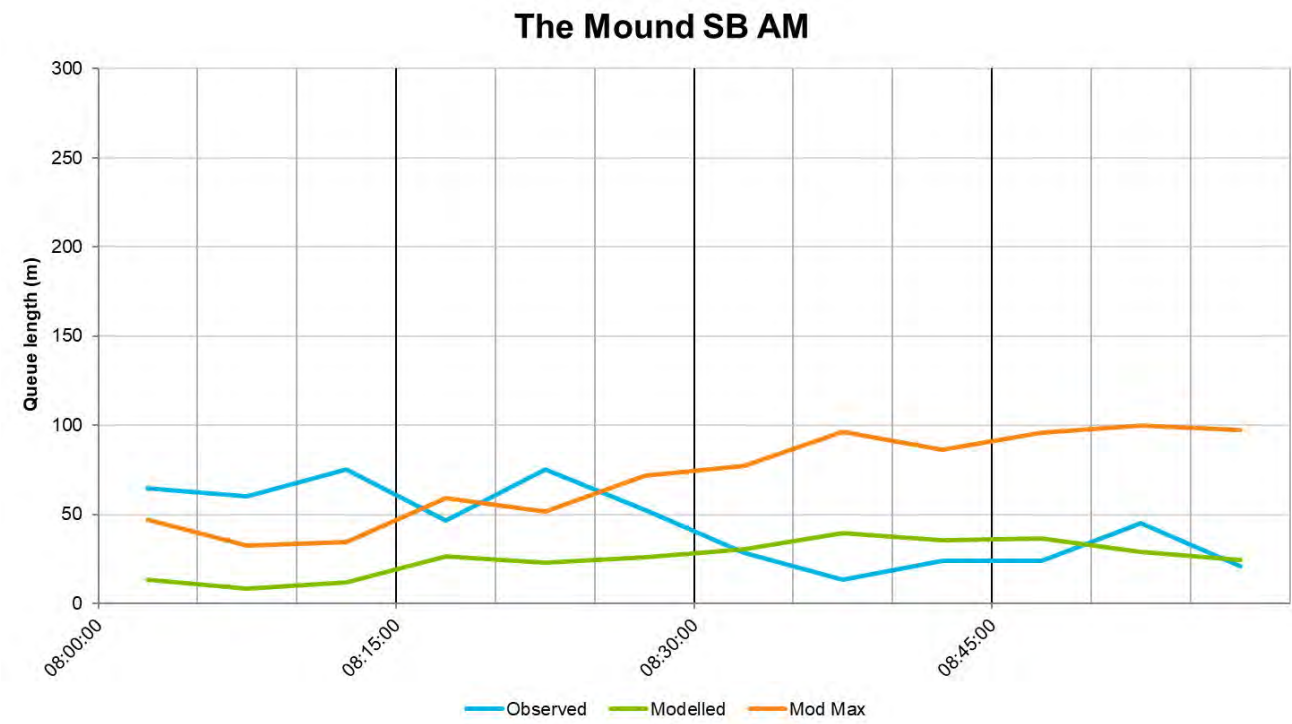


Figure 56: Queue Length Comparison –The Mound / Market Street SB AM

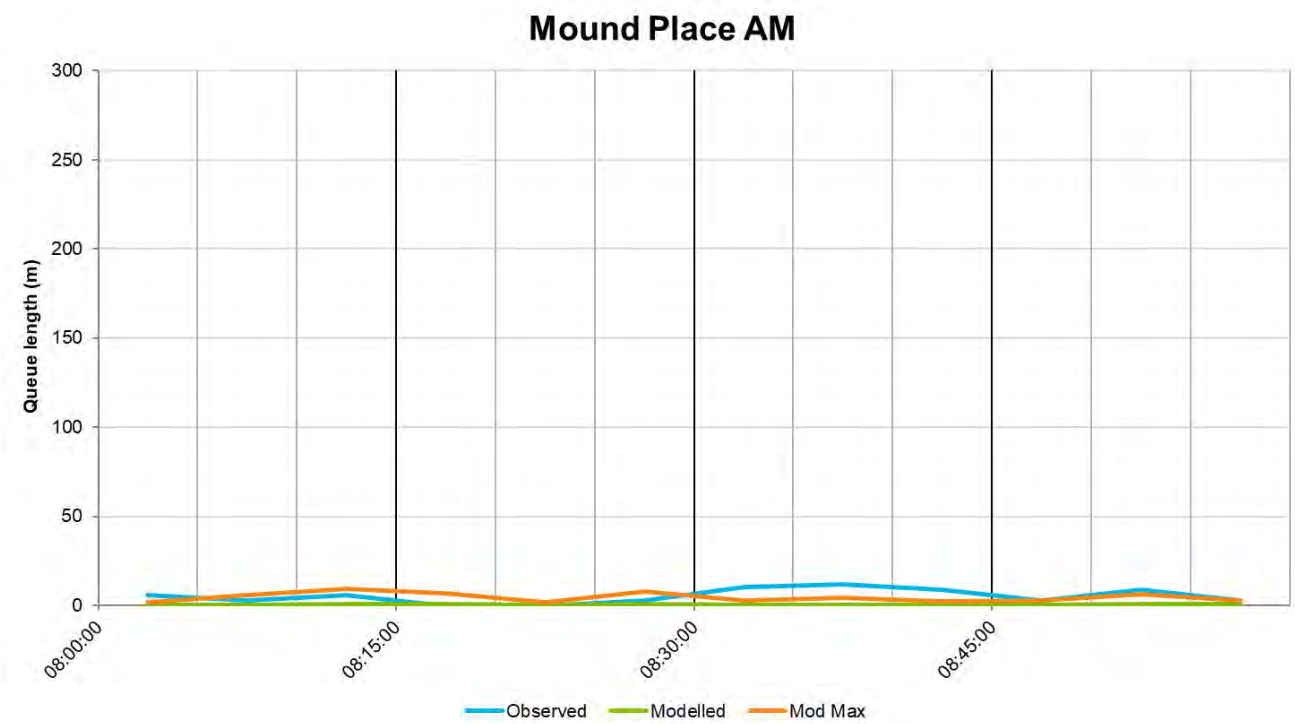


Figure 57: Queue Length Comparison –Mound Place / Market Street AM

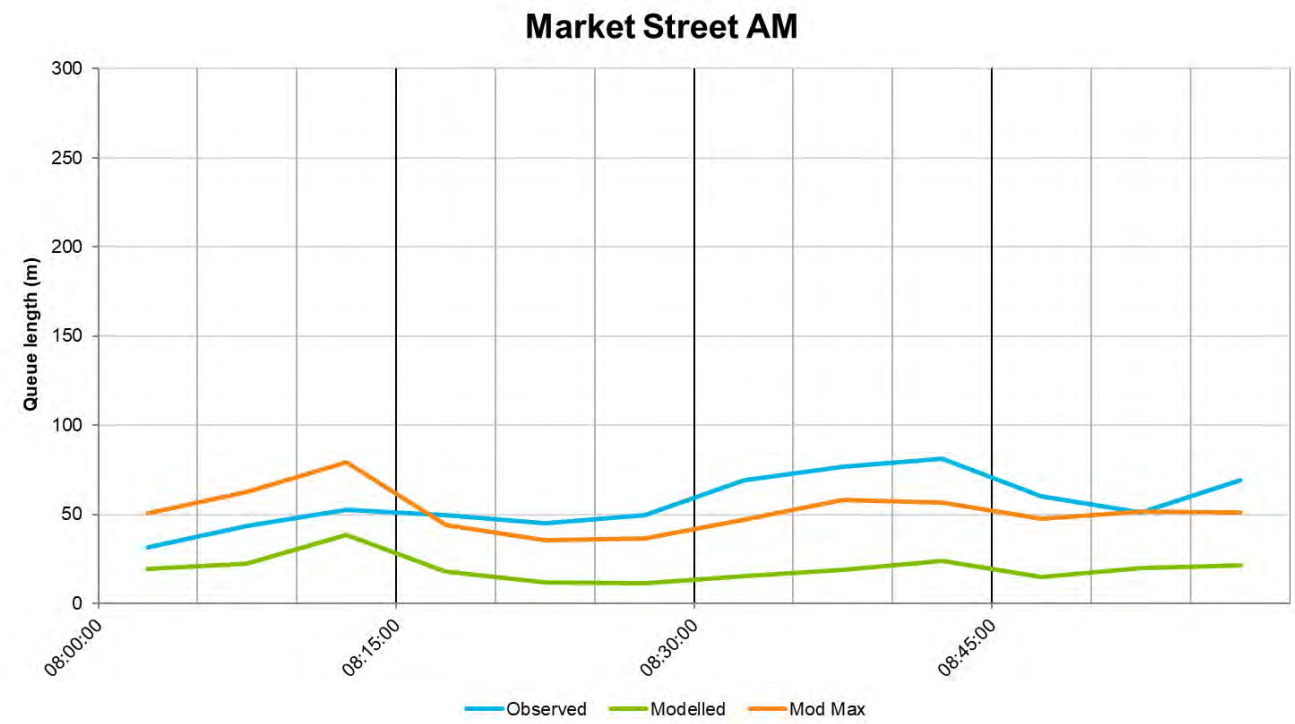


Figure 58: Queue Length Comparison –Market Street / Mound Place AM

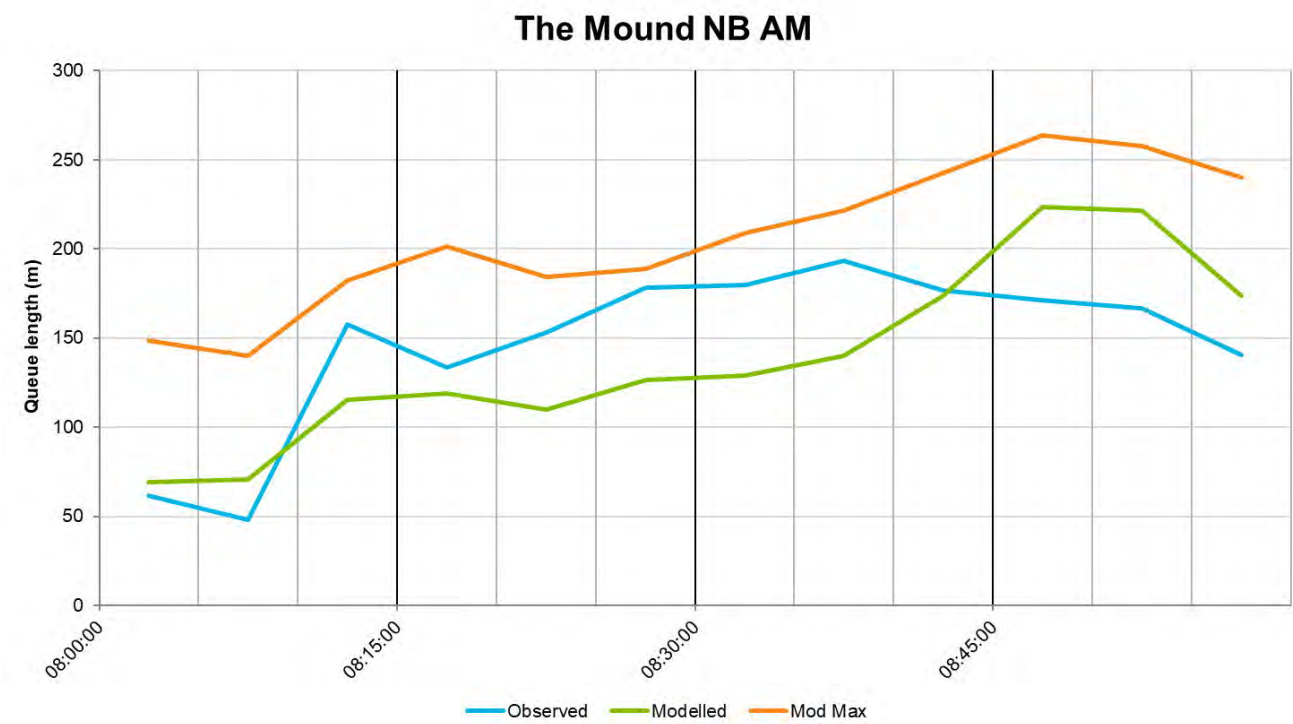


Figure 59: Queue Length Comparison –The Mound / Princes Street SB AM

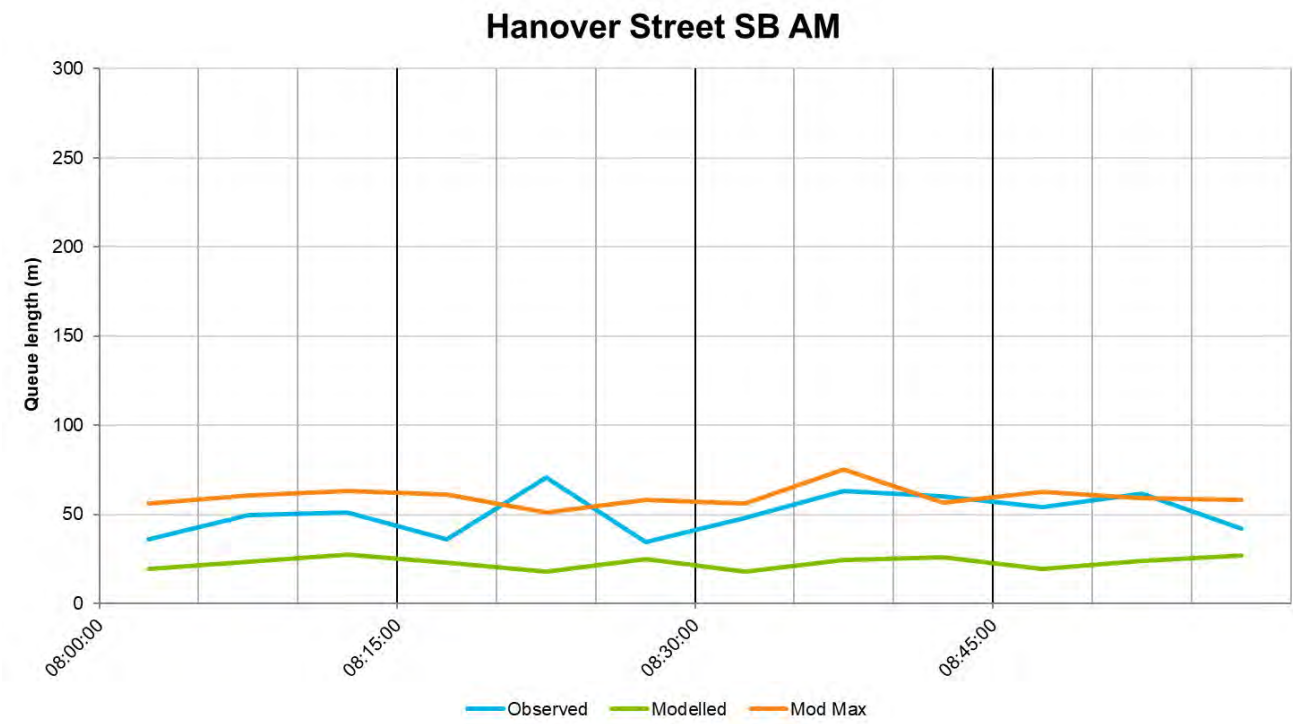


Figure 60: Queue Length Comparison –Hanover Street / Princes Street SB AM

B.2 PM Peak Period

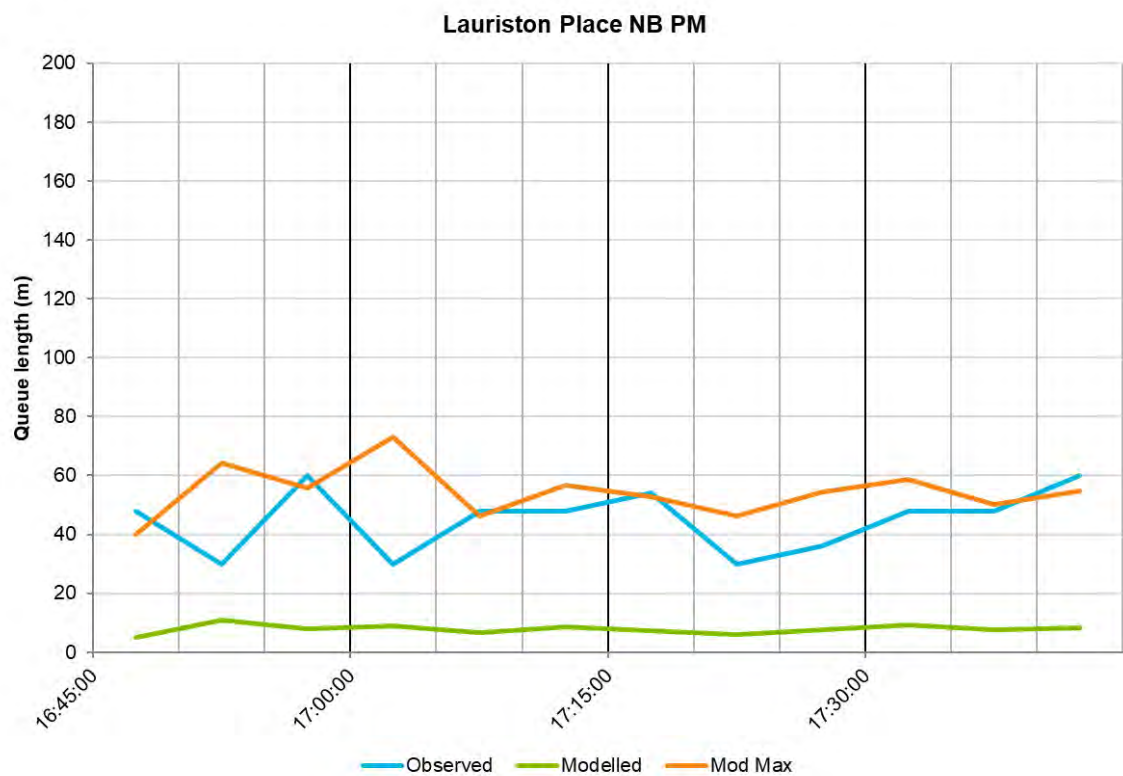


Figure 61: Queue Length Comparison – Lauriston Place/ Forrest Road NB PM

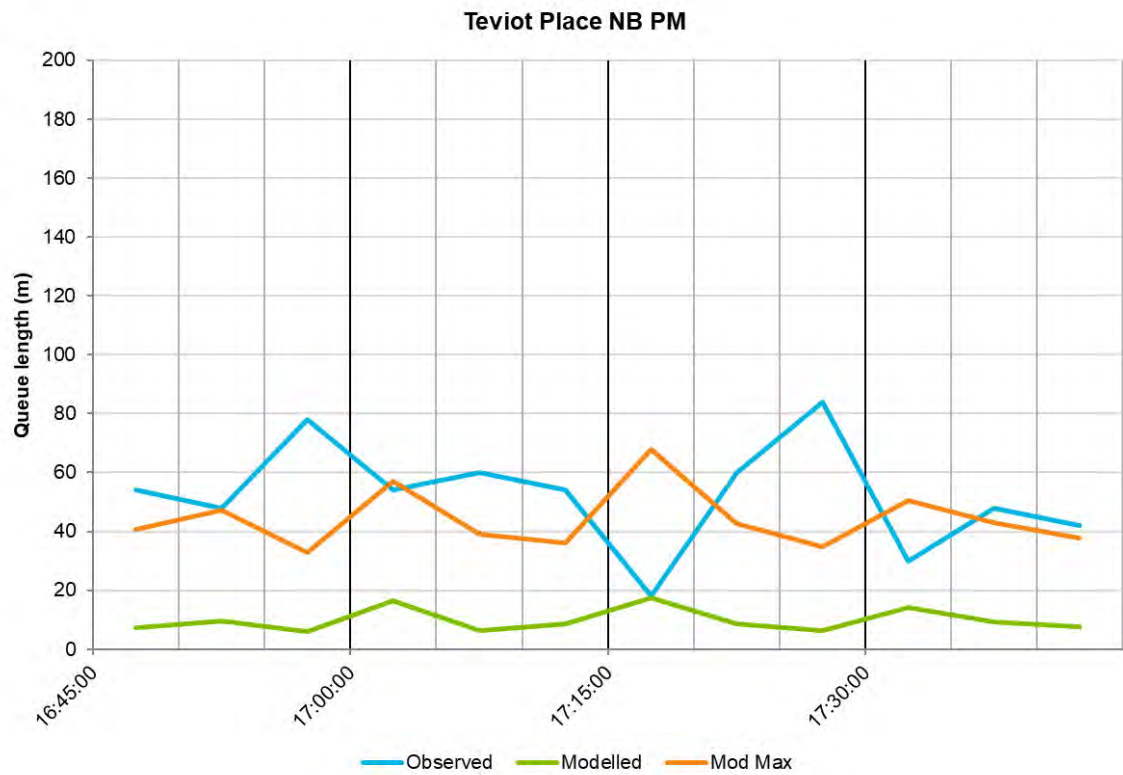


Figure 62: Queue Length Comparison – Teviot Place / Forrest Road NB PM

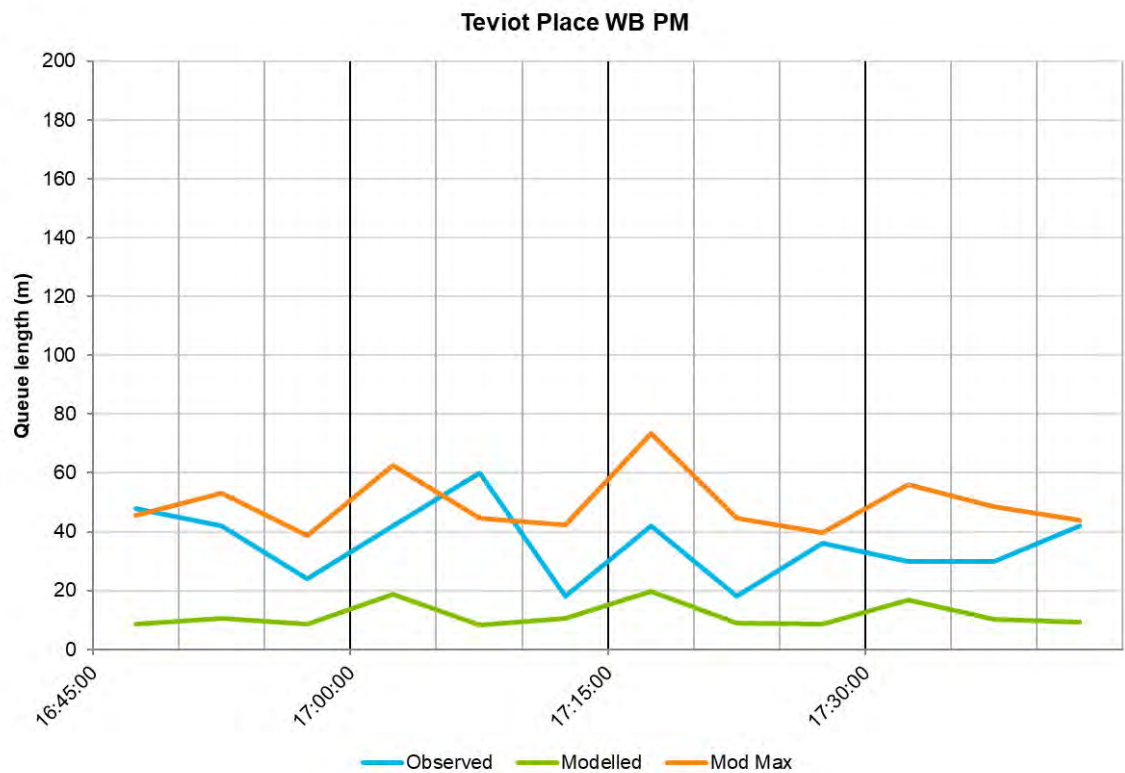


Figure 63: Queue Length Comparison – Teviot Place / Forrest Road WB AM

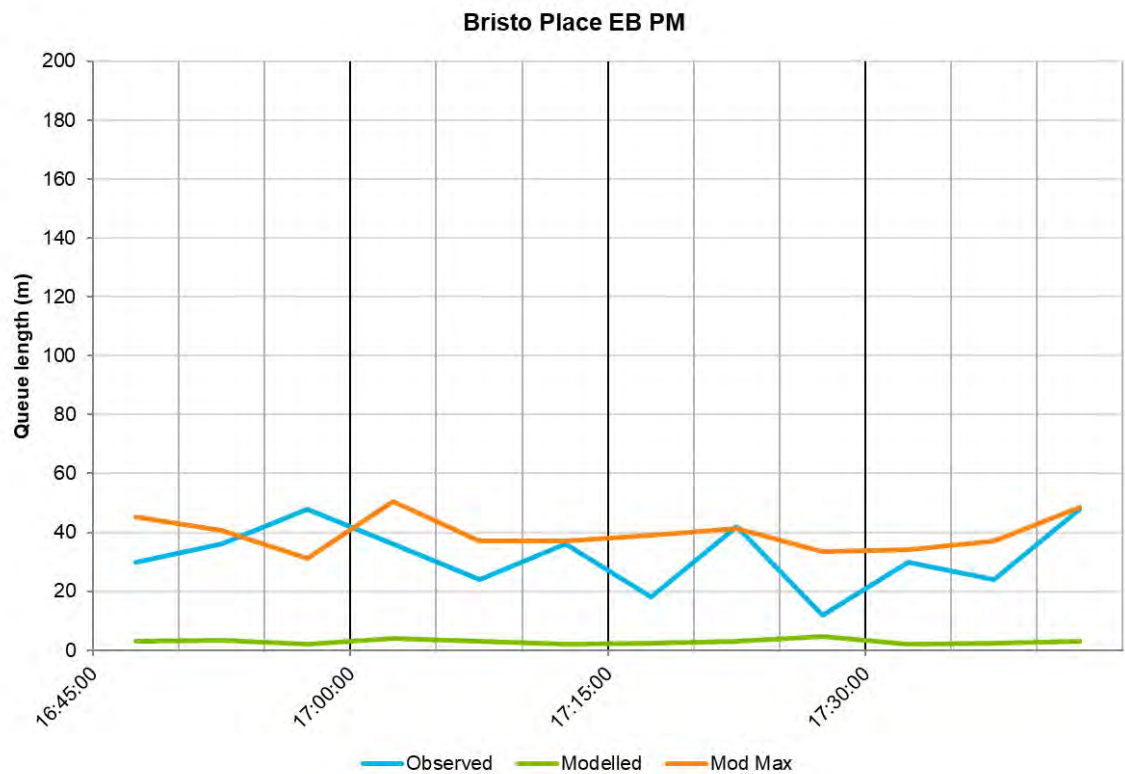


Figure 64: Queue Length Comparison – Bristo Place / Potterrow EB PM

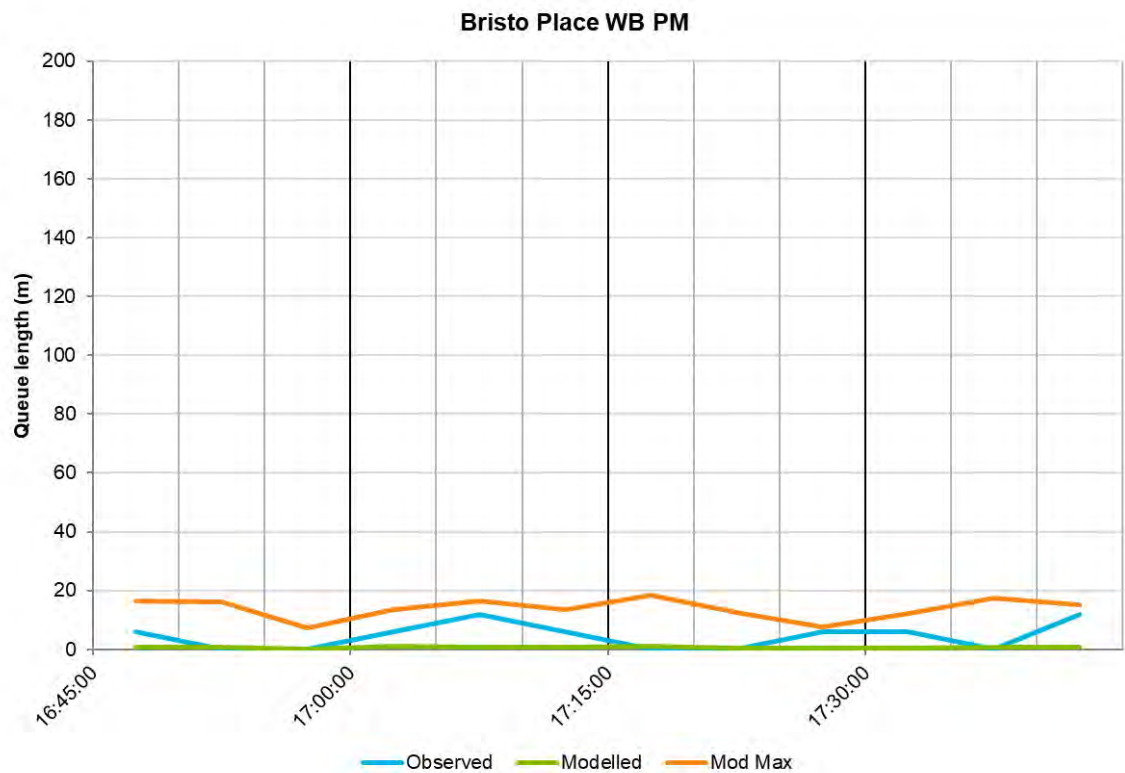


Figure 65: Queue Length Comparison – Bristo Place / Teviot Place WB PM

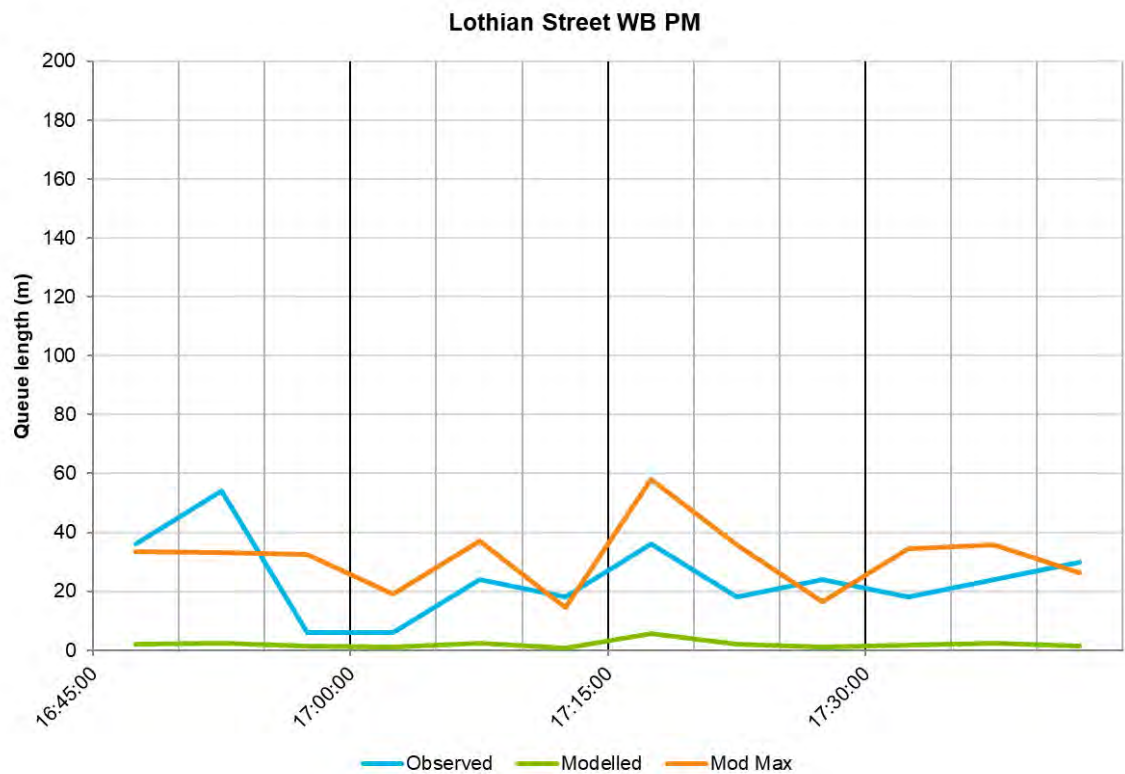


Figure 66: Queue Length Comparison – Lothian Street / Teviot Place WB PM

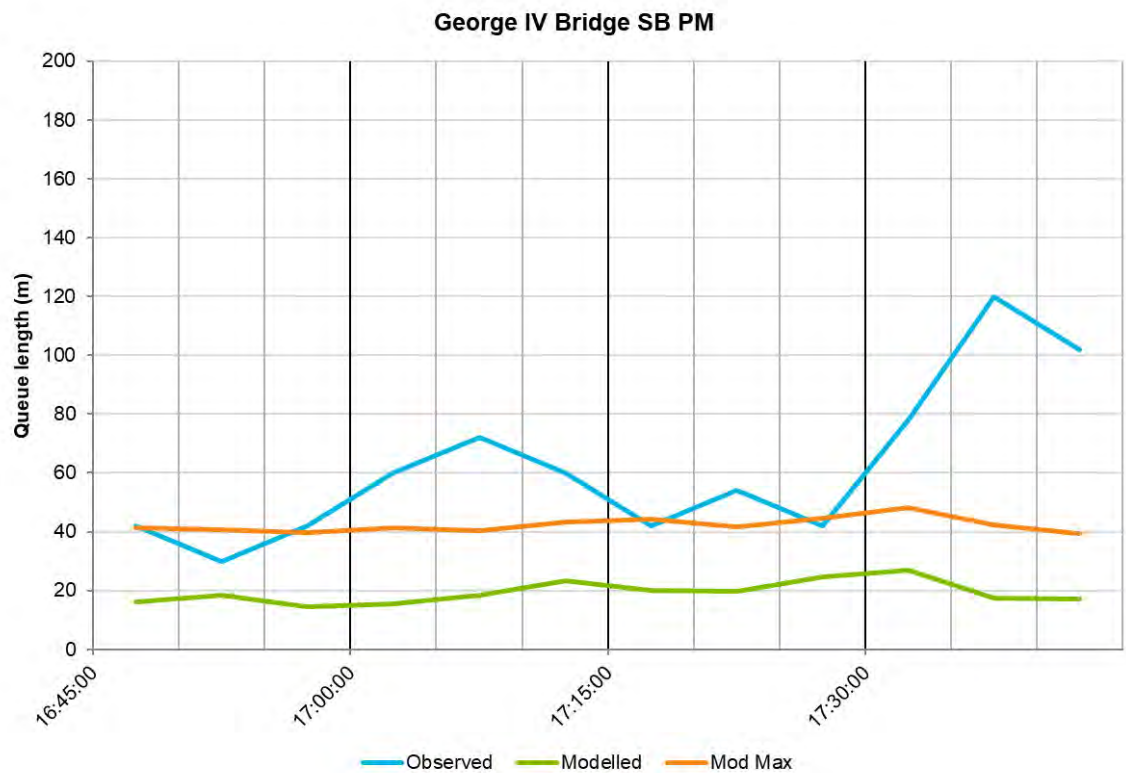


Figure 67: Queue Length Comparison – George IV Bridge/ Bristo Port SB PM

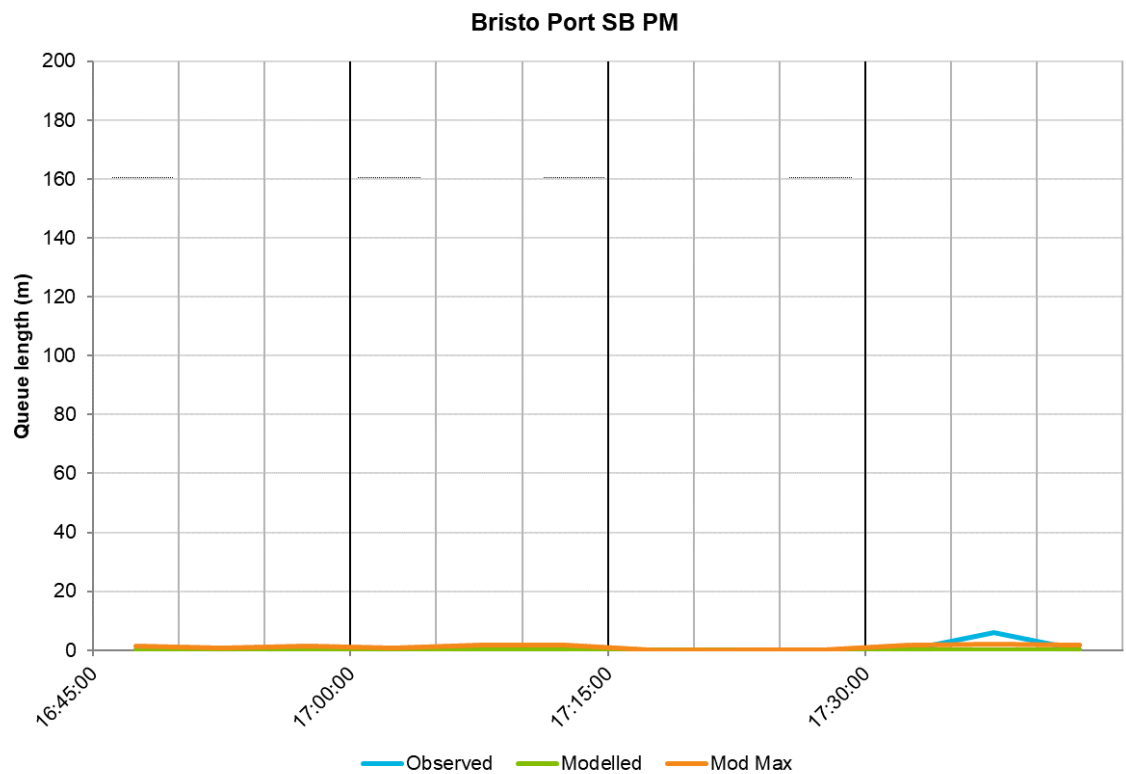


Figure 68: Queue Length Comparison – Bristo Port / George IV Bridge SB PM

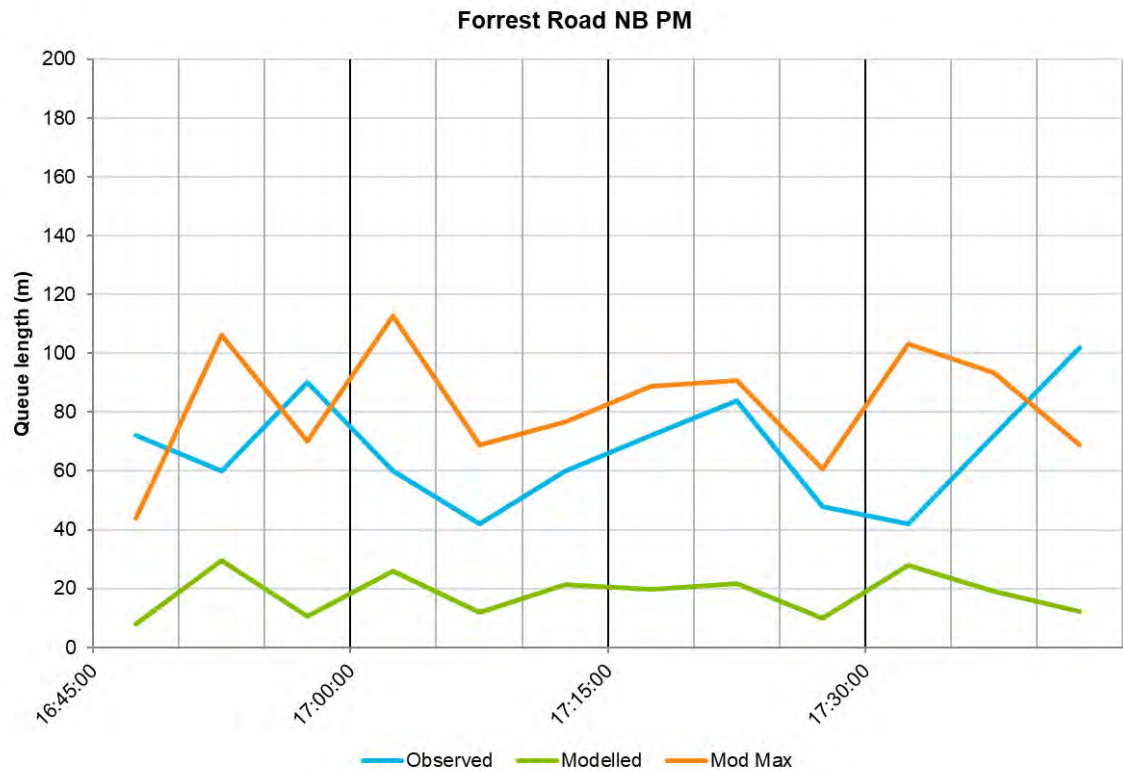


Figure 69: Queue Length Comparison – Forrest Road / Bristo Place NB PM

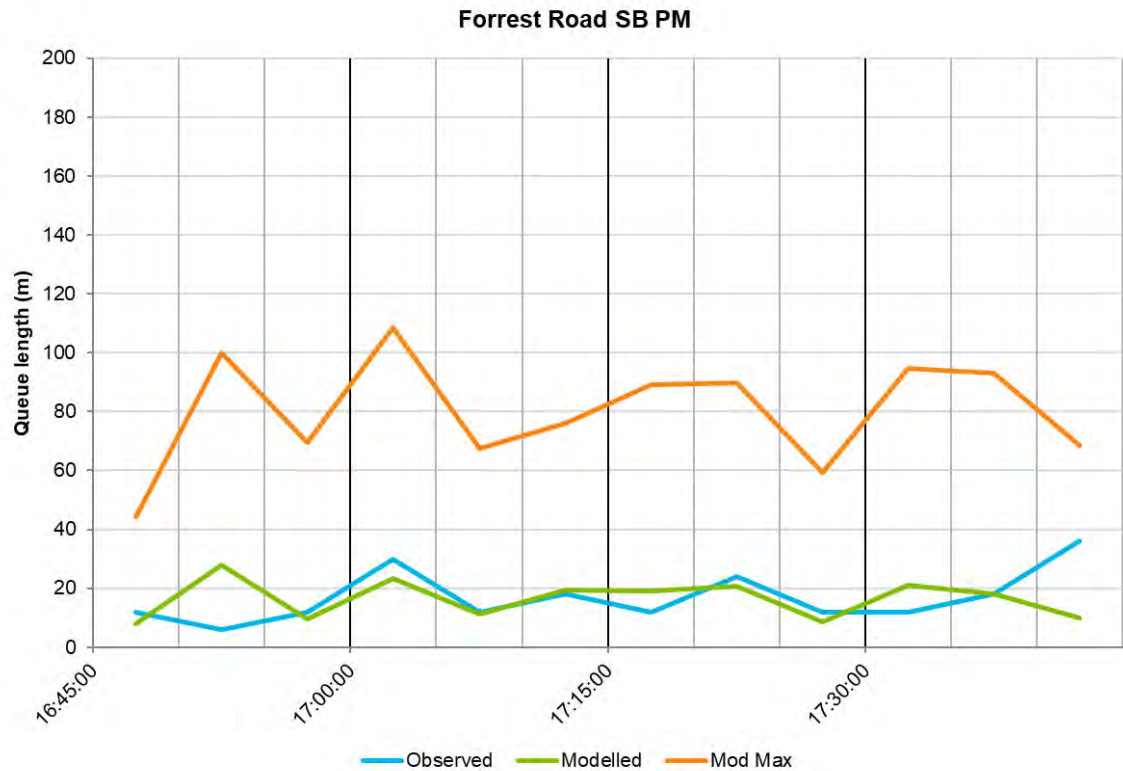


Figure 70: Queue Length Comparison – Forrest Road / Bristo Place SB PM

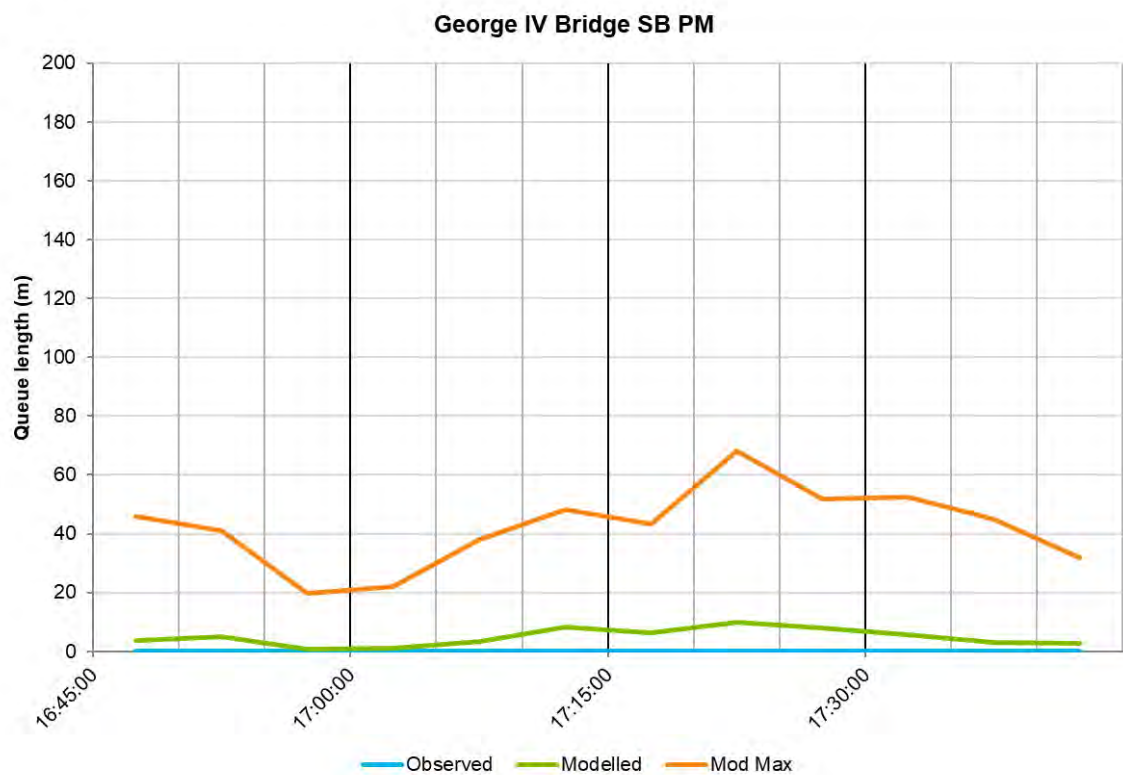


Figure 71: Queue Length Comparison – George IV Bridge / Candlemaker Row SB PM

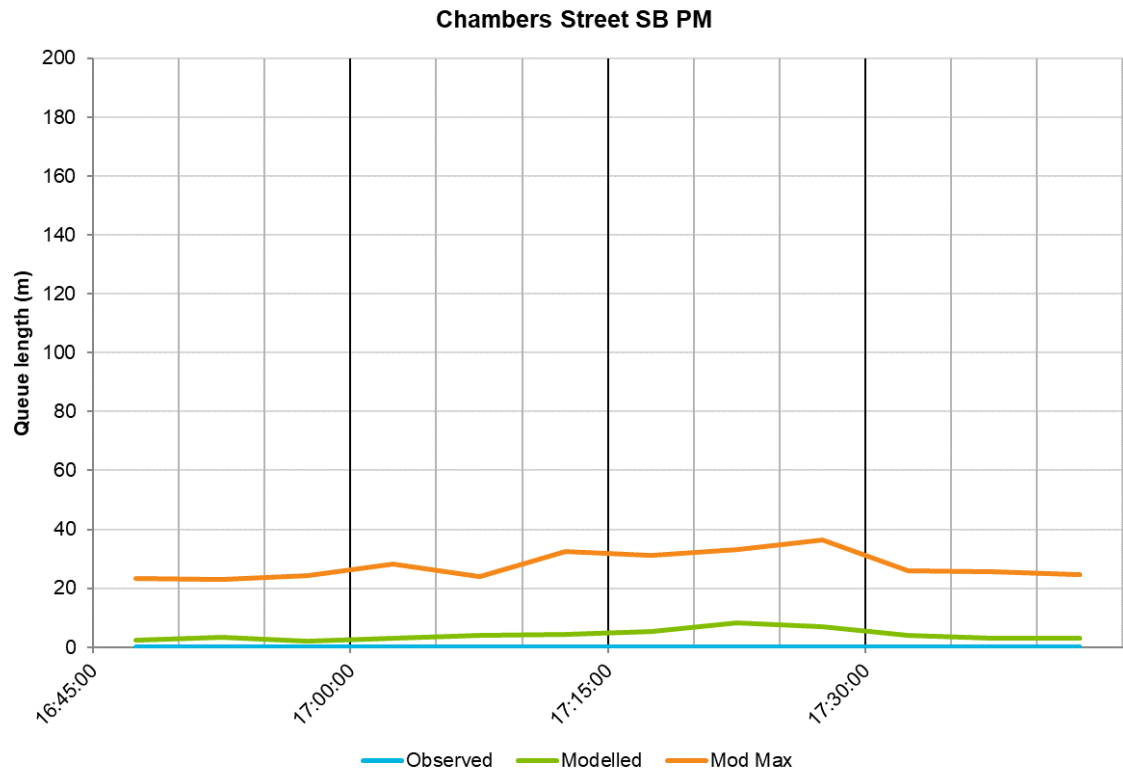


Figure 72: Queue Length Comparison – Chambers Street / George IV Bridge SB PM

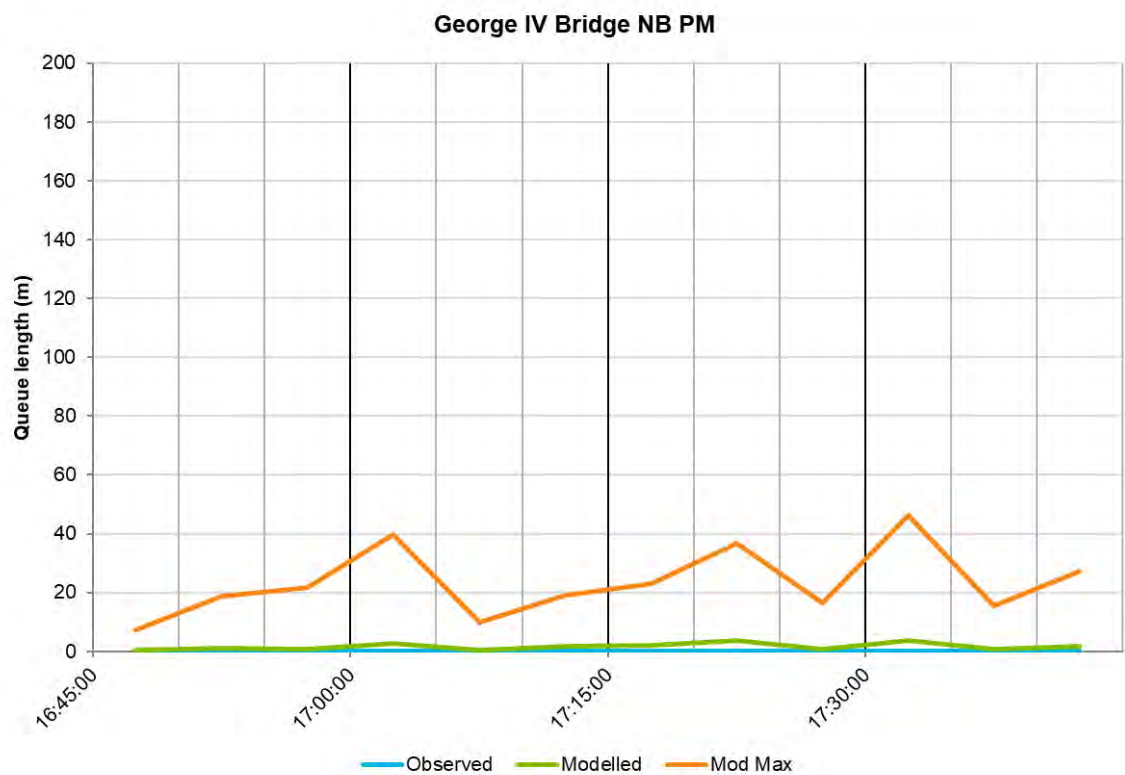


Figure 73: Queue Length Comparison – George IV Bridge / Chambers Street NB PM

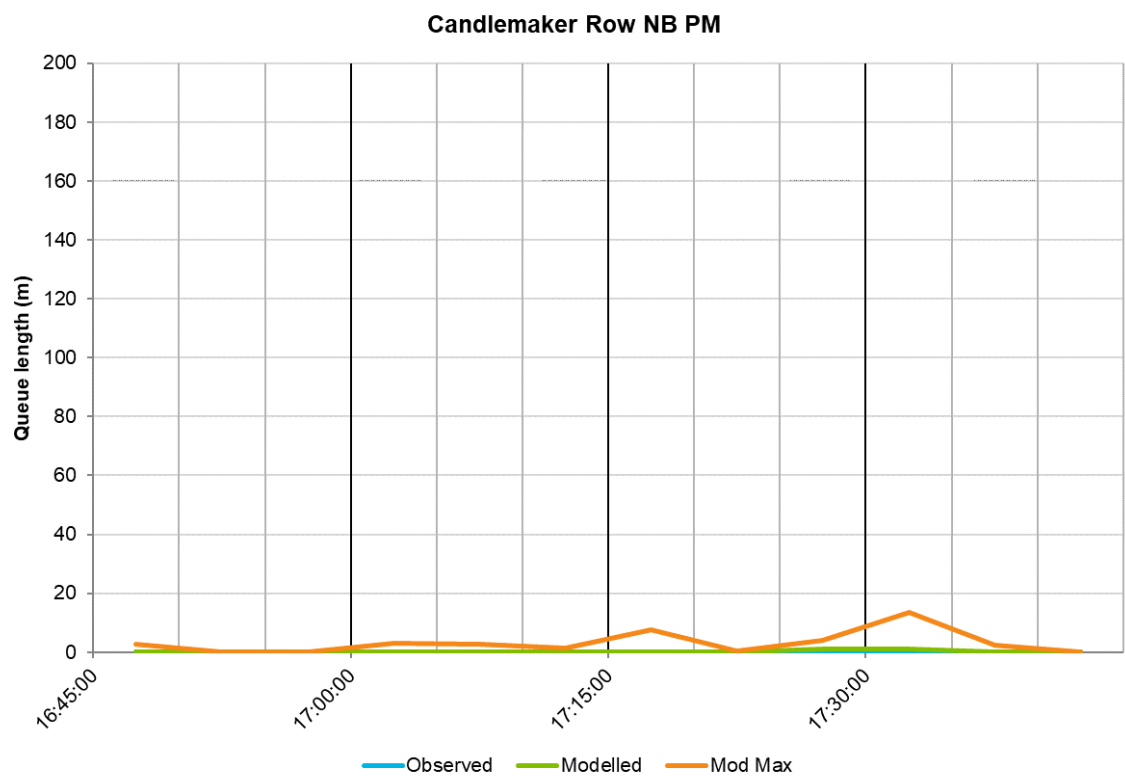


Figure 74: Queue Length Comparison – Candlemaker Row / George IV Bridge NB PM

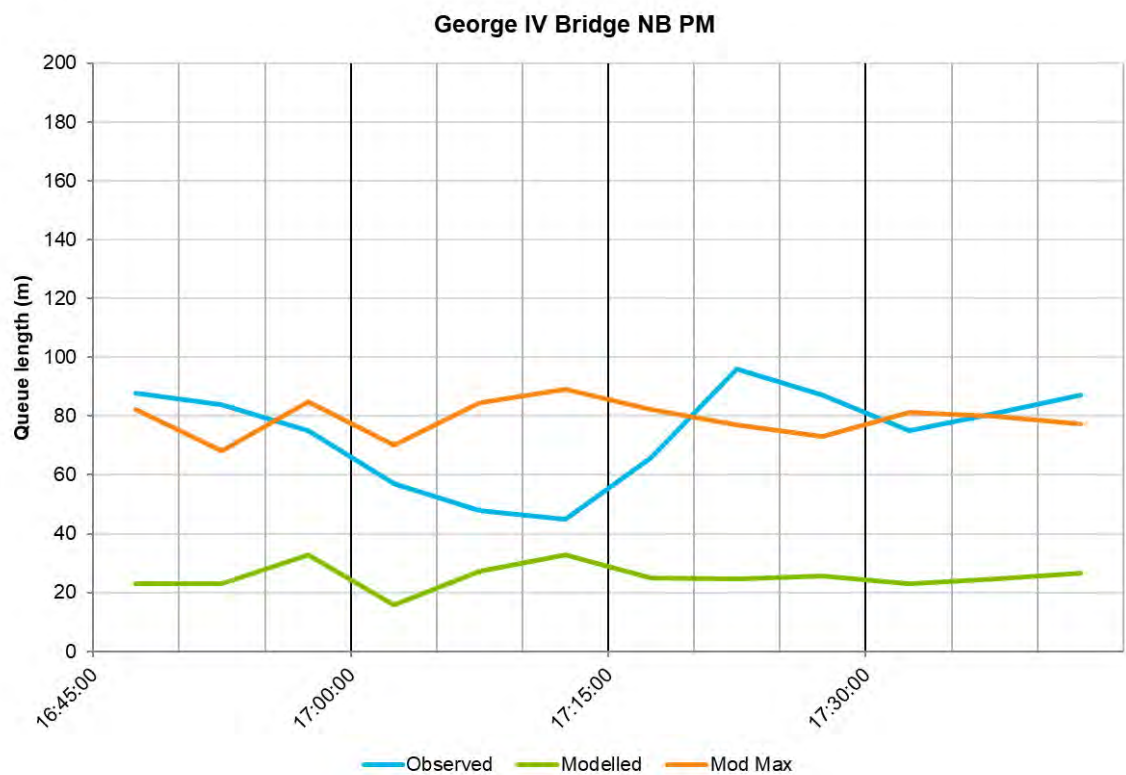


Figure 75: Queue Length Comparison – George IV Bridge / Royal Mile NB PM

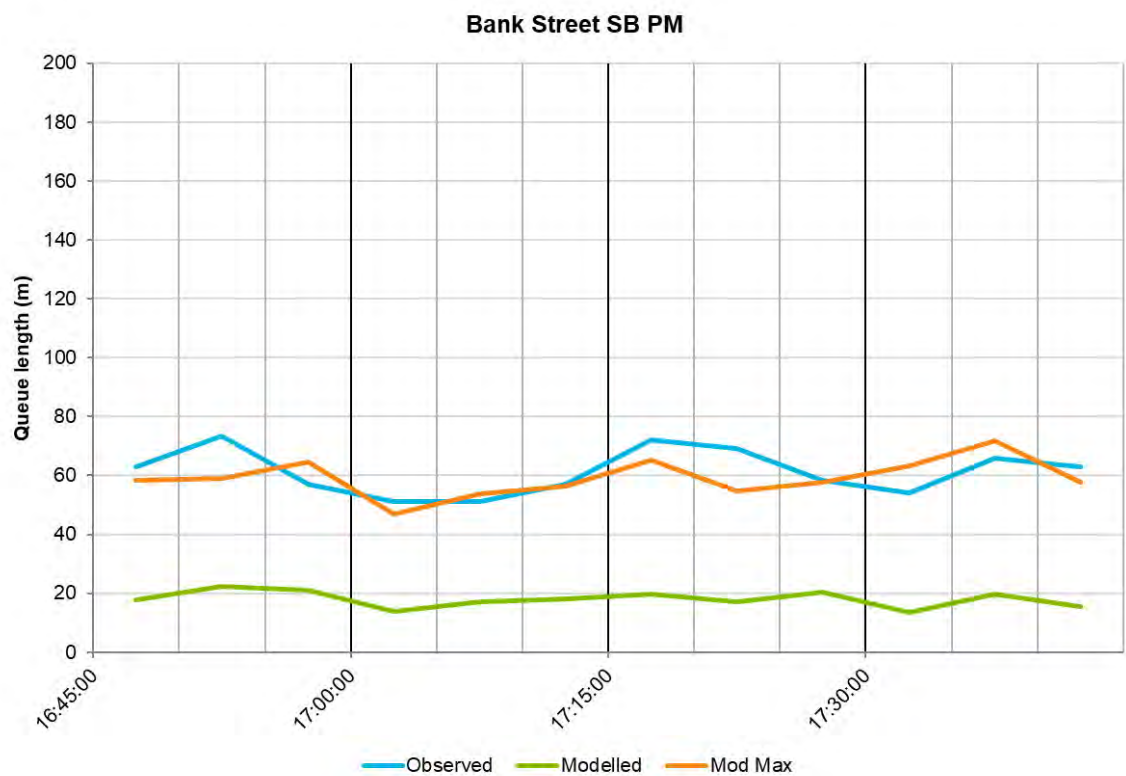


Figure 76: Queue Length Comparison – Bank Street / Royal Mile SB PM

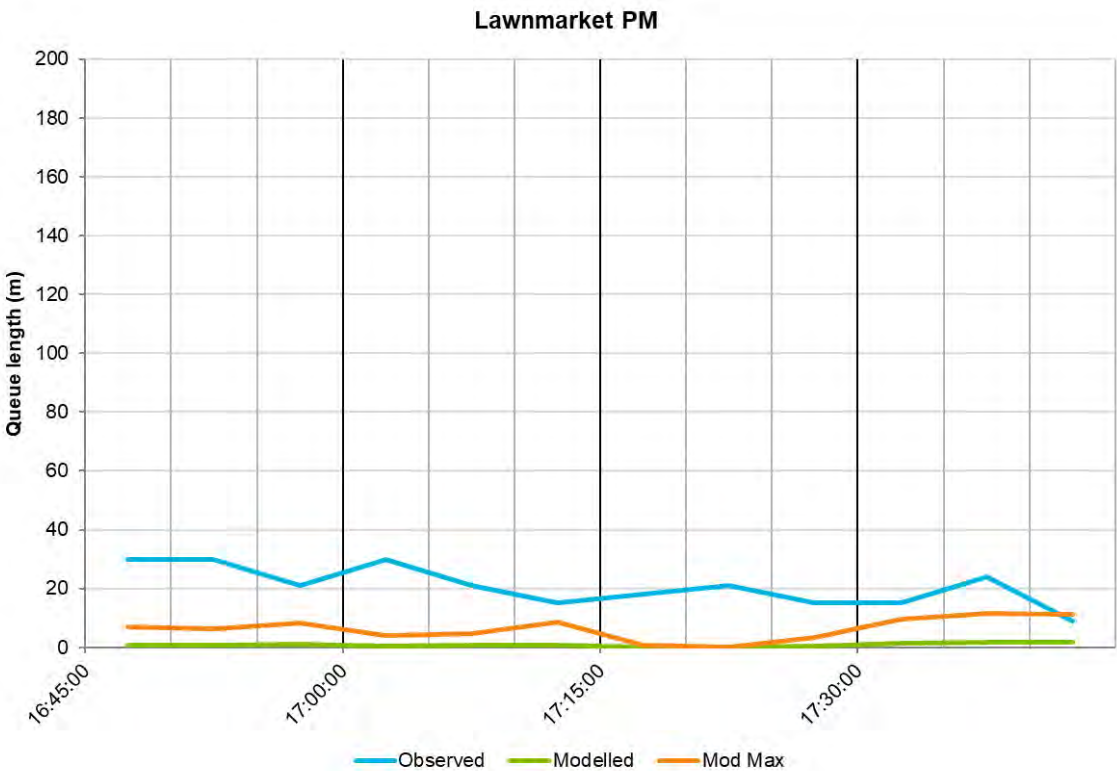


Figure 77: Queue Length Comparison – Lawnmarket / George IV Bridge PM

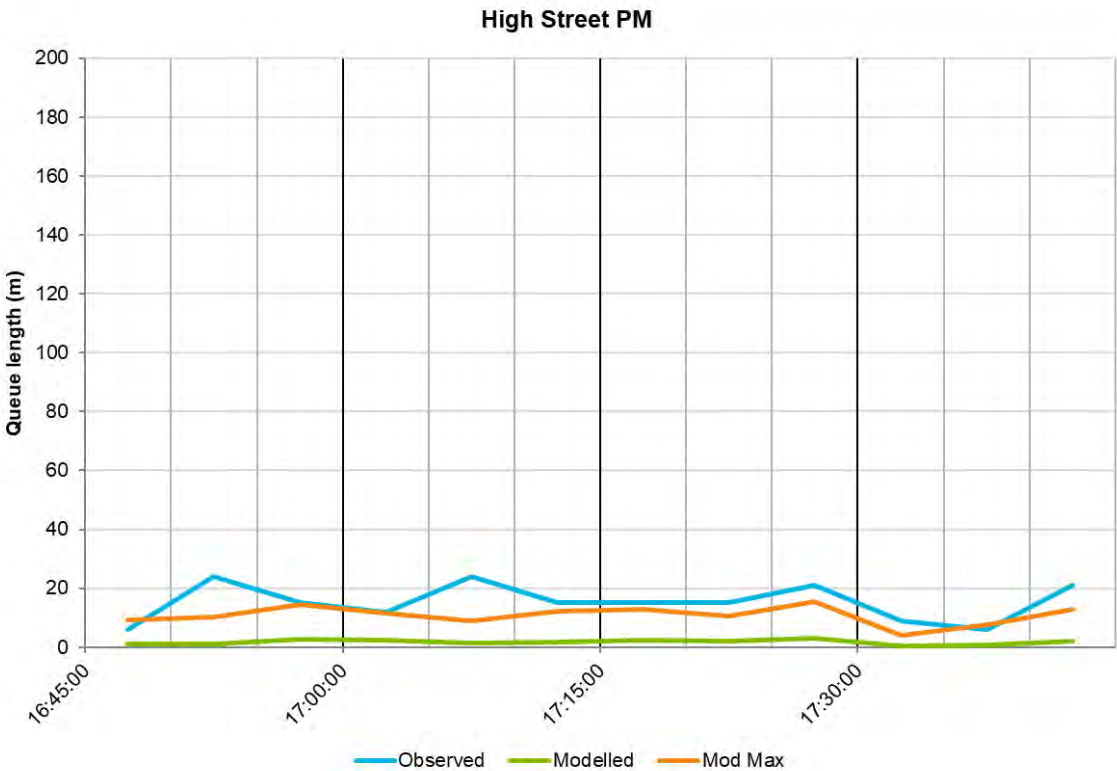


Figure 78: Queue Length Comparison – High Street / George IV Bridge PM

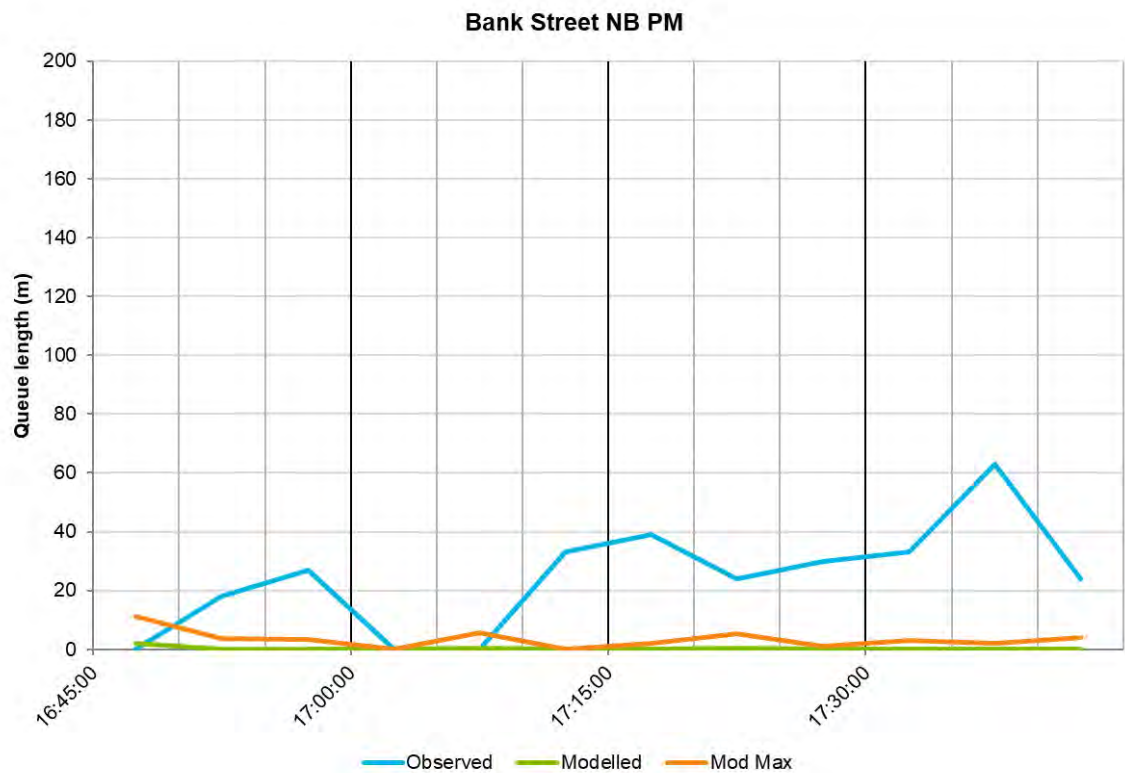


Figure 79: Queue Length Comparison – Bank Street / St Giles Street NB PM

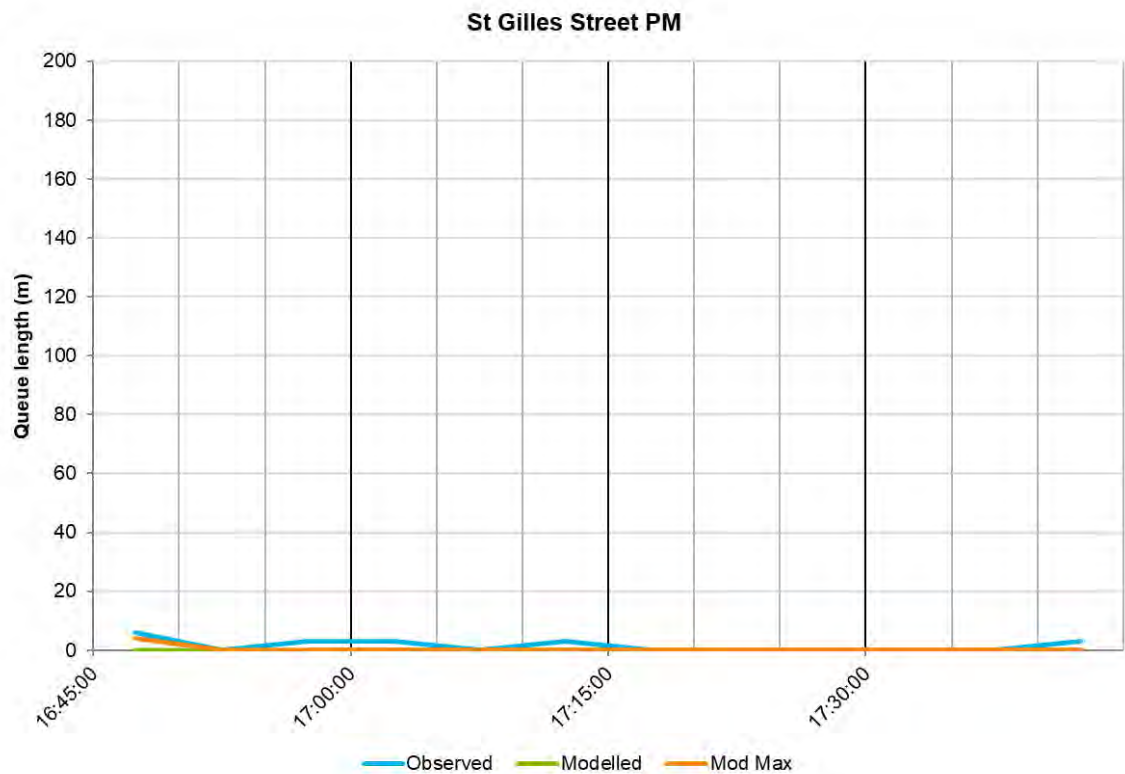


Figure 80: Queue Length Comparison –St Giles Street / Bank Street PM

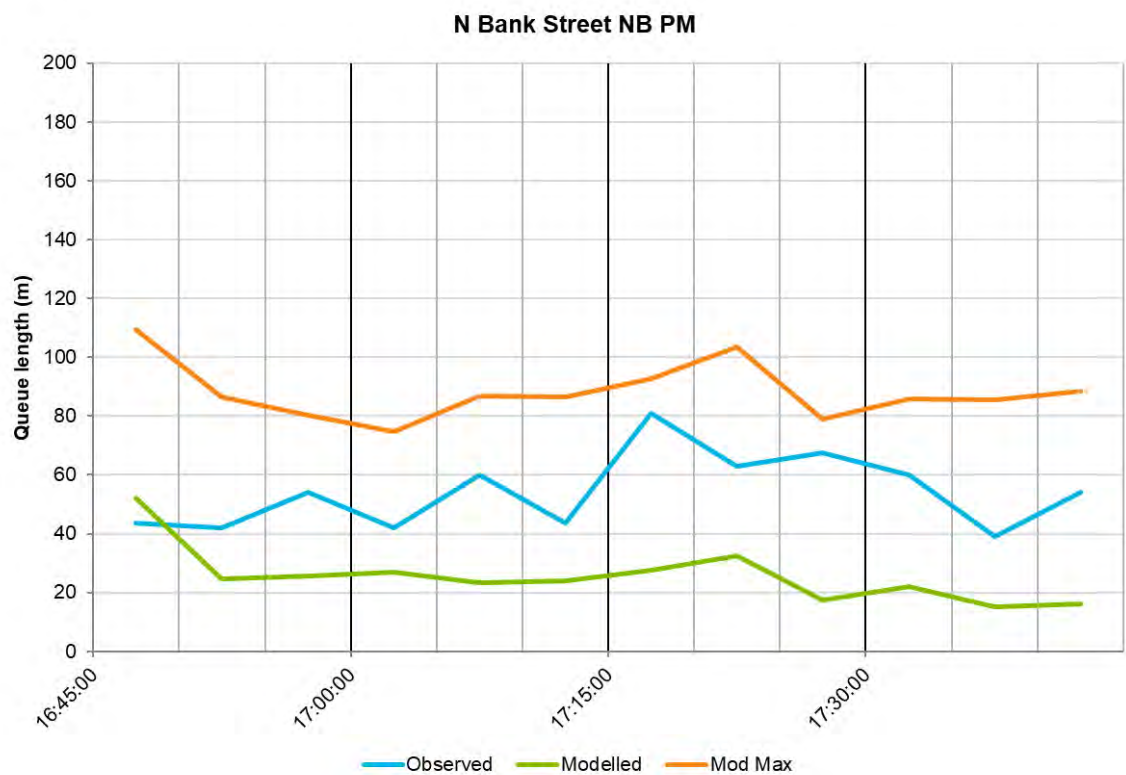


Figure 81: Queue Length Comparison –N Bank Street / Market Street NB PM

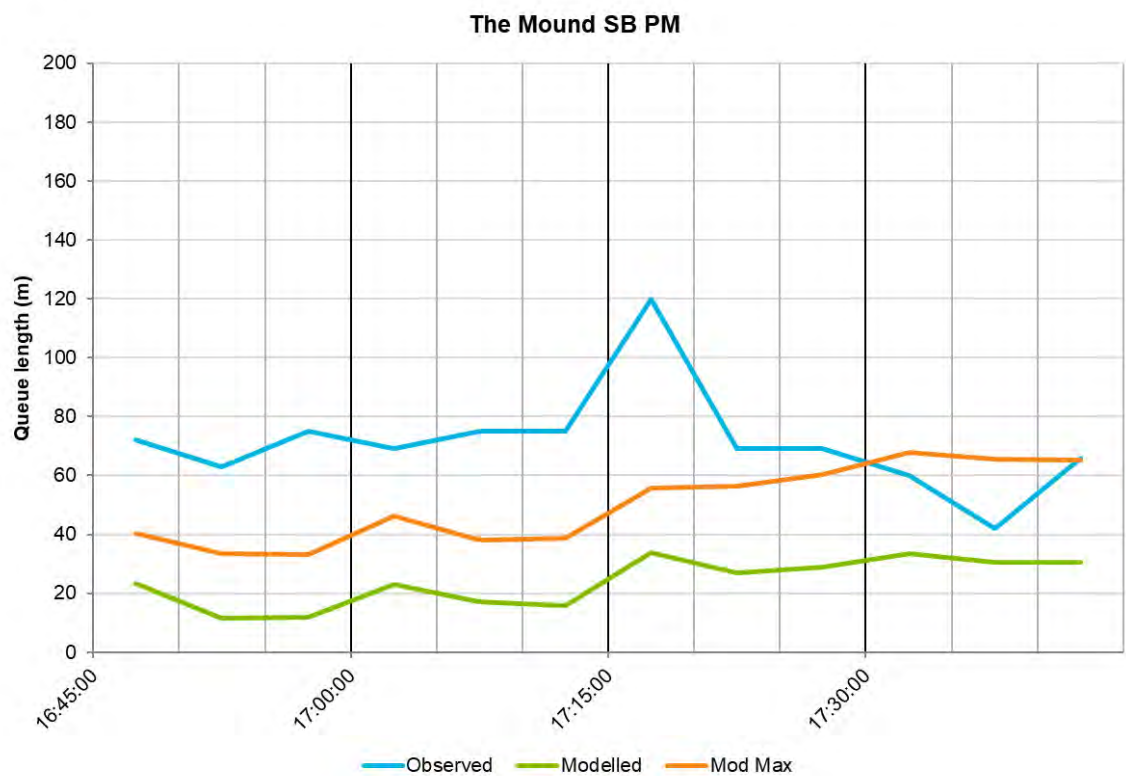


Figure 82: Queue Length Comparison –The Mound / Market Street SB PM

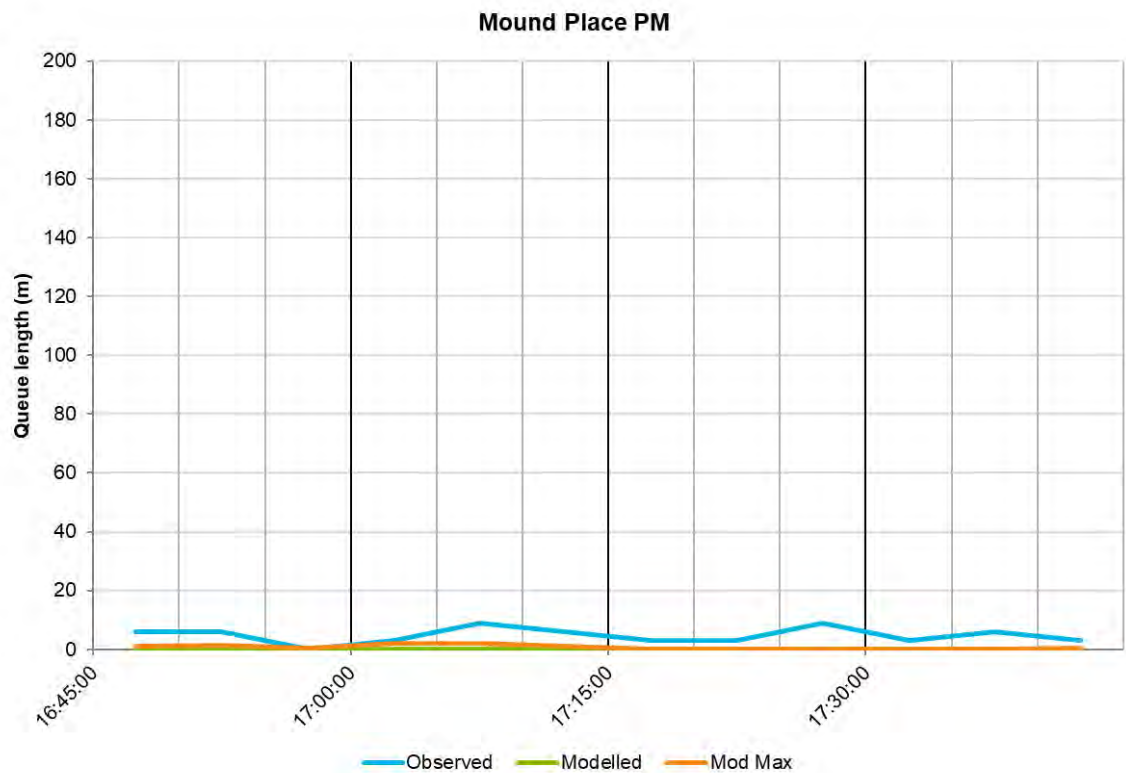


Figure 83: Queue Length Comparison –Mound Place / Market Street PM

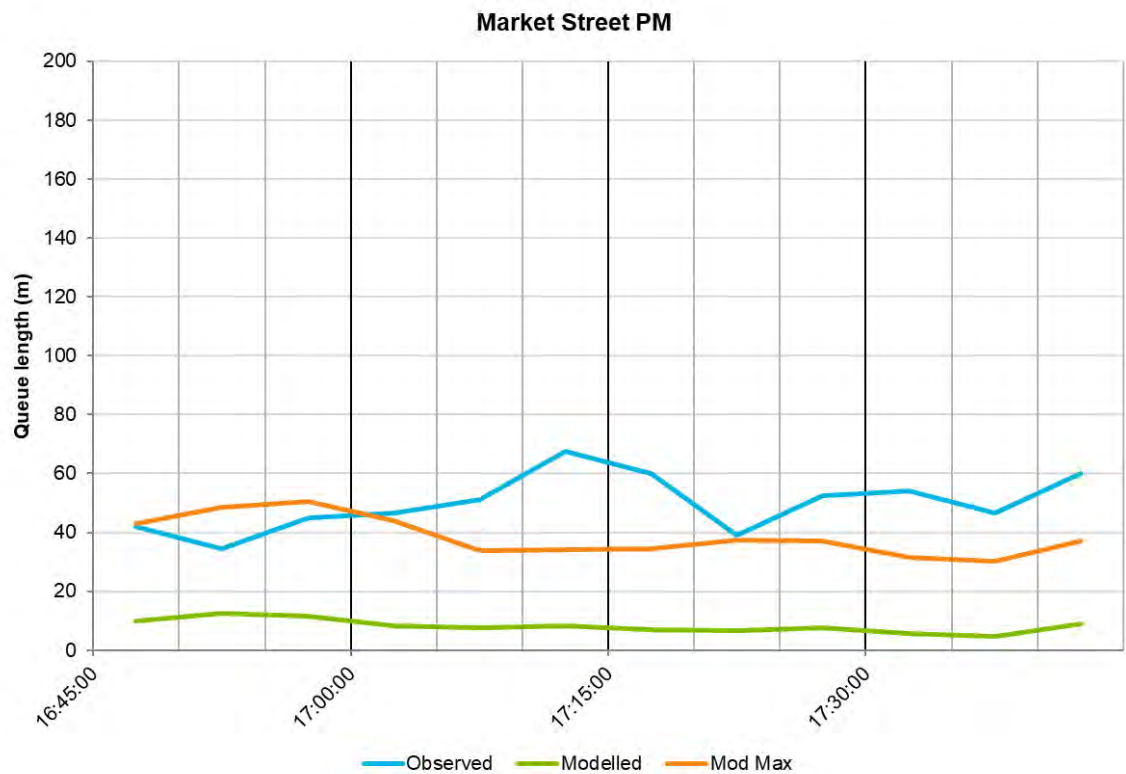


Figure 84: Queue Length Comparison –Market Street / Mound Place PM

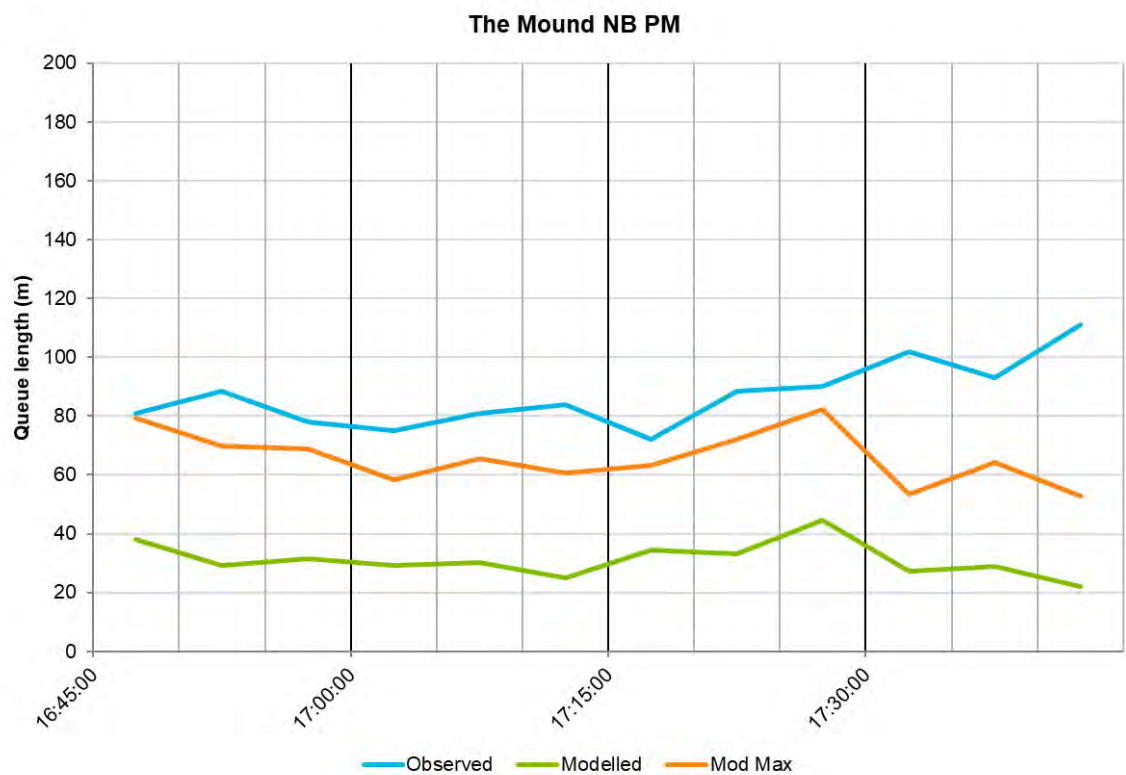


Figure 85: Queue Length Comparison –The Mound / Princes Street PM

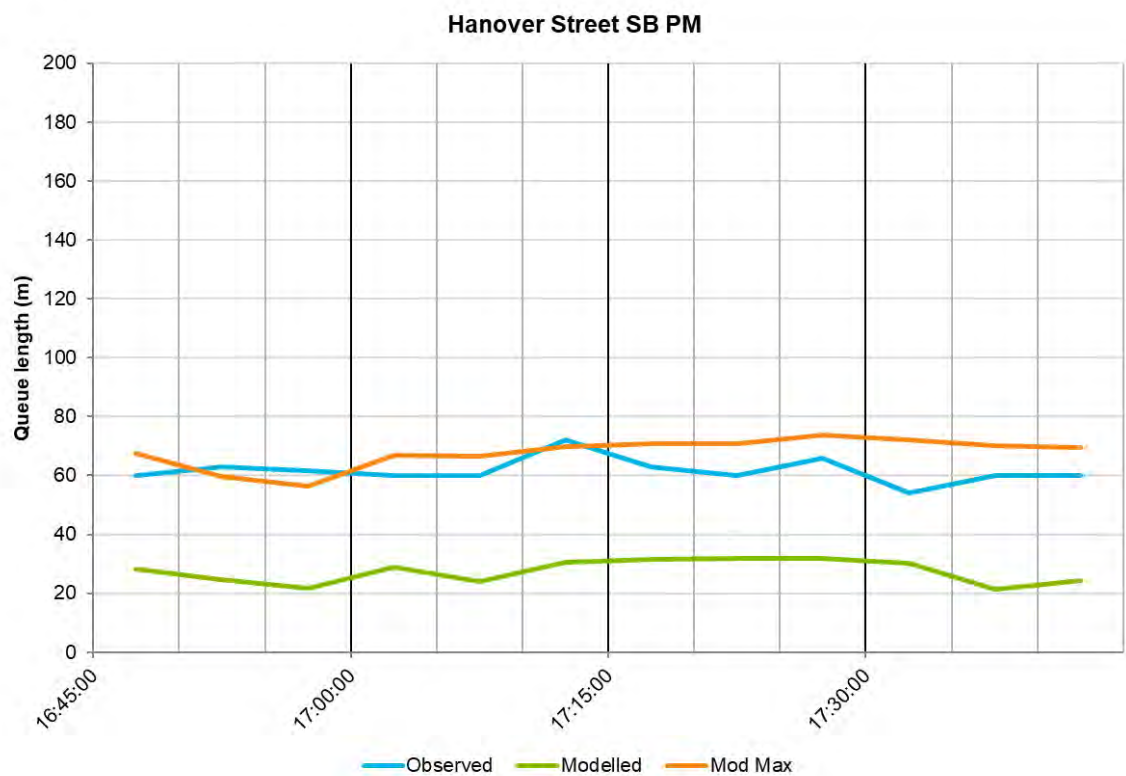


Figure 86: Queue Length Comparison –Hanover Street / Princes Street SB PM

Appendix C : Journey Times

C.1 Route 1 Northbound

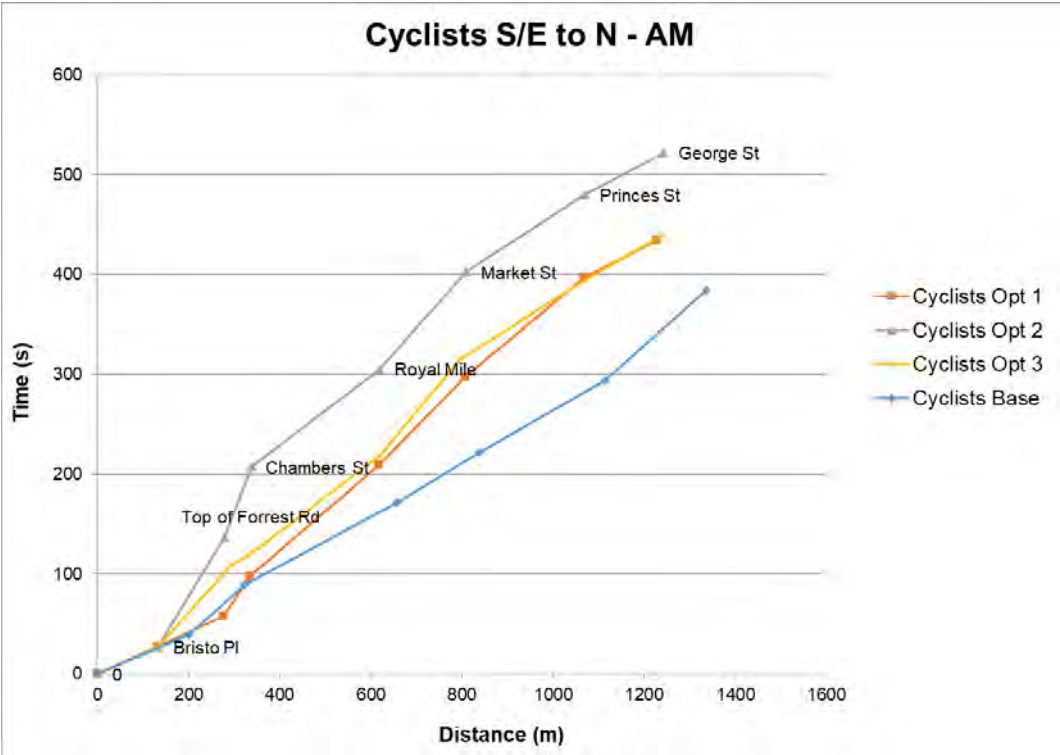


Figure 87: Journey Time Cyclists NB (AM Peak)

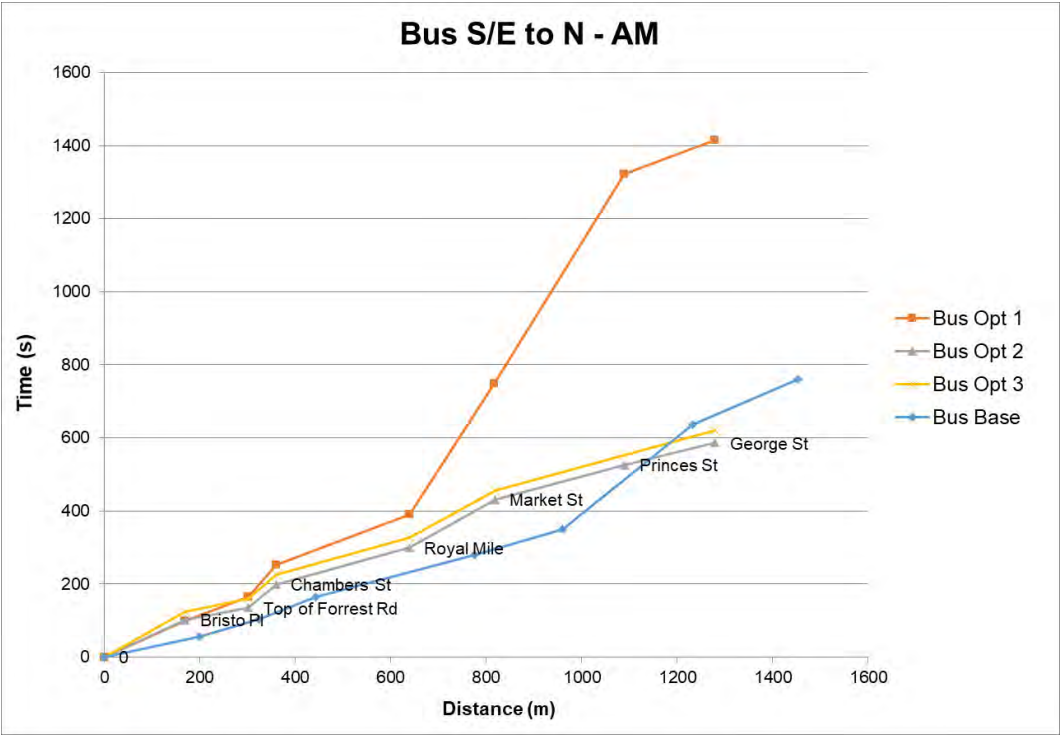


Figure 88: Journey Time Buses NB (AM Peak)

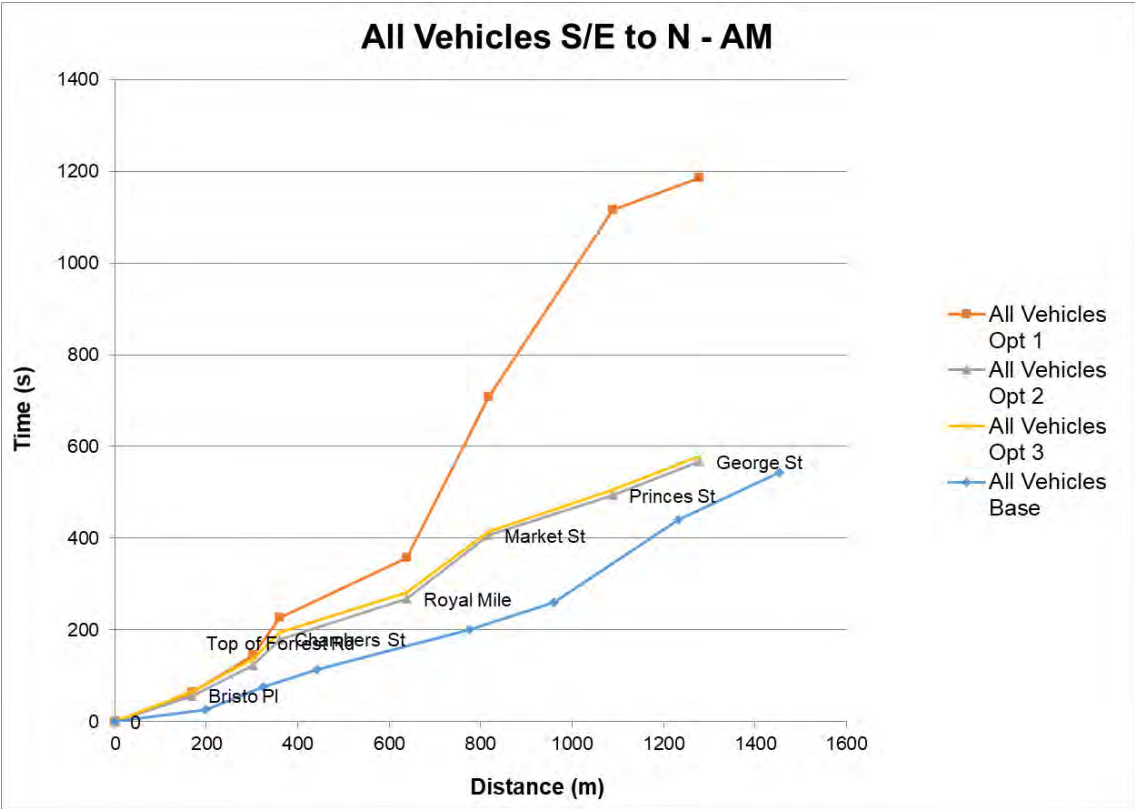


Figure 89: Journey Time All Vehicles NB (AM Peak)

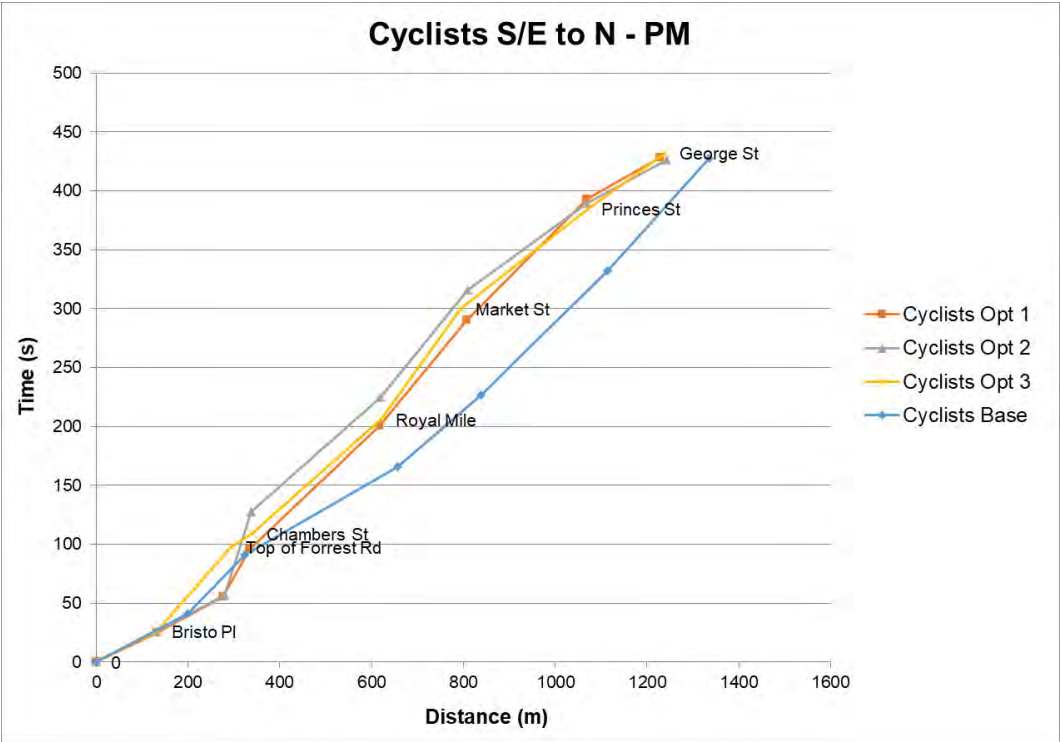


Figure 90: Journey Time Cyclists NB (PM Peak)

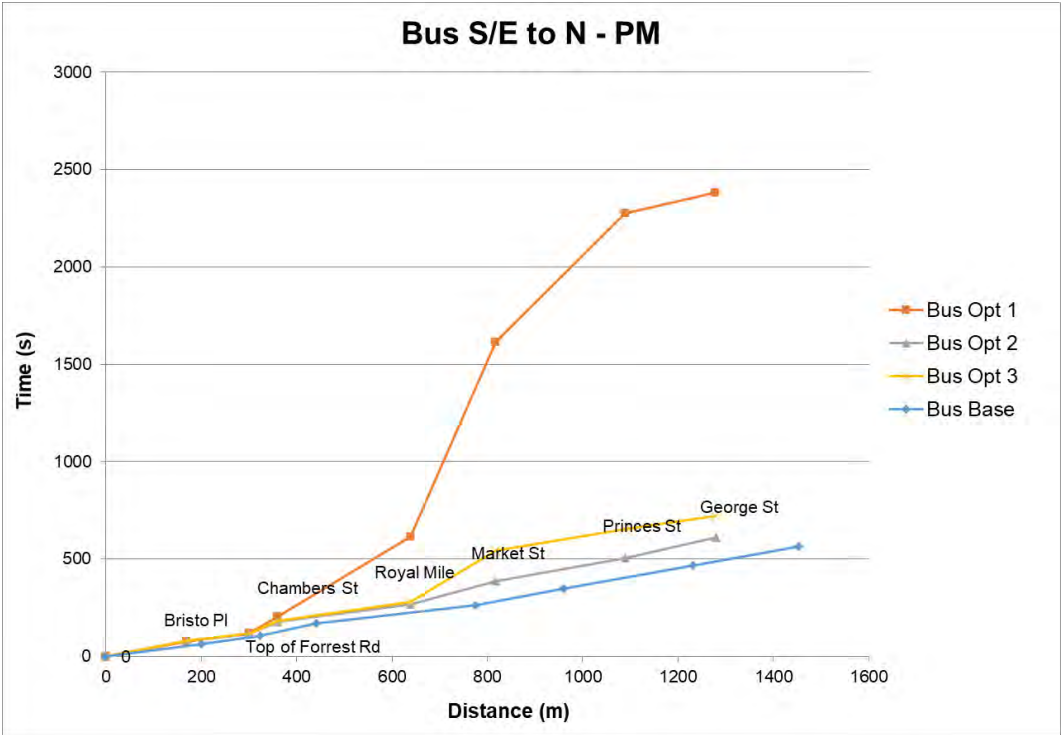


Figure 91: Journey Time Buses NB (PM Peak)

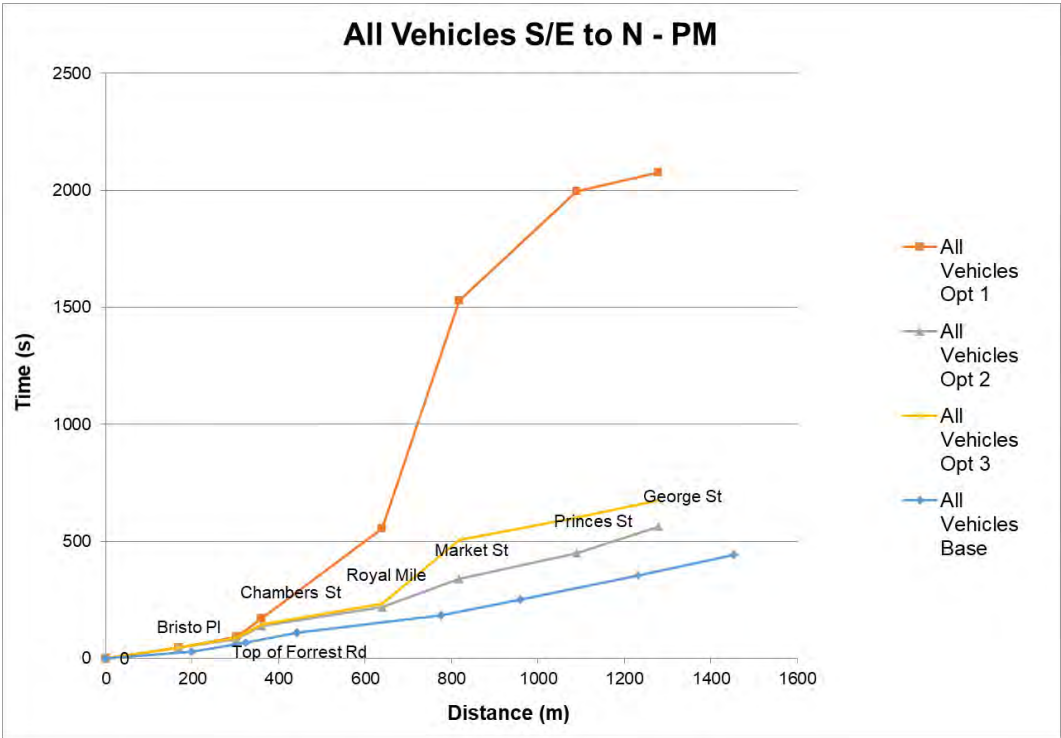


Figure 92: Journey Time All Vehicles NB (PM Peak)

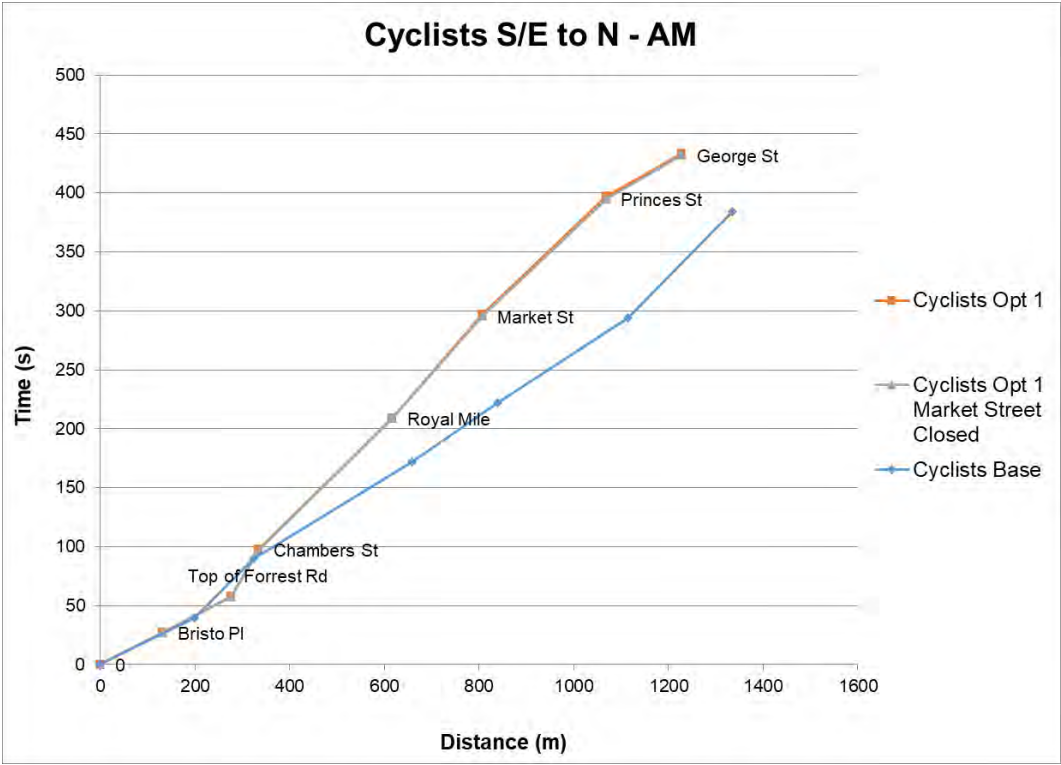


Figure 93: Journey Time Cyclists NB (AM Peak)

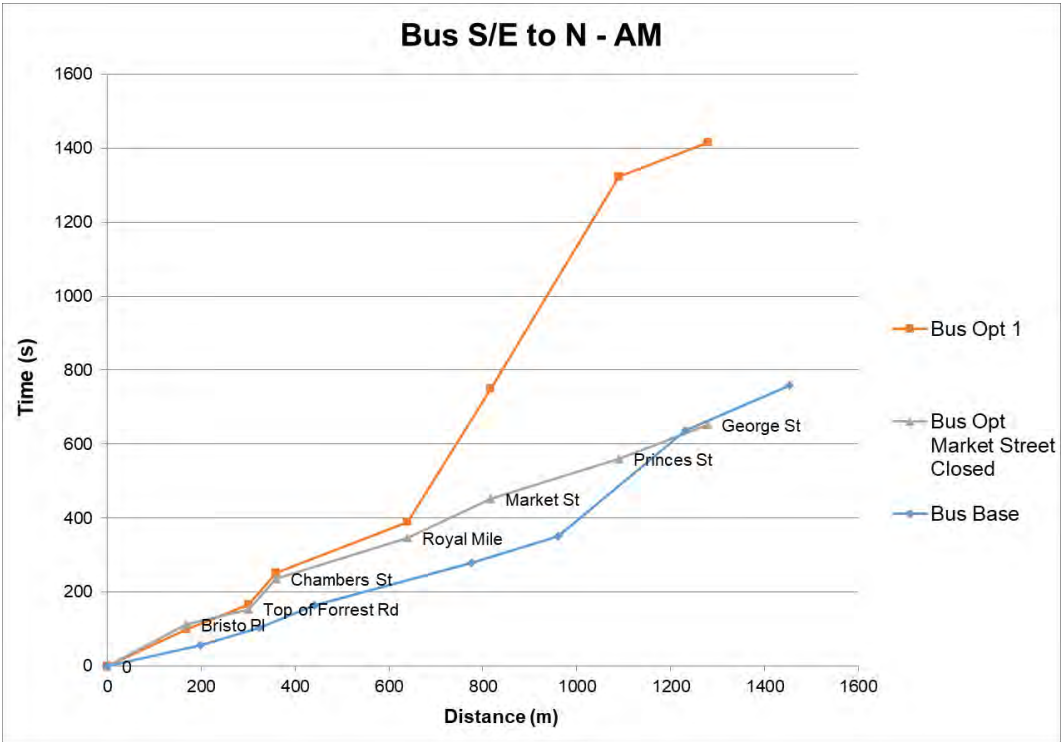


Figure 94: Journey Time Buses NB (AM Peak)

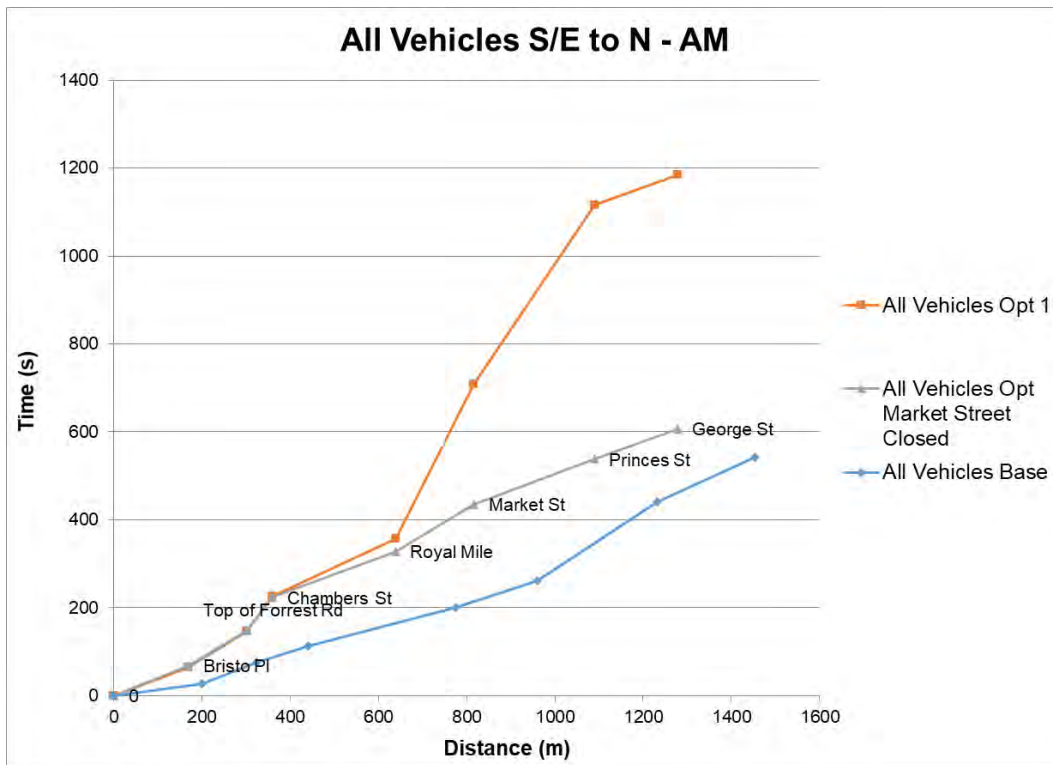


Figure 95: Journey Time All Vehicles NB (AM Peak)

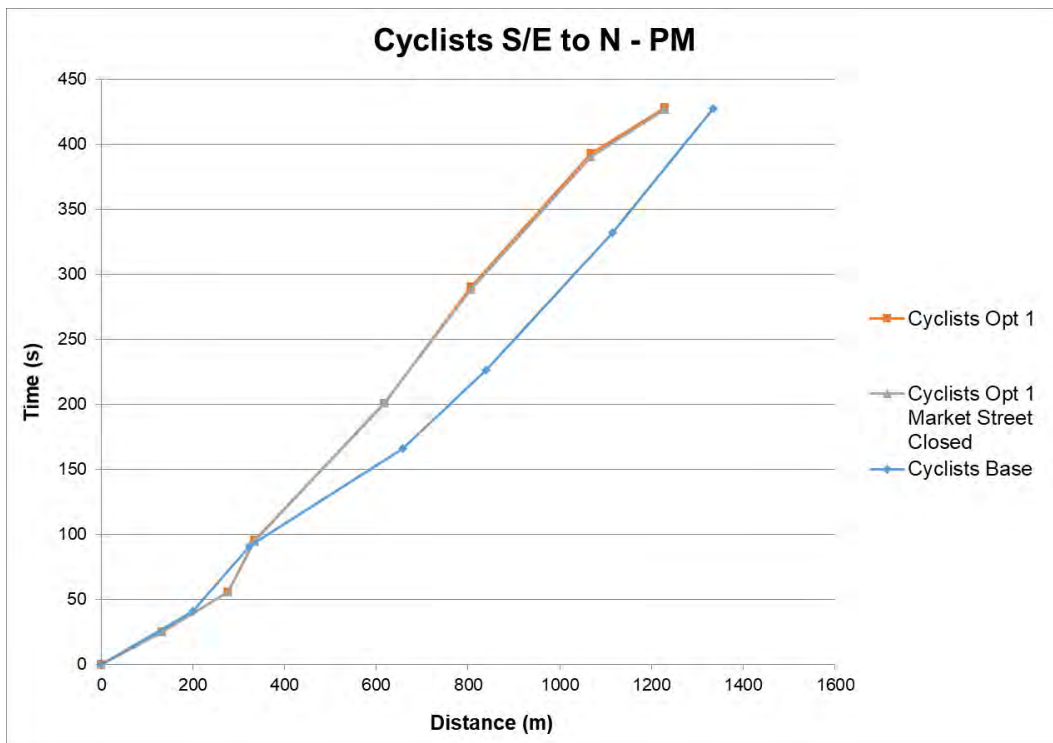


Figure 96: Journey Time Cyclists NB (PM Peak)

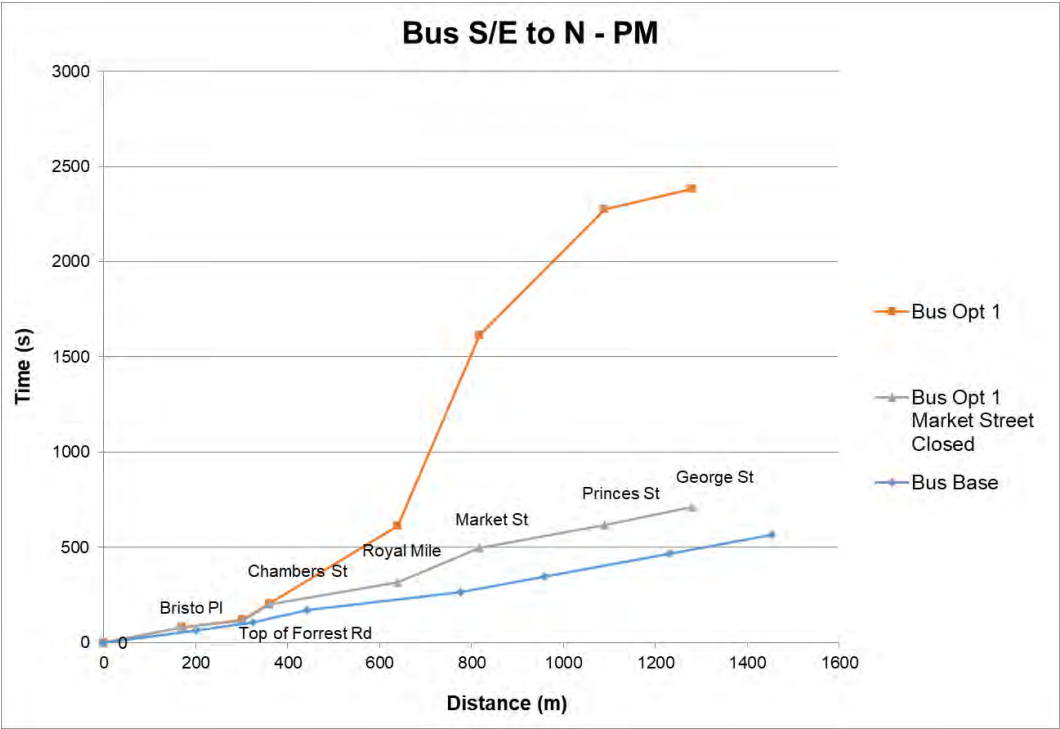


Figure 97: Journey Time Buses NB (PM Peak)

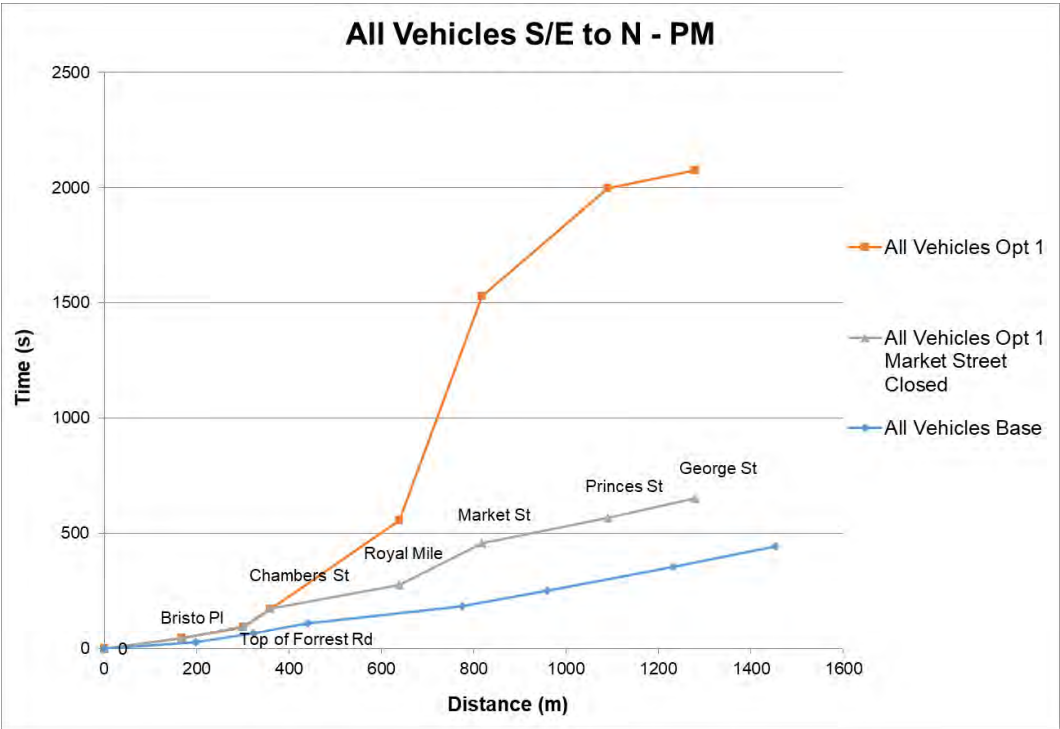


Figure 98: Journey Time All Vehicles NB (PM Peak)

C.2 Route 1 Southbound

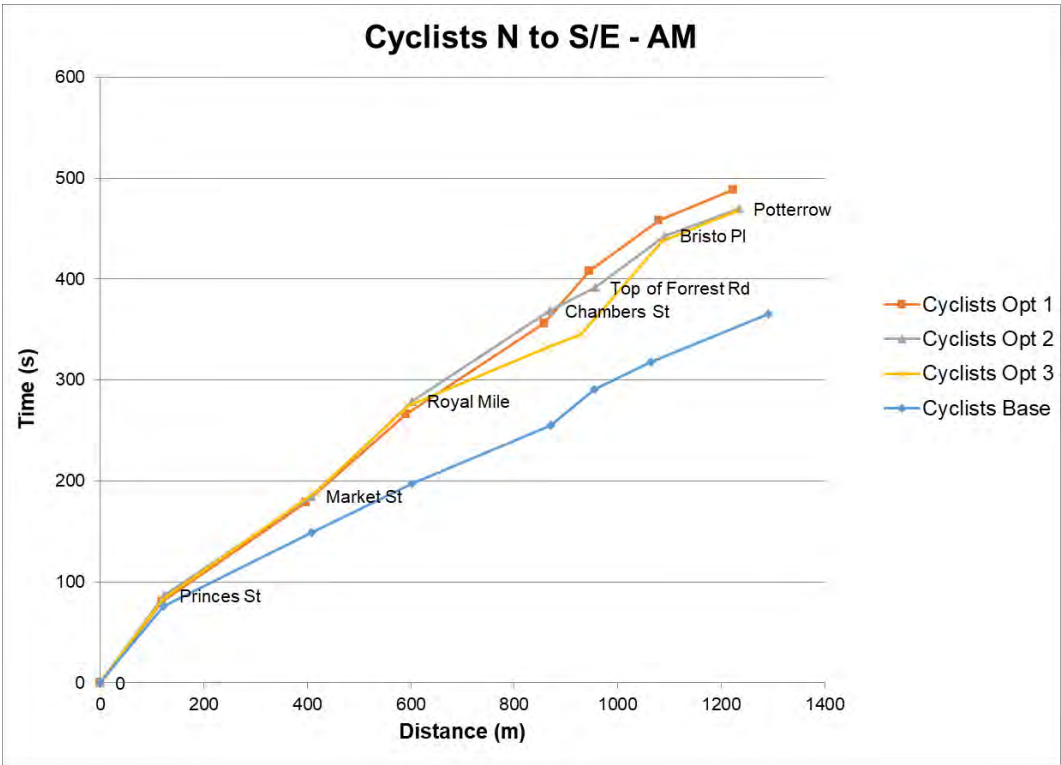


Figure 99: Journey Time Cyclists SB (AM Peak)

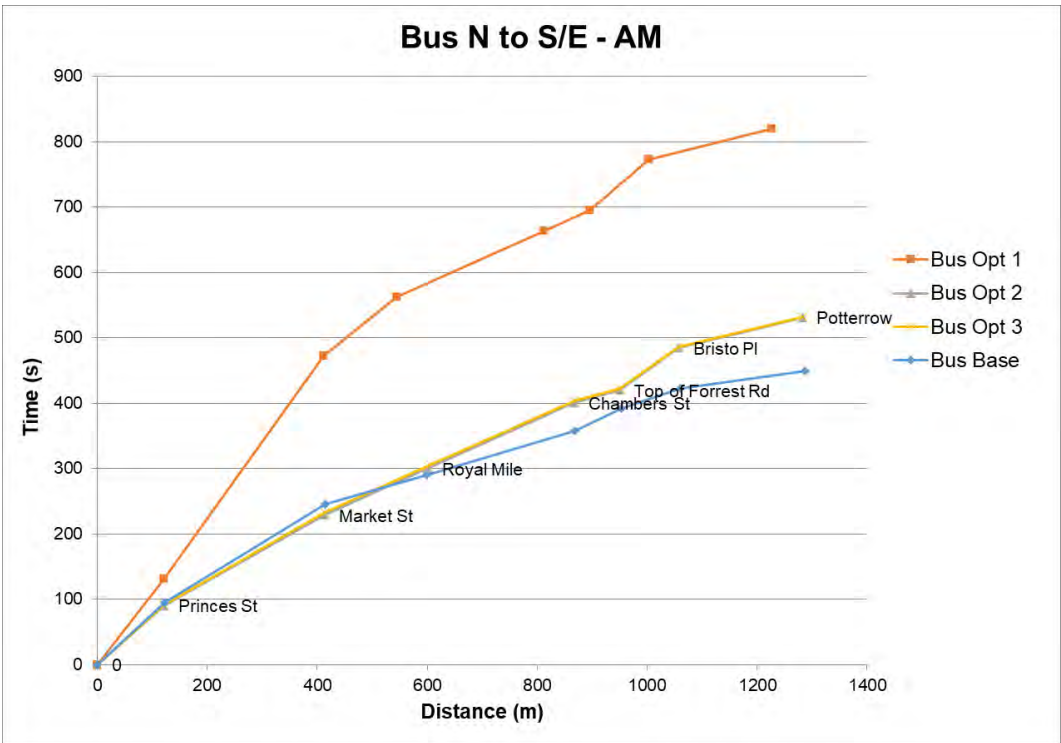


Figure 100 Journey Time Buses SB (AM Peak)

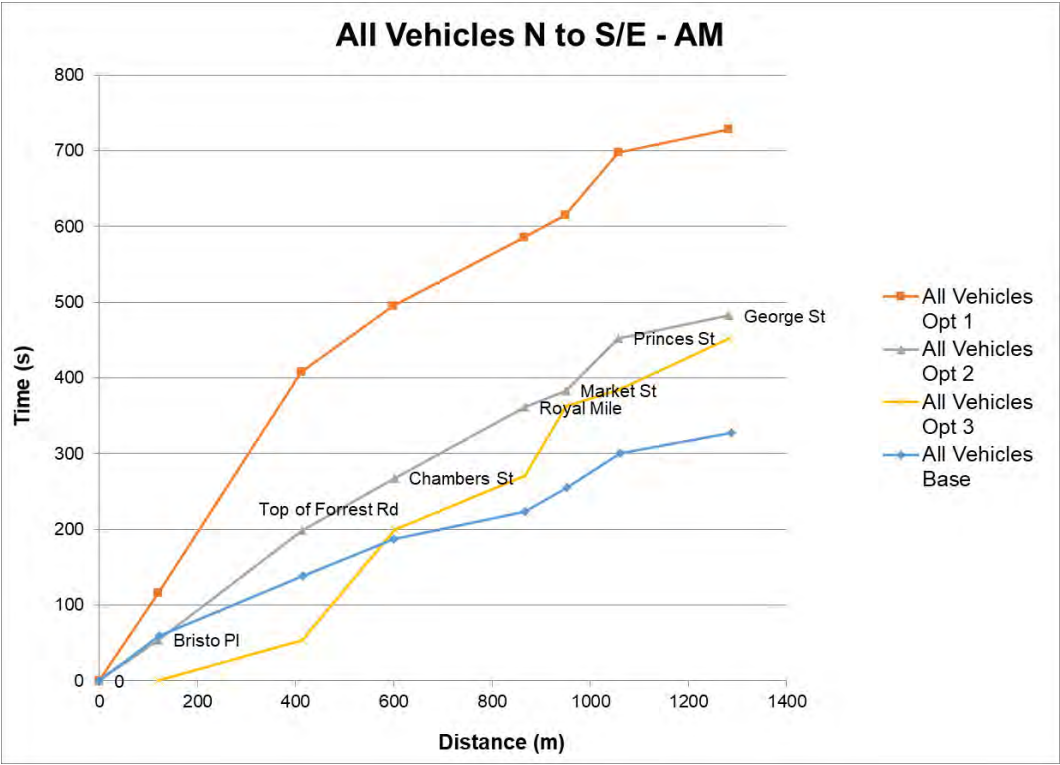


Figure 101: Journey Time All Vehicles SB (AM Peak)

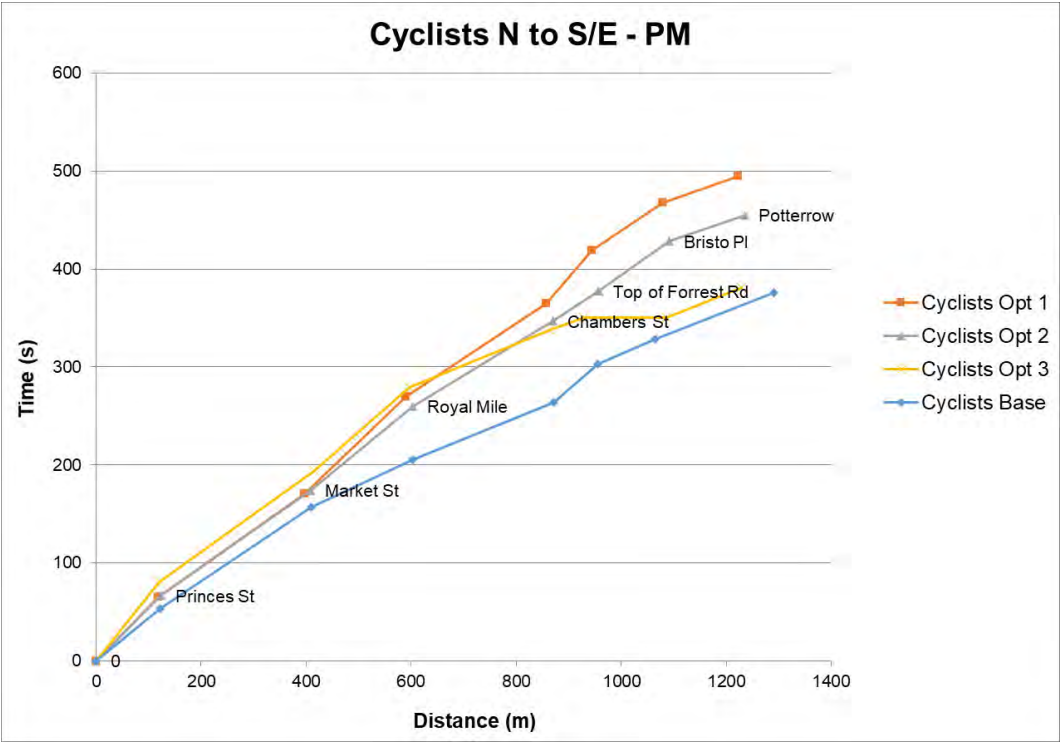


Figure 102: Journey Time Cyclists SB (PM Peak)

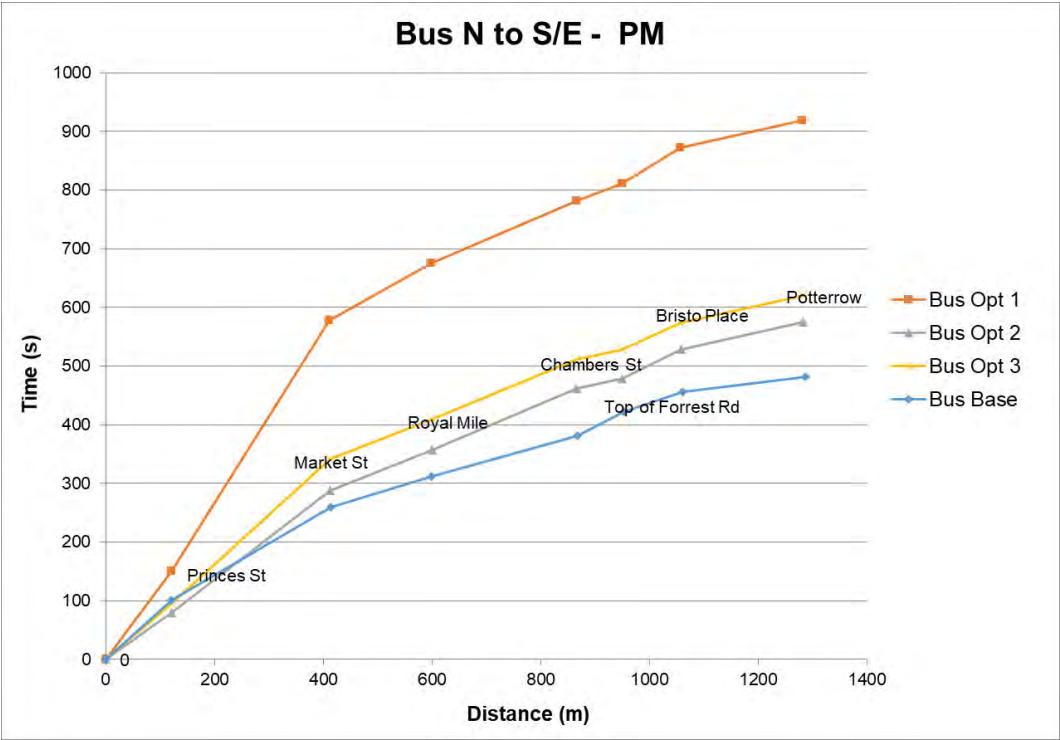


Figure 103: Journey Time Buses SB (PM Peak)

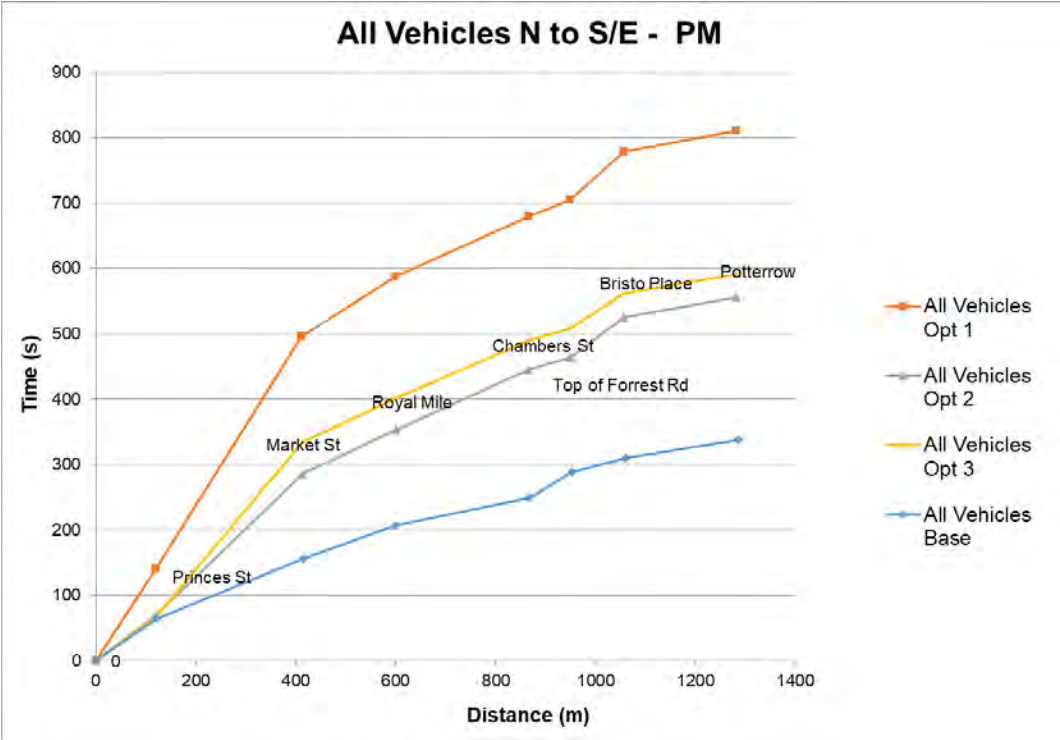


Figure 104: Journey Time All Vehicles SB (PM Peak)

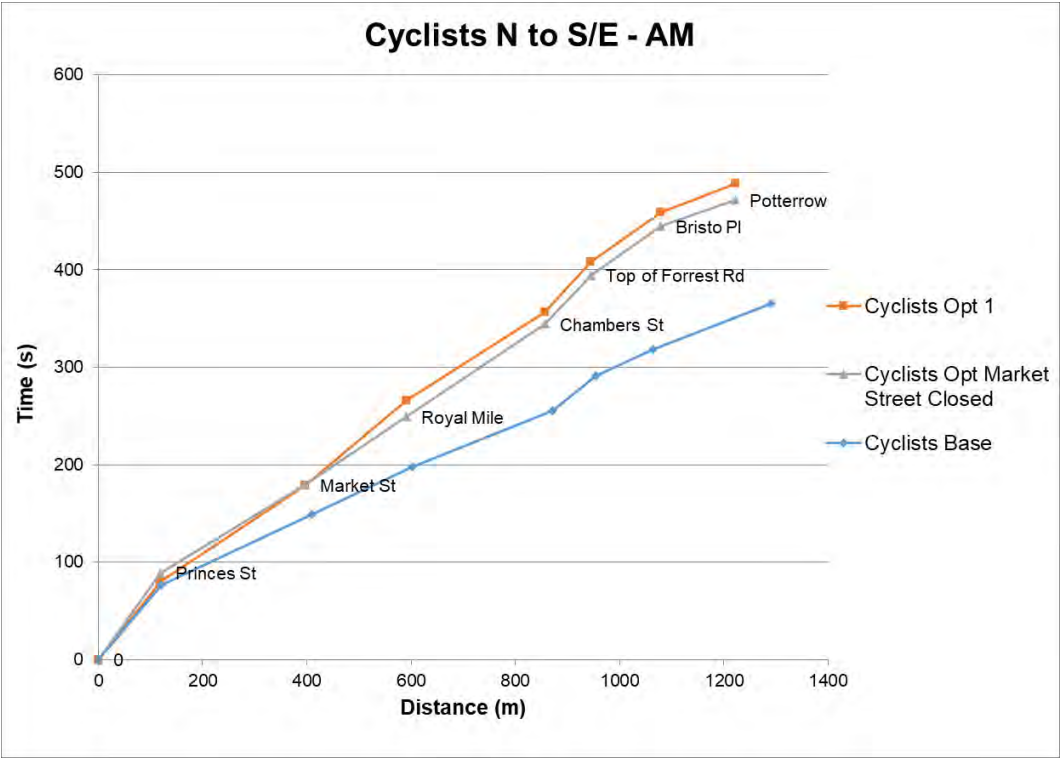


Figure 105: Journey Time Cyclists SB (AM Peak)

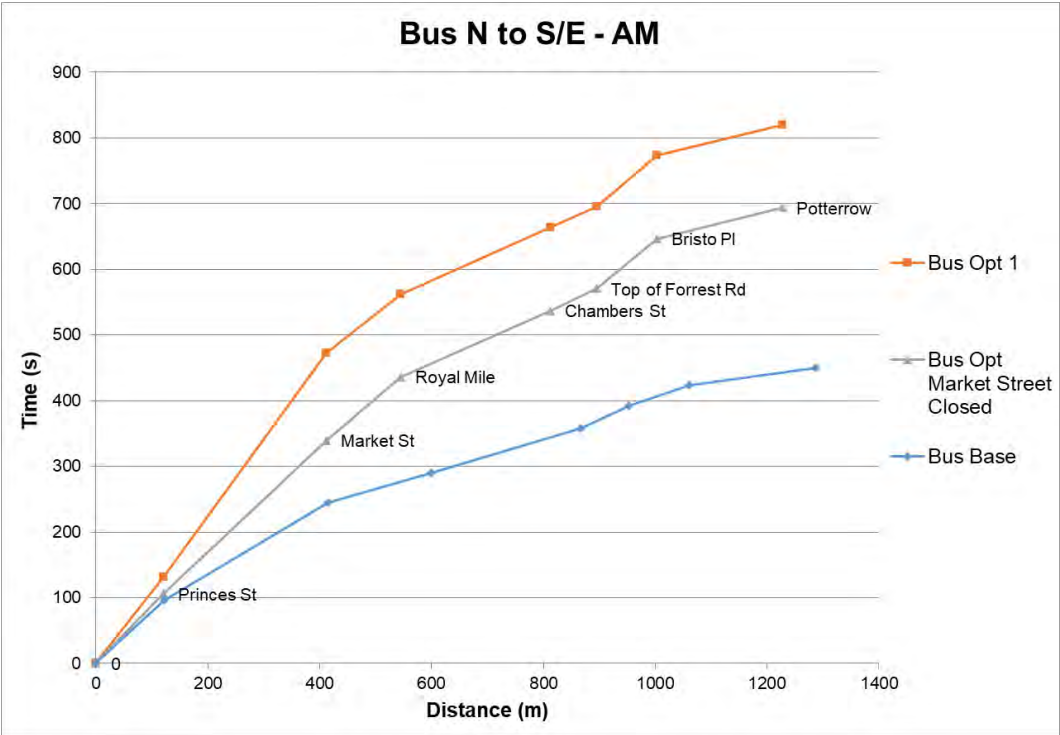


Figure 106: Journey Time Buses SB (AM Peak)

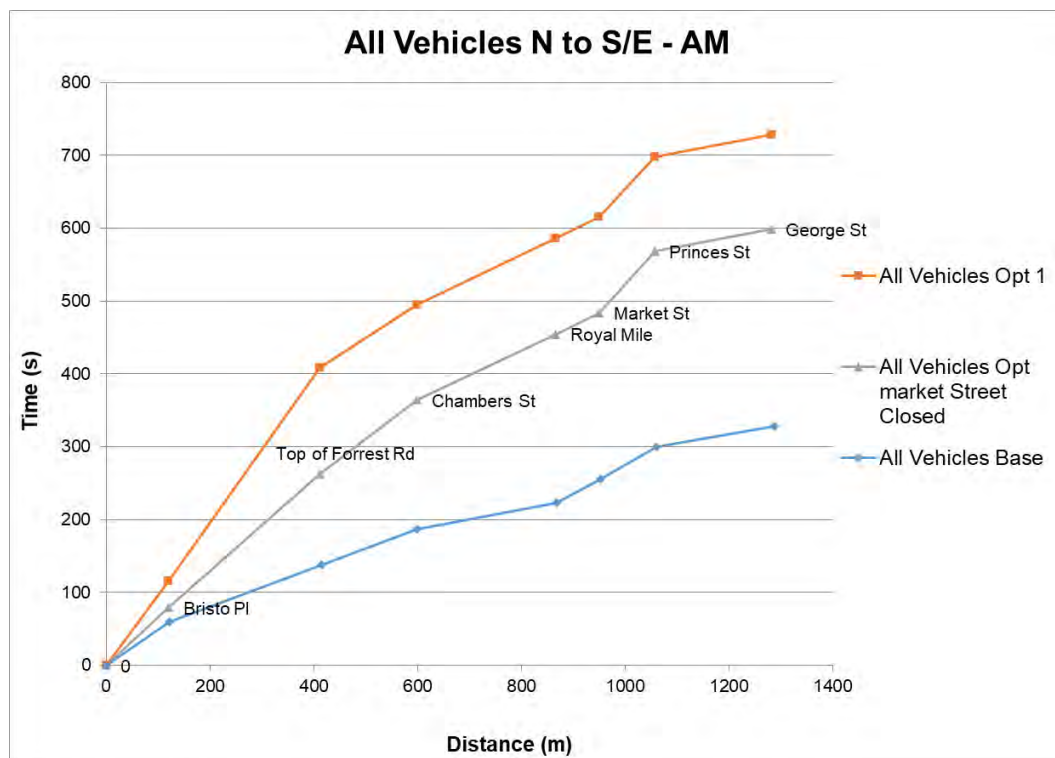


Figure 107: Journey Time All Vehicles SB (AM Peak)

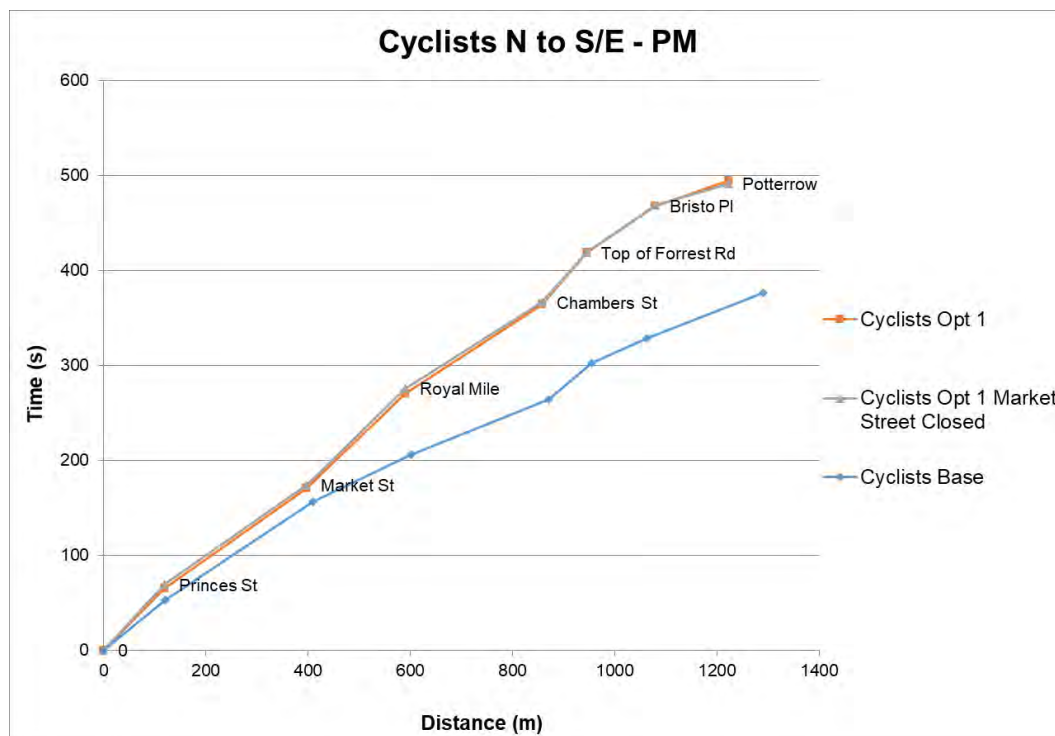


Figure 108: Journey Time Cyclists SB (PM Peak)

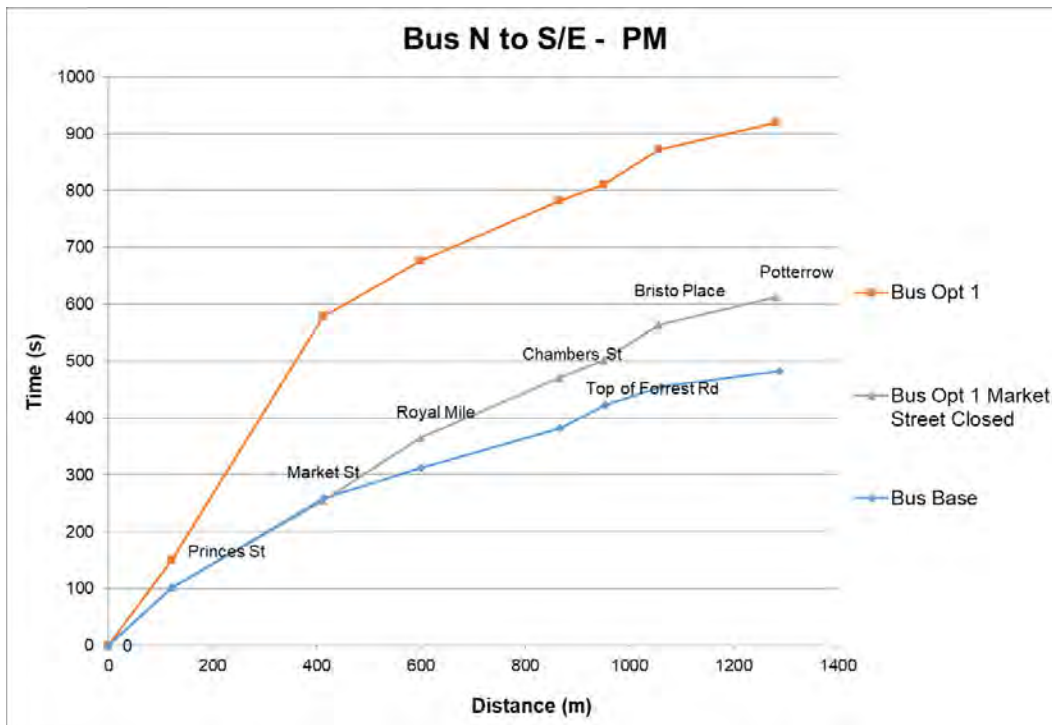


Figure 109: Journey Time Buses SB (PM Peak)

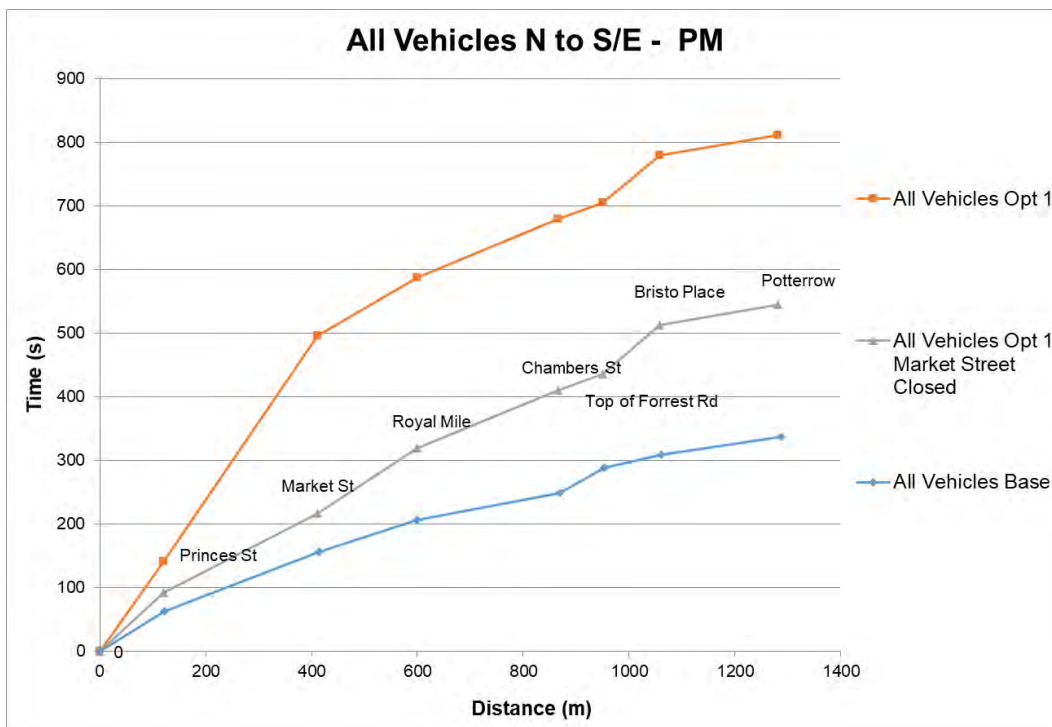


Figure 110: Journey Time All Vehicles SB (PM Peak)

C.3 Route 2 Northbound

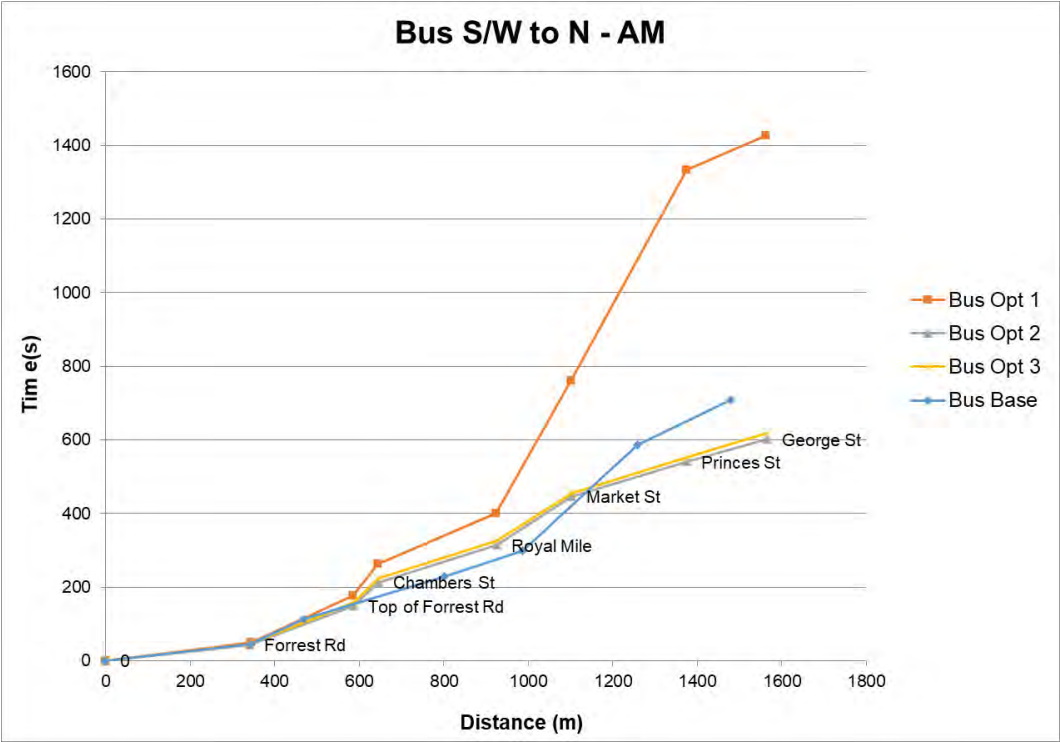


Figure 111: Journey Time Buses NB (AM Peak)

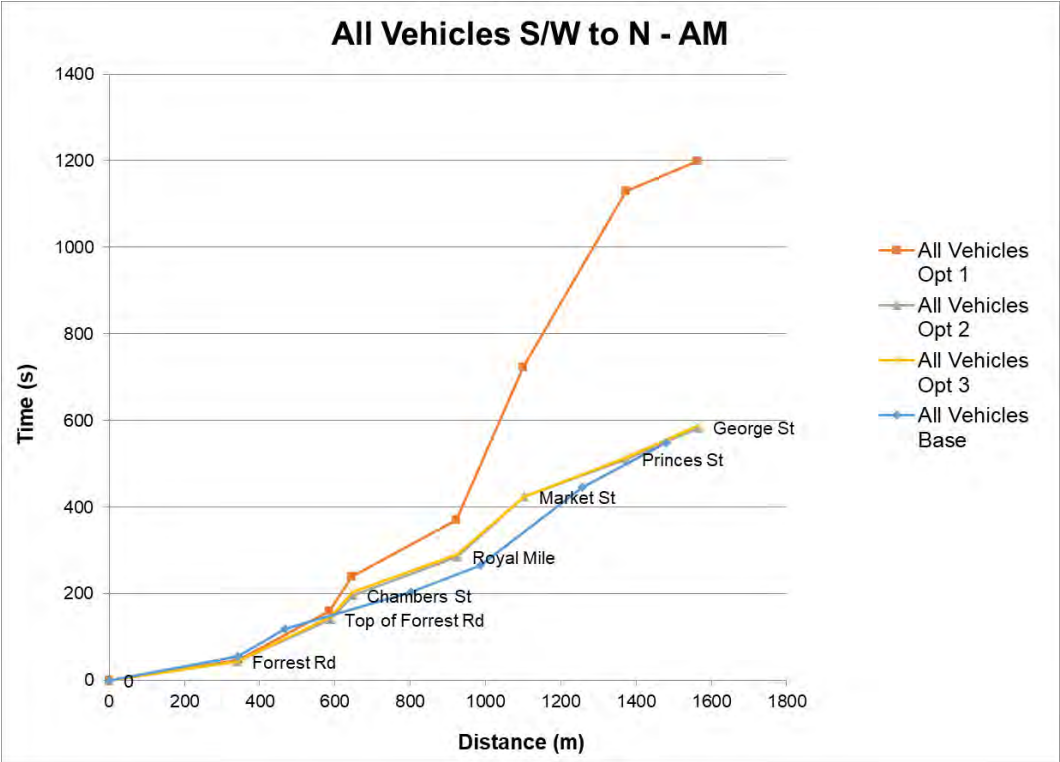


Figure 112: Journey Time All Vehicles NB (AM Peak)

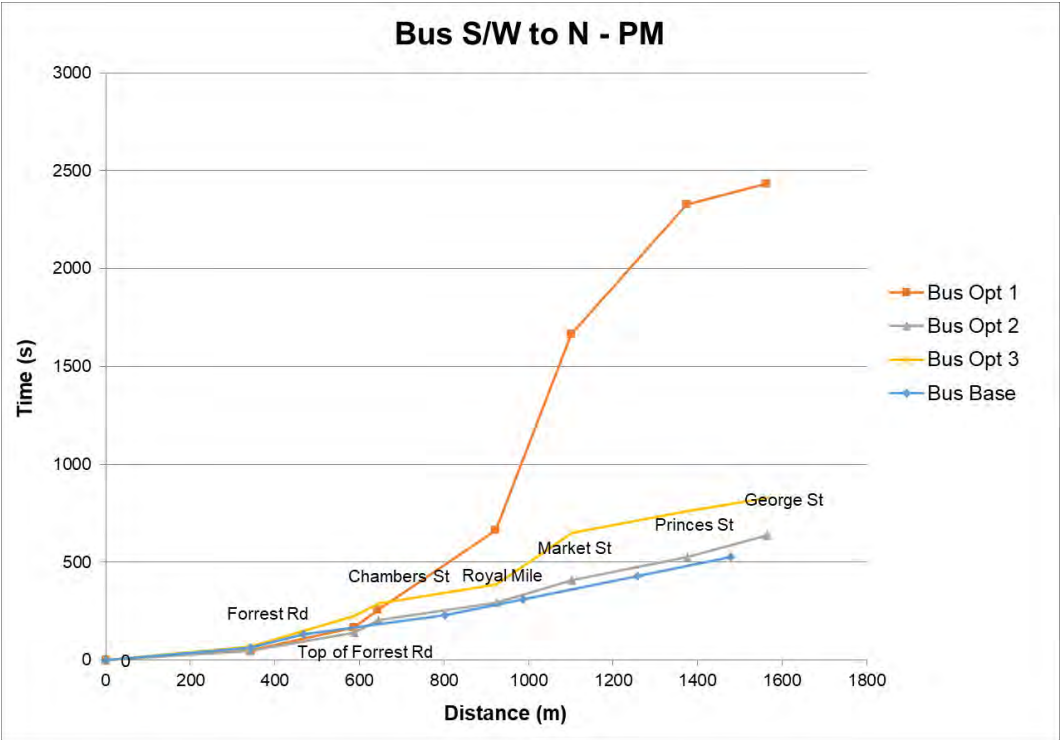


Figure 113: Journey Time Buses NB (PM Peak)

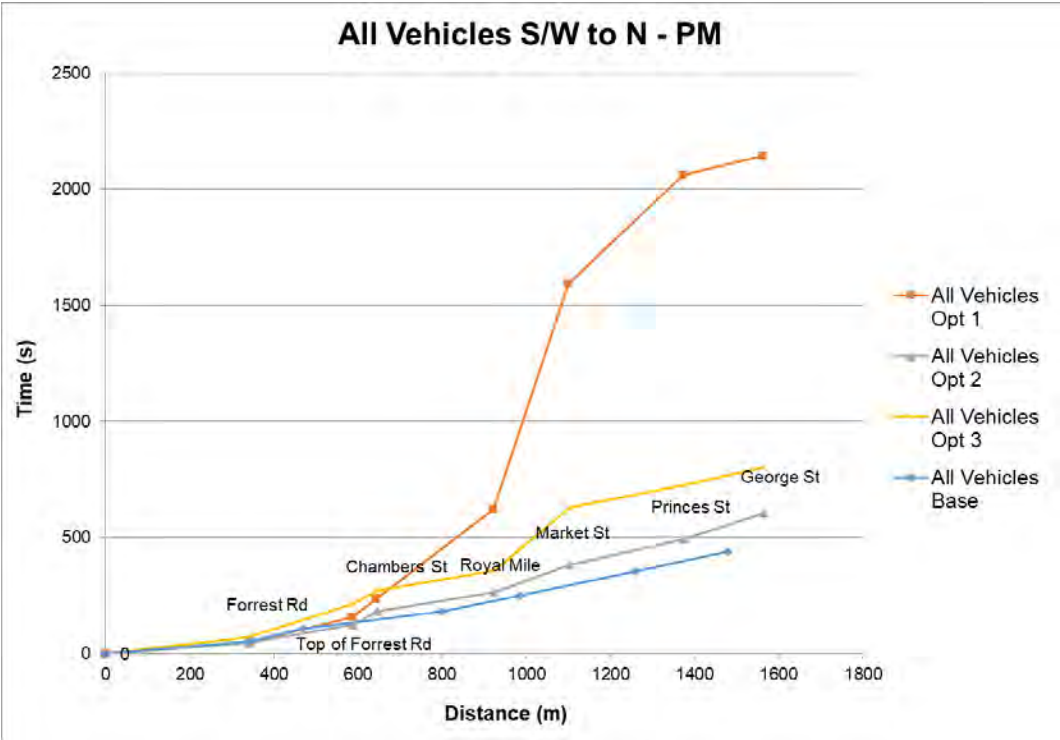


Figure 114: Journey Time All Vehicles NB (PM Peak)

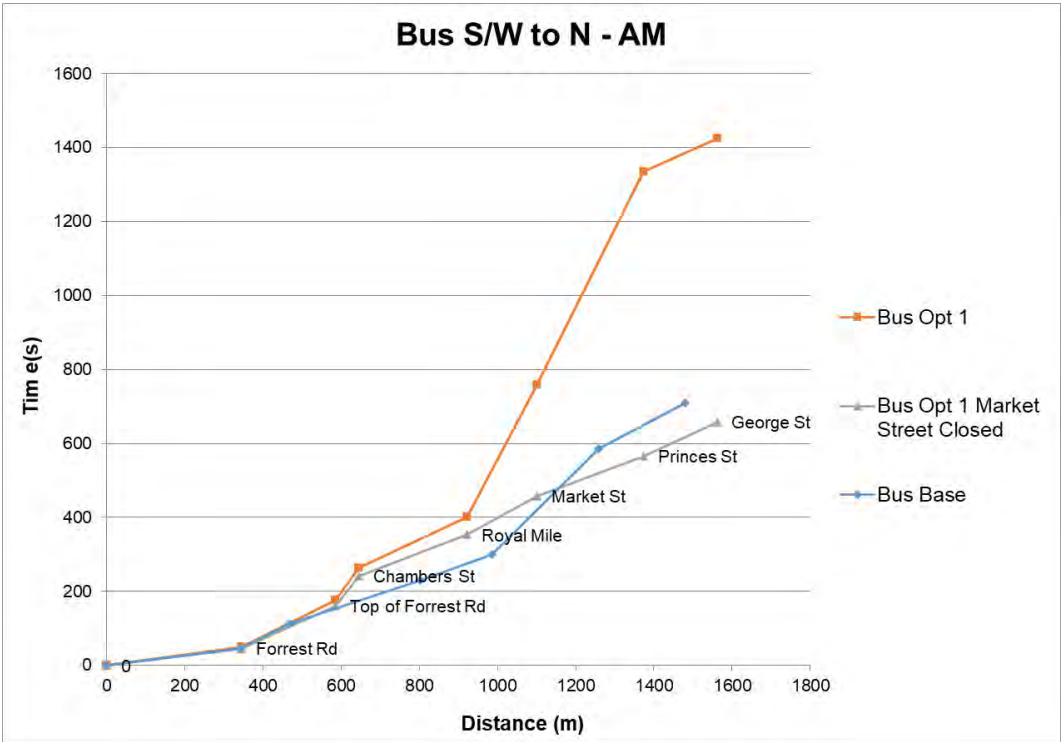


Figure 115: Journey Time Buses NB (AM Peak)

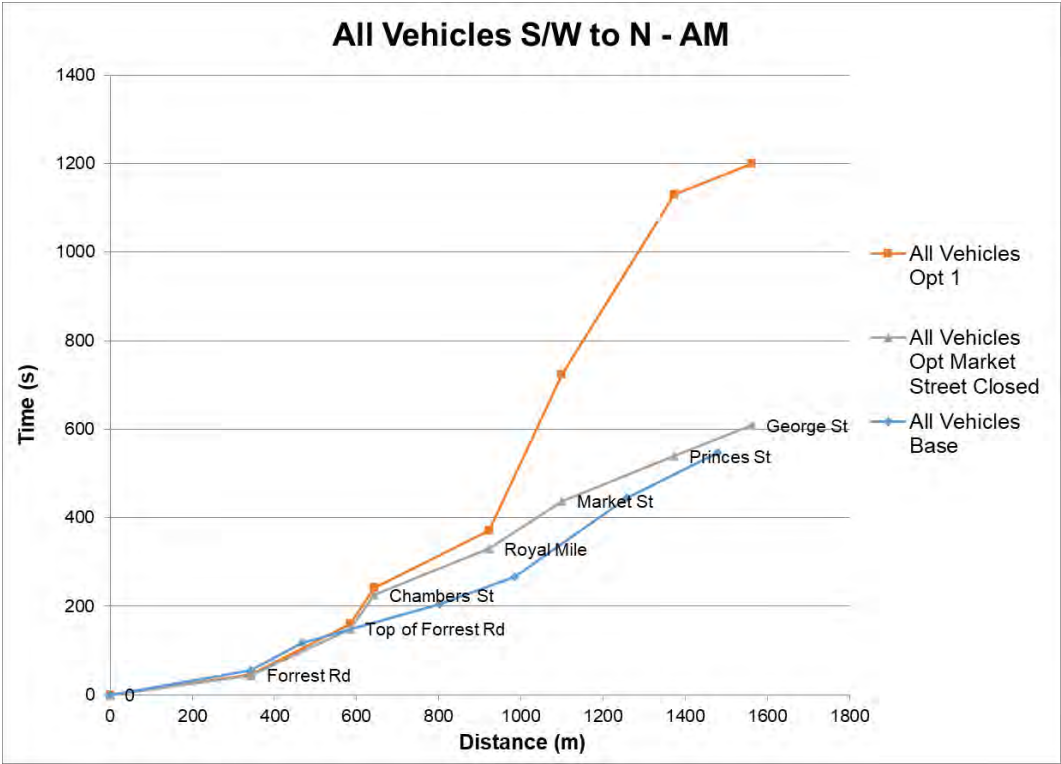


Figure 116: Journey Time All Vehicles NB (AM Peak)

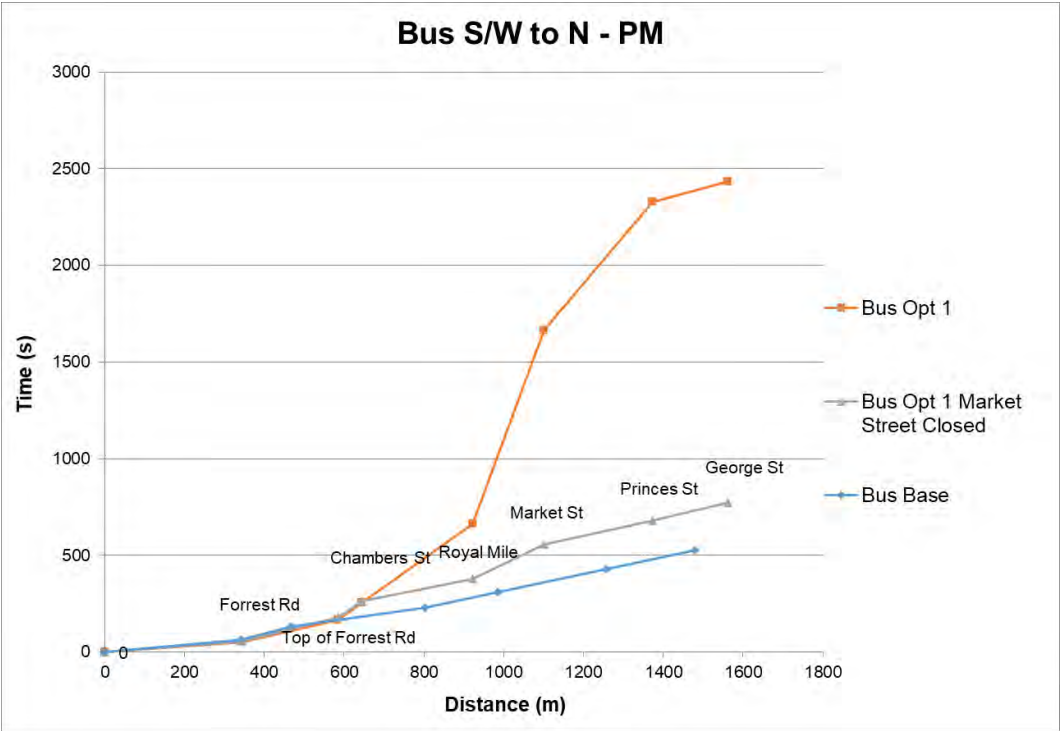


Figure 117: Journey Time Buses NB (PM Peak)

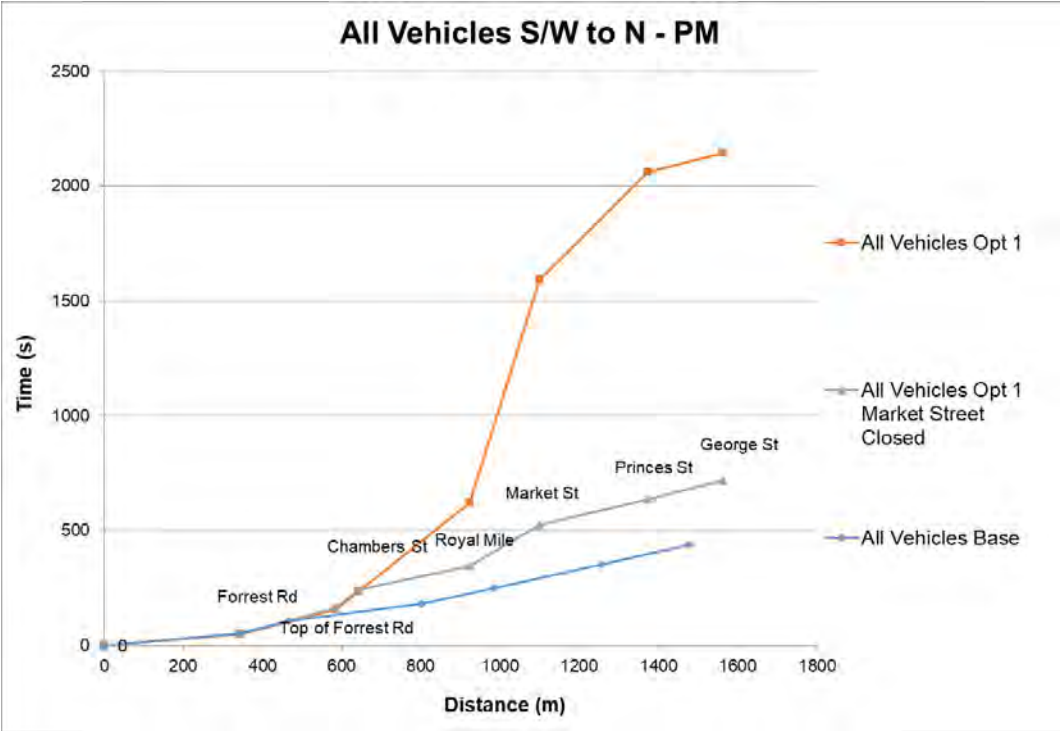


Figure 118: Journey Time All Vehicles NB (PM Peak)

C.4 Route 2 Southbound

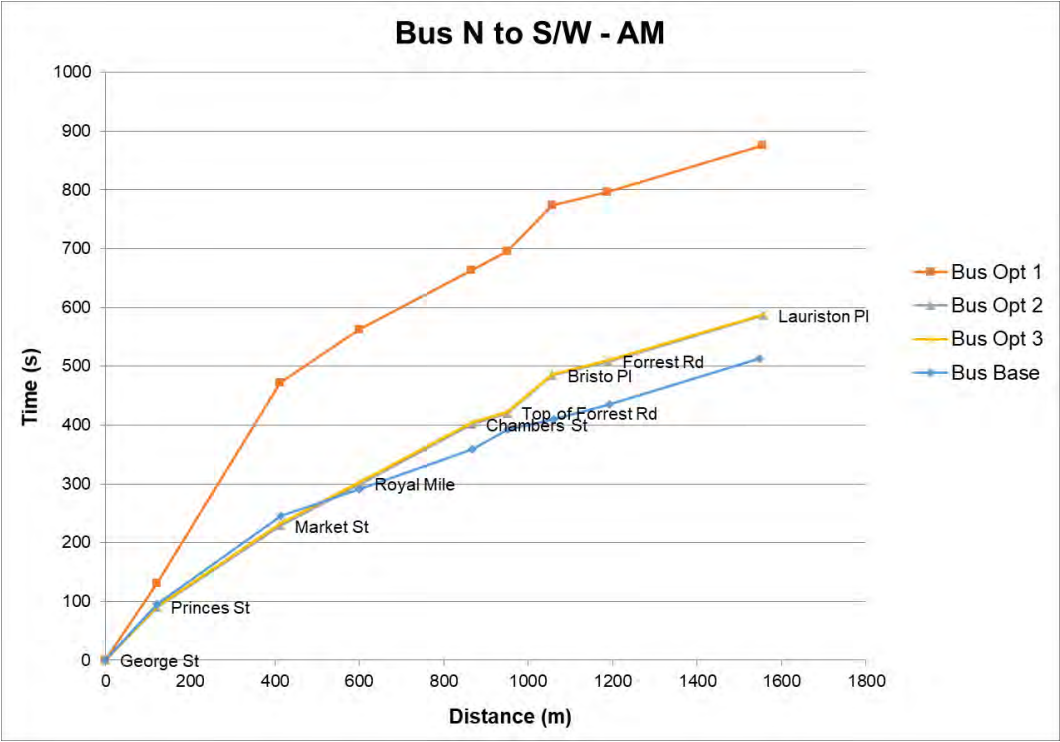


Figure 119: Journey Time Buses SB (AM Peak)

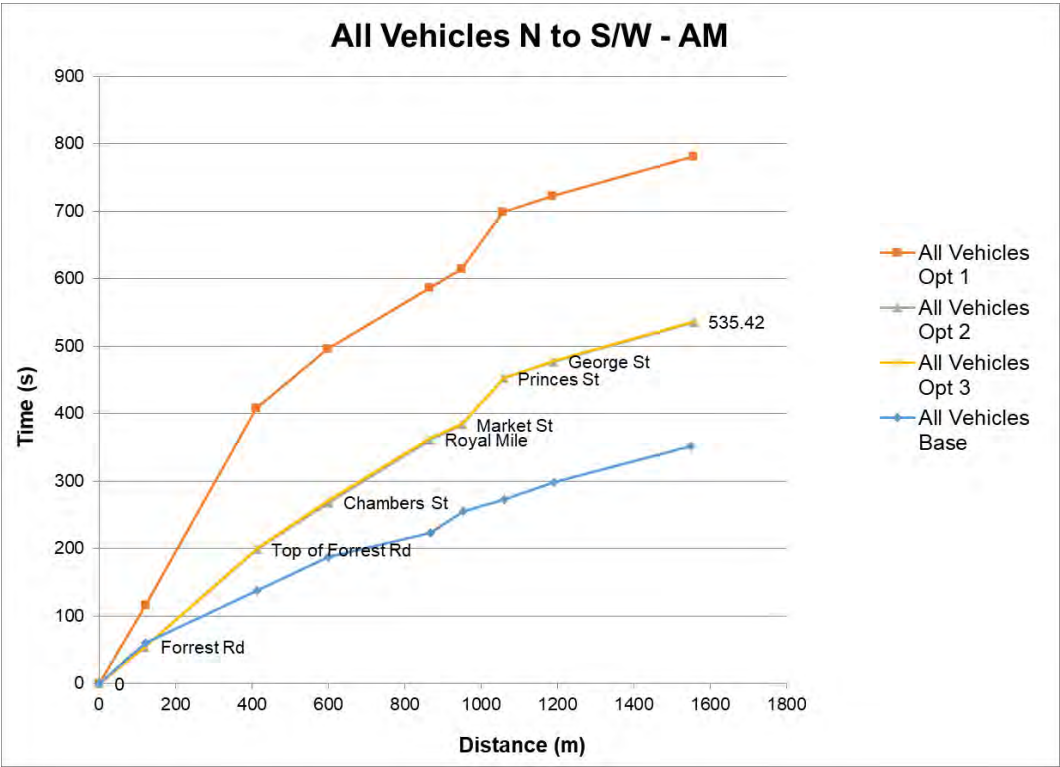


Figure 120: Journey Time All Vehicles SB (AM Peak)

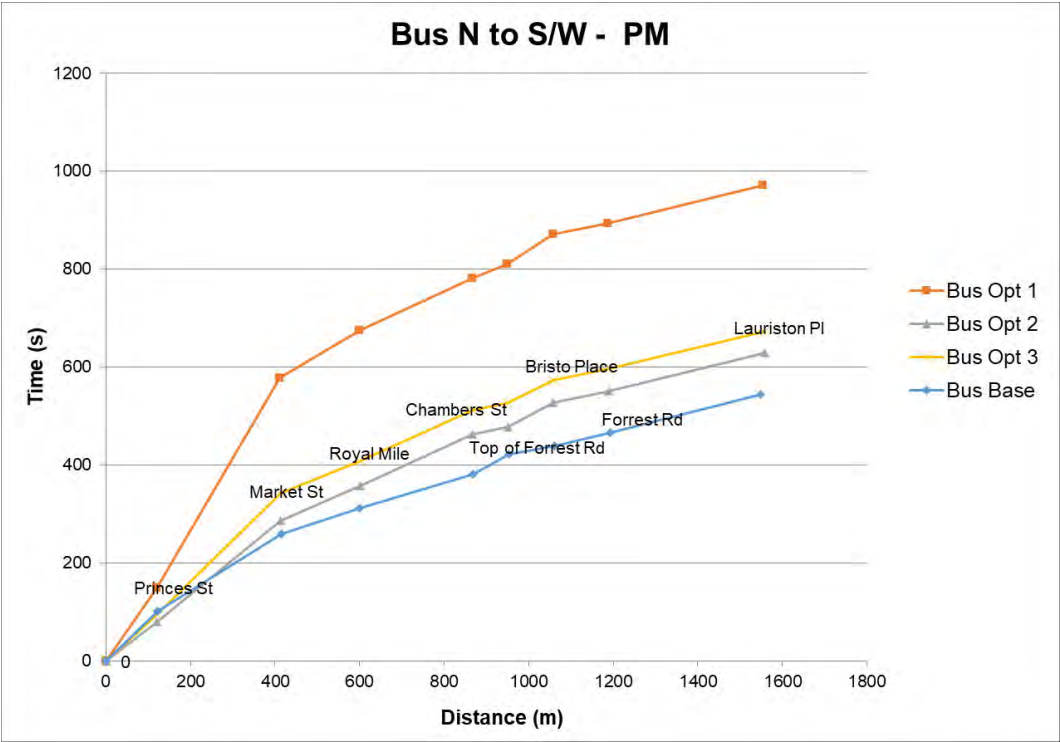


Figure 121: Journey Time Buses SB (PM Peak)

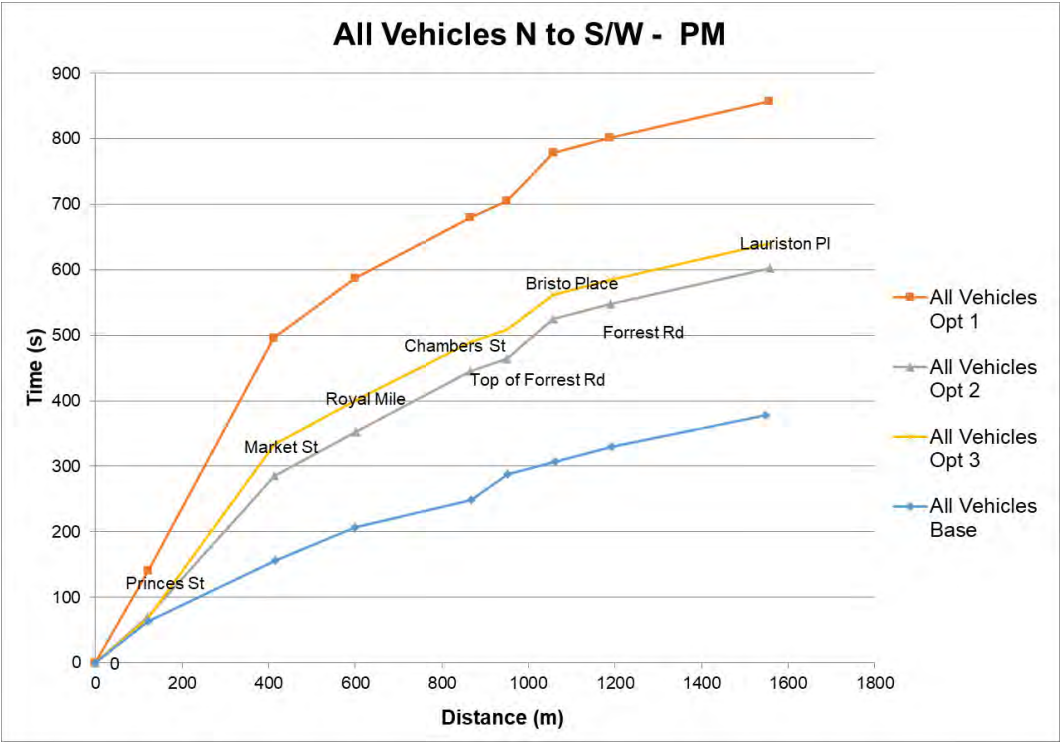


Figure 122: Journey Time All Vehicles SB (PM Peak)

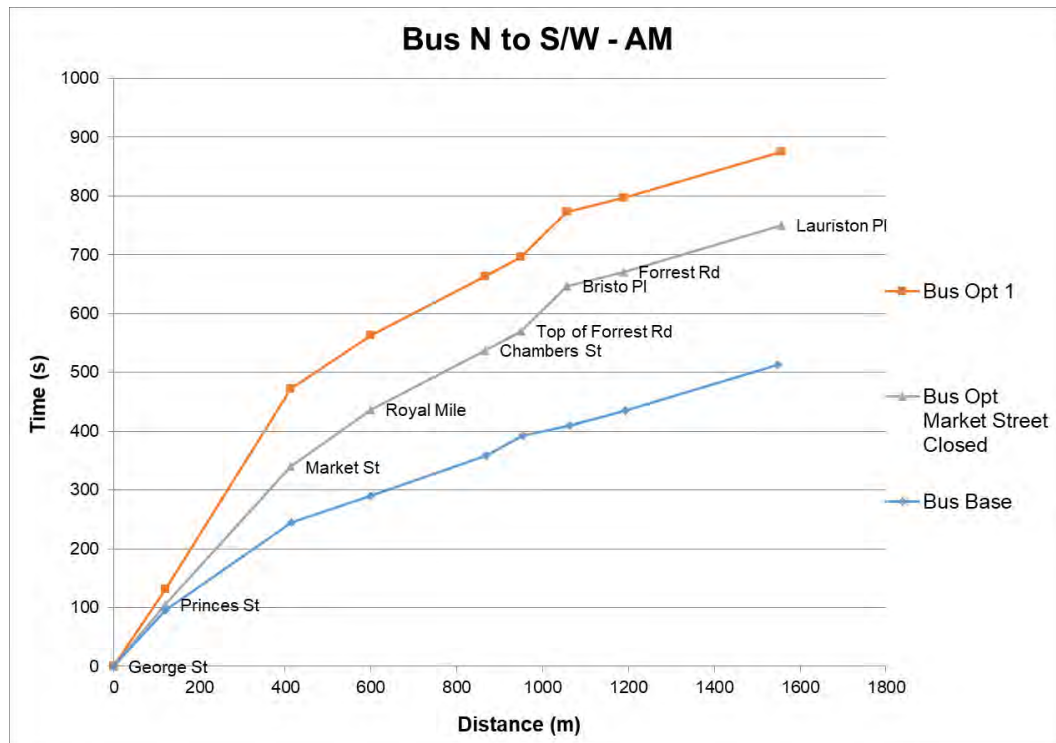


Figure 123: Journey Time Buses SB (AM Peak)

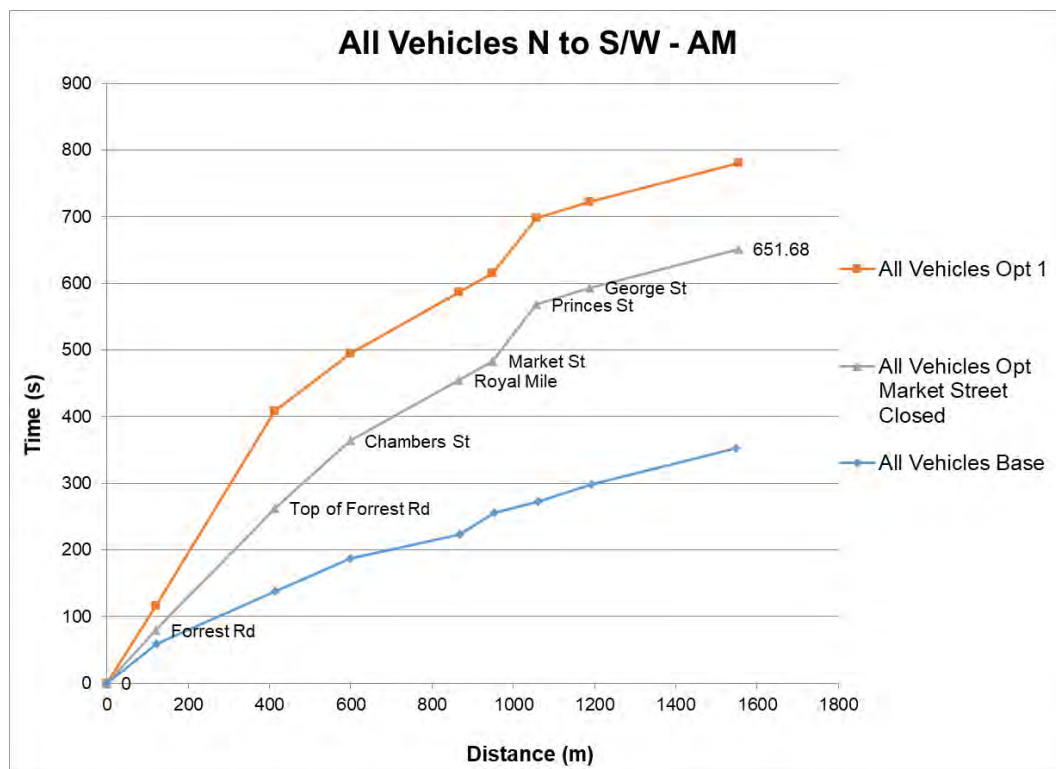


Figure 124: Journey Time All Vehicles SB (AM Peak)

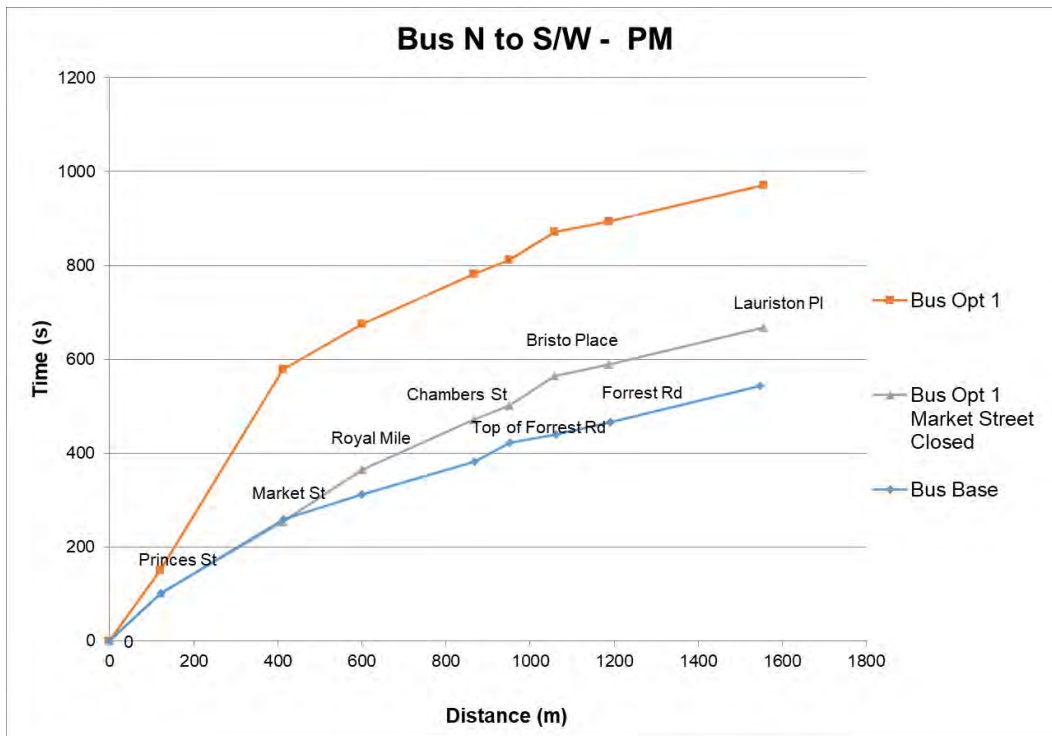


Figure 125: Journey Time Buses SB (PM Peak)

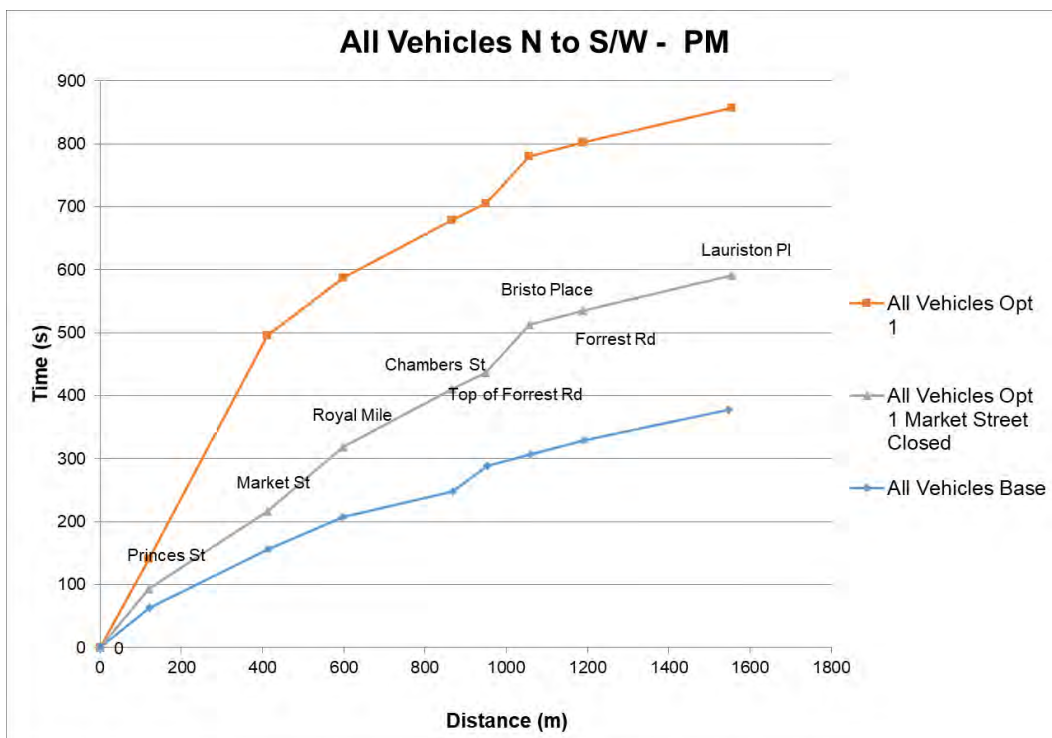


Figure 126: Journey Time All Vehicles SB (PM Peak)

C.5 Route 3 Cyclists Northbound

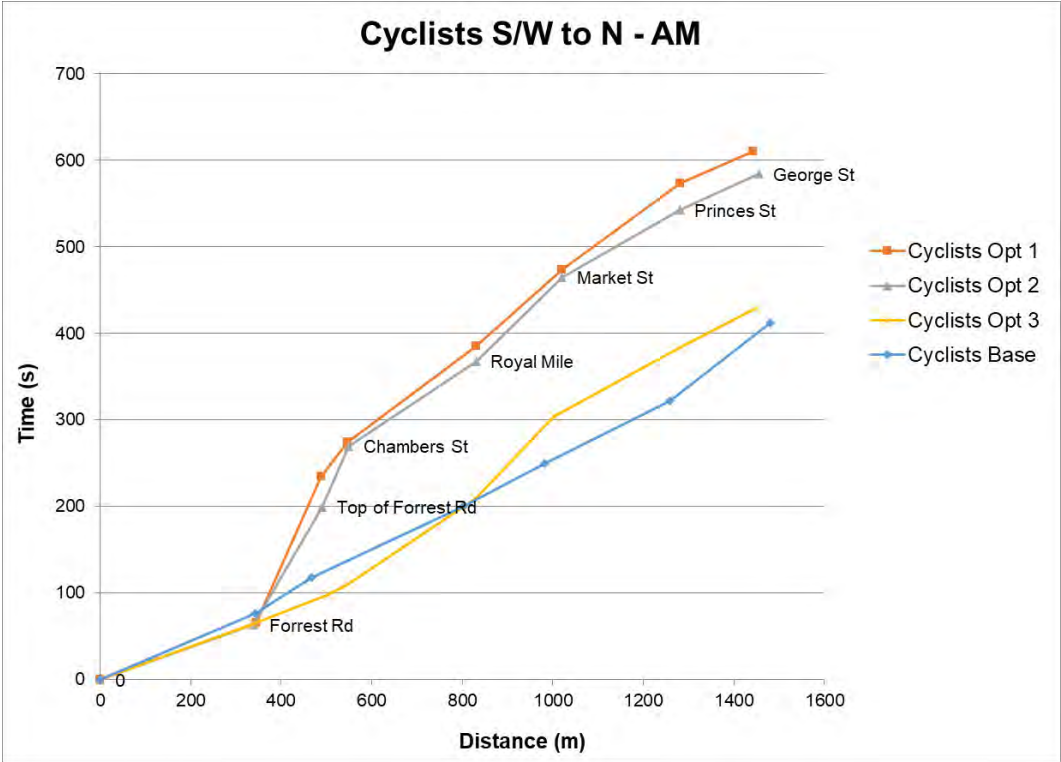


Figure 127: Journey Time Cyclists NB (AM Peak)

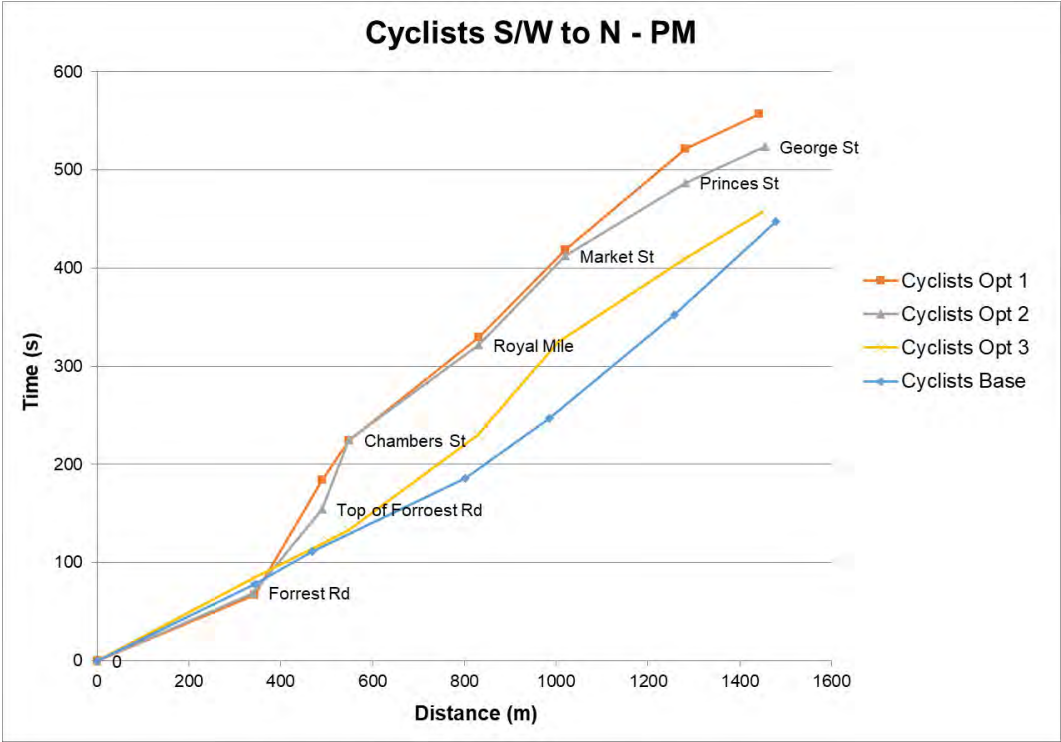


Figure 128: Journey Time Cyclists NB (PM Peak)

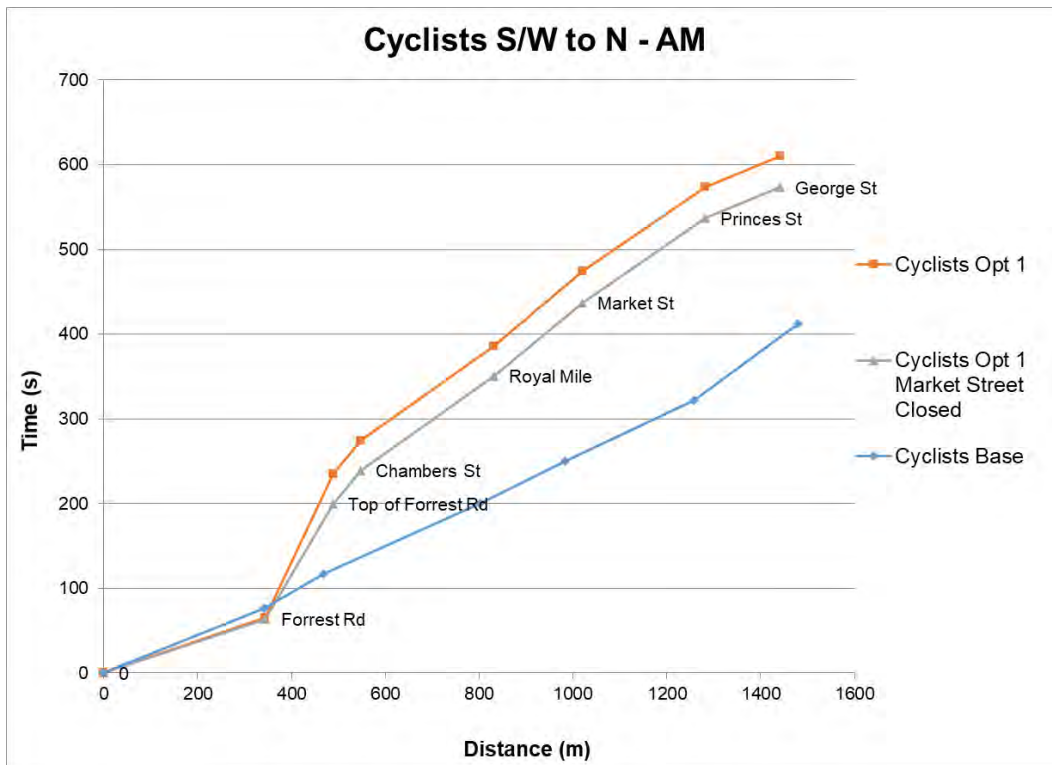


Figure 129: Journey Time Cyclists NB (AM Peak)

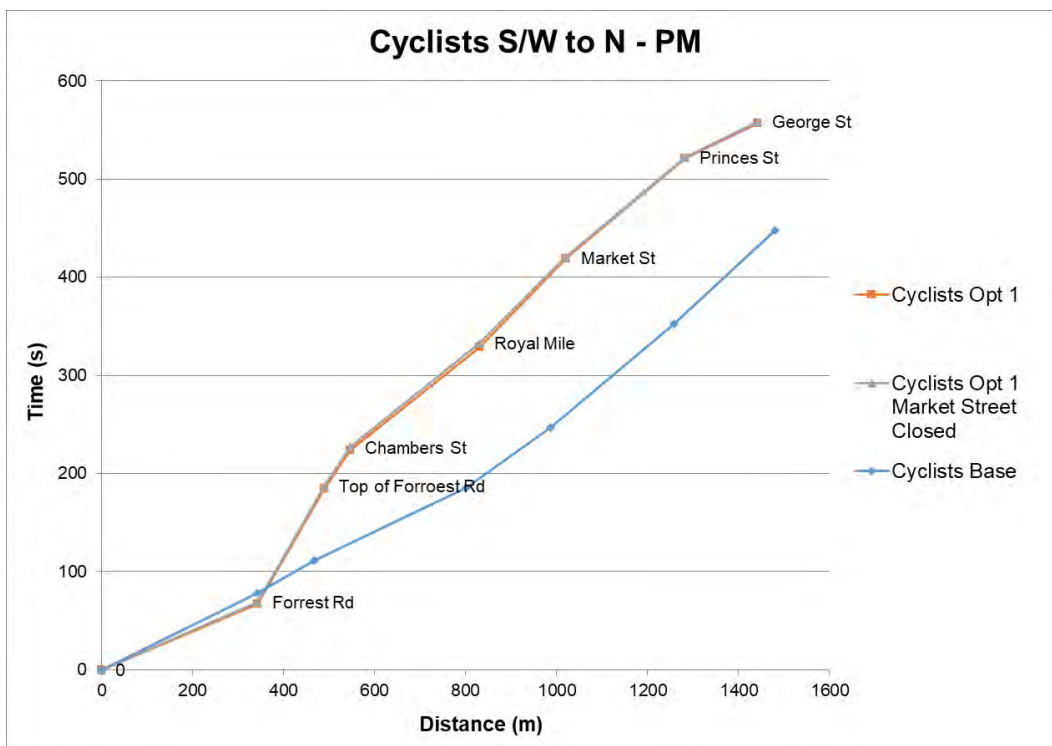


Figure 130: Journey Time Cyclists NB (PM Peak)

C.6 Route 3 Cyclists Southbound

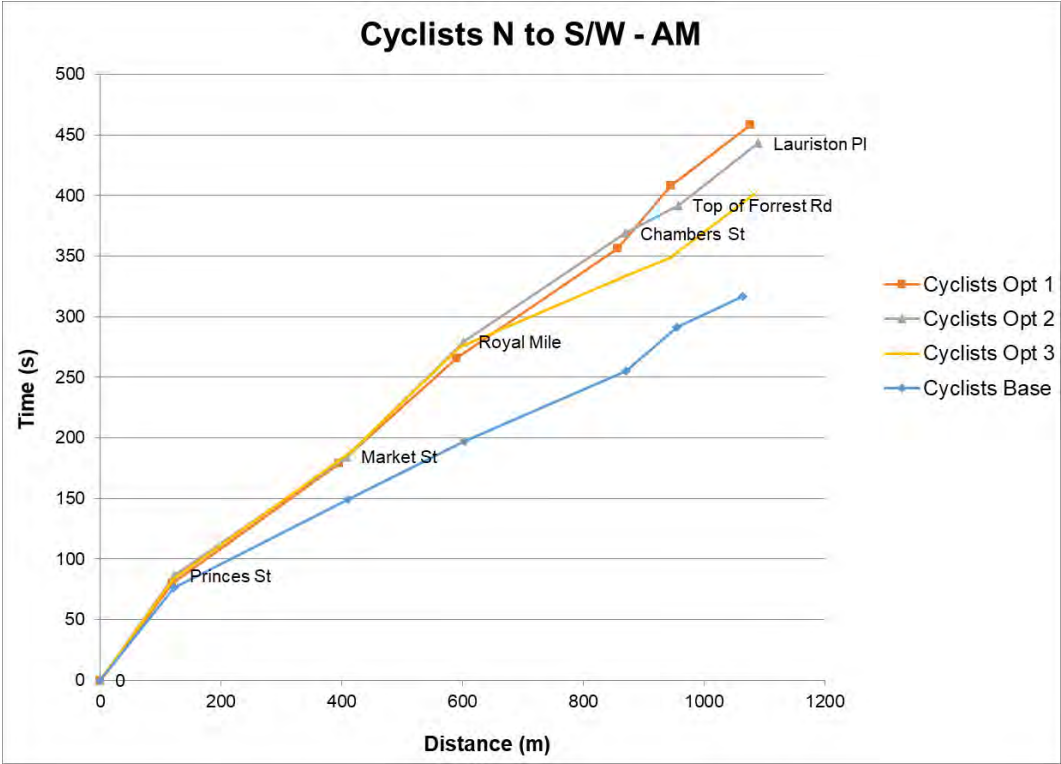


Figure 131: Journey Time Cyclists SB (AM Peak)

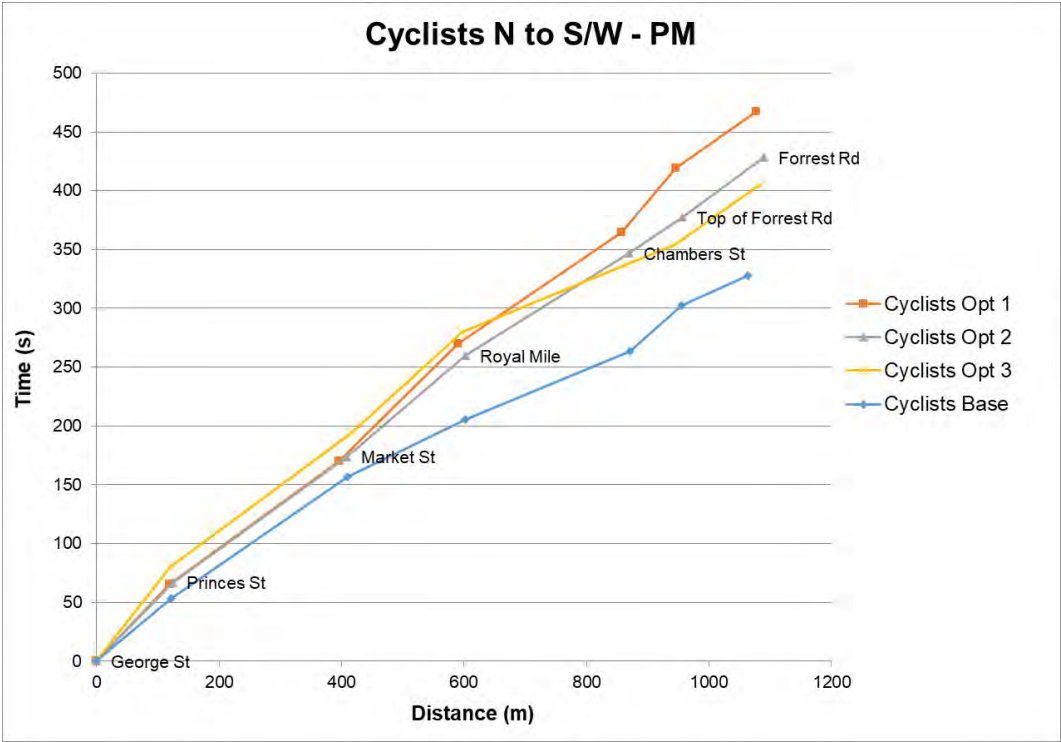


Figure 132: Journey Time Cyclists SB (PM Peak)

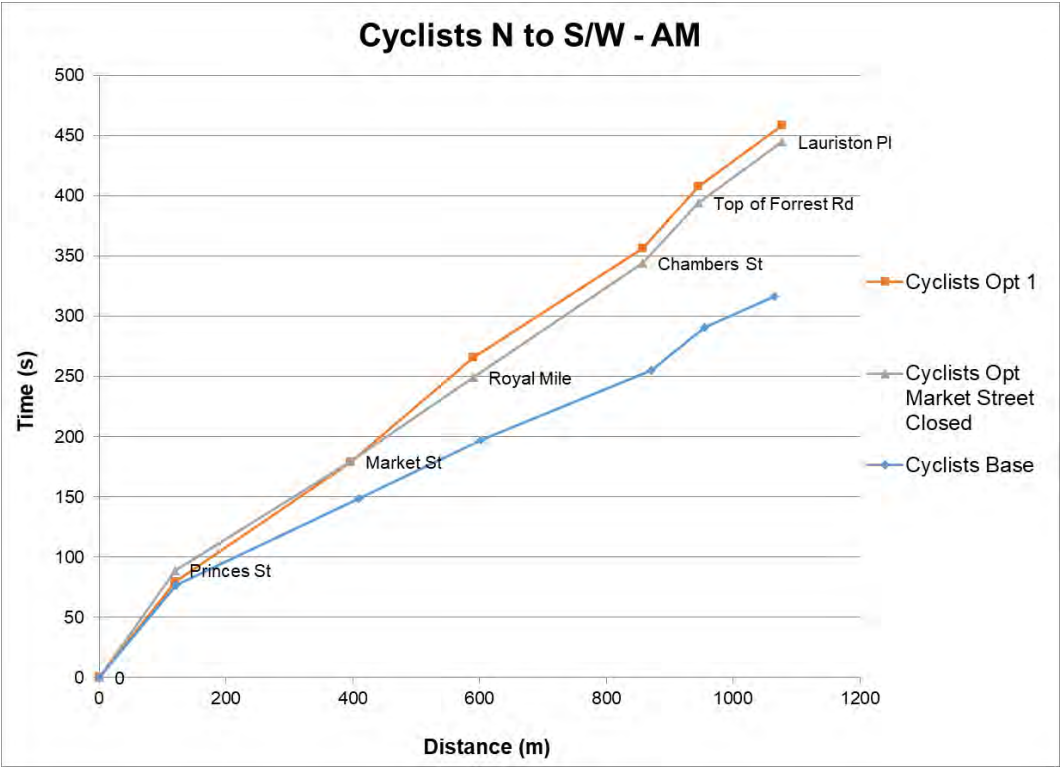


Figure 133: Journey Time Cyclists SB (AM Peak)

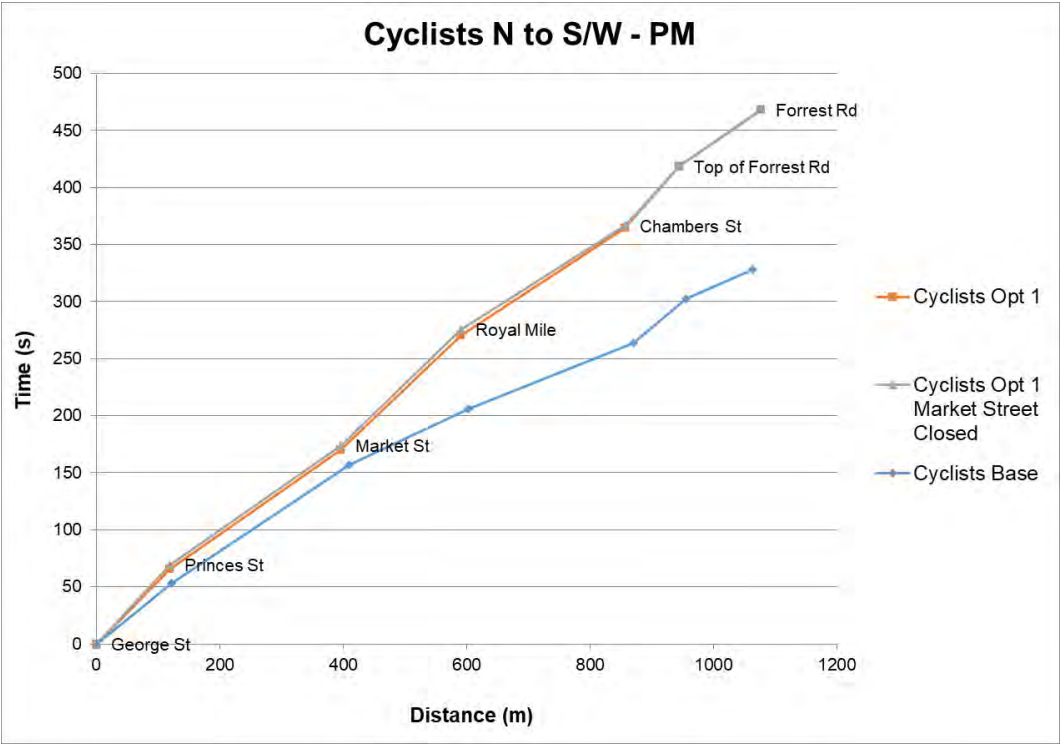


Figure 134: Journey Time Cyclists SB (PM Peak)

Appendix D : Additional Modelling

Appendix D describes the additional modelling tests that were carried out, which were carried out after discussions with City of Edinburgh Council about the modelling results of Option 1, Option 2 and Option 3.

Since the completion of the previous modelling options, as described in the main body of the report, CEC have asked AECOM to make the following improvements to the existing models:

1. Increase the number of cyclists in the option models in order to increase the sample size;
2. Modification of the signal settings at the High Street / George IV Bridge junction to implement a second pedestrian stage;
3. Improve the effectiveness of the shuttle work between High Street and Market Street;
4. Introduction of an Advanced Stop Line (ASL) for cyclists on the southern approach to the George IV Bridge / Chamber Street junction; and
5. Introduction of an “early release” green phase for cyclists on the southern approach to the George IV Bridge / Chamber Street junction.

The remainder of this Appendix is structured as follows:

- D.1 Number of Cyclists – Outlines the “CL+ Meadows to George Street” Business Case, and the methodology used to estimate the increase in cyclists;
- D.2 Option 2 Hybrid – This section describes the new “Hybrid” option in detail and presents figures to illustrate the proposals;
- D.3 Journey Time Results – This section presents and describes the modelling results that were obtained;
- D.4 Cyclist Sub-Test – The cyclist sub-tests that were carried out are described;
- D.5 Shuttle Work Sub-Test – This section describes the shuttle work sub-test that was carried out;
- D.6 Bus Stop Sub-Test – This section described the “Victoria Street” bus stop sub test that was carried out;
- D.6 Summary and Recommendations – This section presents the conclusions and recommendations that have been drawn from the modelling outputs.

D.1 Number of Cyclists

According to the “CL+ Meadows to George Street” Business Case study conducted by the AECOM Transport Planning team, the number of cyclists using the proposed cycling route will increase by **88%** in 2022. This was estimated using a “Comparative Study Approach”, which was based on the estimated growth for Edinburgh’s “City Centre West to East Link” (CCWEL) project.

It should be noted that using a “Disaggregate Mode Choice Model Approach” predicts that the scheme would deliver a 37% increase in cycle commute levels. The larger value of 88% has been used in the tests described in the following sections, as this will be giving the larger demand that needs to be accommodated.

D.2 Option 2 Hybrid

A new “Hybrid” version of the scheme design was created to improve cyclists’ journey time and safety in comparison to Option 1, Option 2 and Option 3. This option is a synthesis of the Option 1 and Option 2 designs. In the remainder of this Appendix the option will be referred to as “Option 2 Hybrid”.

Similarly to Option 2, the Option 2 Hybrid design includes the closure of Forrest Road for general traffic, the closure between Market Street and Chambers Street for general traffic, the closure of Victoria Road, the introduction of shuttle working on Bank Street, the introduction of traffic signals at the junction of George IV Bridge and Chambers Street, and the introduction of a signalised crossing at the Forrest Road / Bristo Place junction. As before, due to the closure of Forrest Road, Bristo Place becomes two-way with one lane in each direction for general traffic. Furthermore, similarly to Option 1, the Option 2 Hybrid design includes the dedicated

cycling stage at George IV Bridge / High Street junction, The Mound / Market Street junction and The Mound / Princes Street junction. The separate stage for cyclists at The Mound / Princes Street junction should improve the safety of cyclists and provide a sense of priority.

The main difference in the design between Option 2 and Option 2 Hybrid is the layout of the segregated cycleway. In Option 2 Hybrid, the cycleway is on the east side of the road from the bottom of Forrest Road to The Mound / Princes Street junction as in Option 2, but it continues on the west side of the road from Princes Street to George Street.

Figure 135 shows the Option 2 Hybrid VISSIM network with the segregated cycleway (in WHITE), which is positioned on the east side of the corridor up to Princes Street and on the west side of the road from Princes Street to George Street.

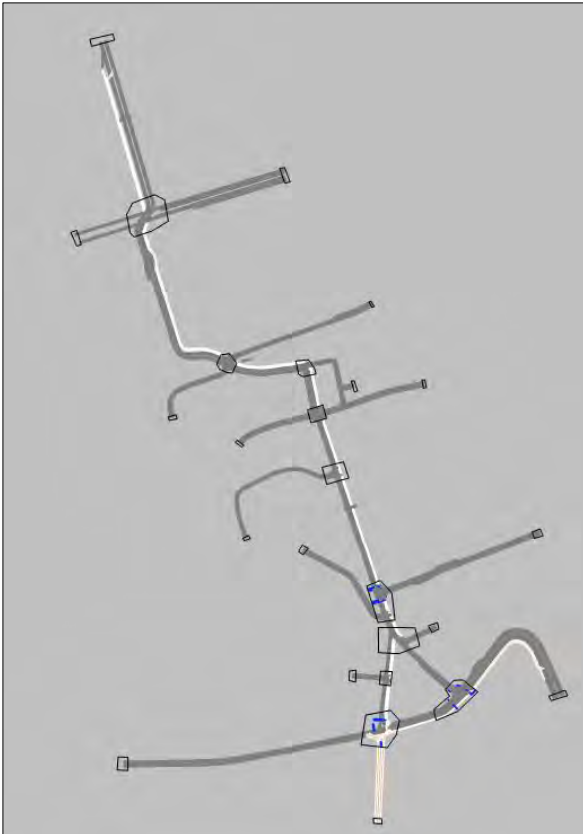


Figure 135: Option 2 Hybrid VISSIM Layout

D.3 Journey Time Results

The Option 2, Option 2 Hybrid and Option 3 models were re-run with an increased number of cyclists (as described in D.1) for two scenarios:

1. Market Street being open to general traffic; and
2. Market Street being closed to general traffic.

Table 22 below summarises the journey times for cyclists for all option models. It shows that the closure of Market Street has a minor impact on cyclist journey time, even though the number of cyclists was increased by 88%. The difference in journey time along the route is minimal, at between 0 and 1 second. The obtained journey times appear sensible and support the previous journey time results described in section 7 of the main report.

It is important to note that the difference in cyclists journey time results between Table 22 below and Table 7 in section 7 is caused by the changes to the cyclist journey time route, introduction of the early release green time to at the George IV Bridge / Chambers Street junction and an increased capacity of cycleway at the Forrest Road / Bristo Place junction. The new cyclist journey time route starts from Middle Meadow Walk and ends after the signalised crossing at the Rose Street / Hanover Street junction, whereas previously cyclist journey time routes started from Lauriston Place or Potterow.

Table 22: Cycle Journey Time

Route Name	Modelling Option	AM Journey Time (Market Street Open)	AM Journey Time (Market Street Closed)	PM Journey Time (Market Street Open)	PM Journey Time (Market Street Closed)
Meadows – George Street NB	Option 2	00:08:36	00:08:35	00:08:06	00:08:08
	Option 3	00:06:51	00:06:50	00:06:30	00:06:33
	Option 2 Hybrid	00:09:01	00:09:00	00:08:51	00:08:50
George Street – Meadows SB	Option 2	00:07:47	00:07:47	00:08:06	00:08:08
	Option 3	00:07:07	00:07:07	00:06:30	00:06:33
	Option 2 Hybrid	00:07:47	00:07:48	00:08:51	00:08:50

It should be noted that the journey times for cyclists in the Option 2 Hybrid models are slowed in both directions compared to the journey times in options 2 and 3.

Figure 136 and Figure 137 present journey time profile graphs for each option for the AM peak period in both directions.

According to Figure 136, Option 3 is faster between Lauriston Place and Chambers Street because the cycleway is on the west side of the road, which means that cyclists do not need to cross Bristo Place and Chambers Street to go northbound. The journey times for cyclists in Option 2 and Option 2 Hybrid are the same for the route section from Lauriston Place to Market Street. However, Option 2 Hybrid shows a longer journey time to pass through the Princes Street / The Mound junction, due to the dedicated cycling stage.

Similarly, Figure 137 shows that Option 3 is faster between the Royal Mile and Lauriston Place, because cyclists do not need to cross Bristo Place and Chambers Street to go southbound. There is no significant difference in journey times between Option 2 and Option 2 Hybrid at the Hanover Street / Princes Street junction, due to the lower number of cyclists going southbound in the morning and the green wave from George Street to Princes Street.

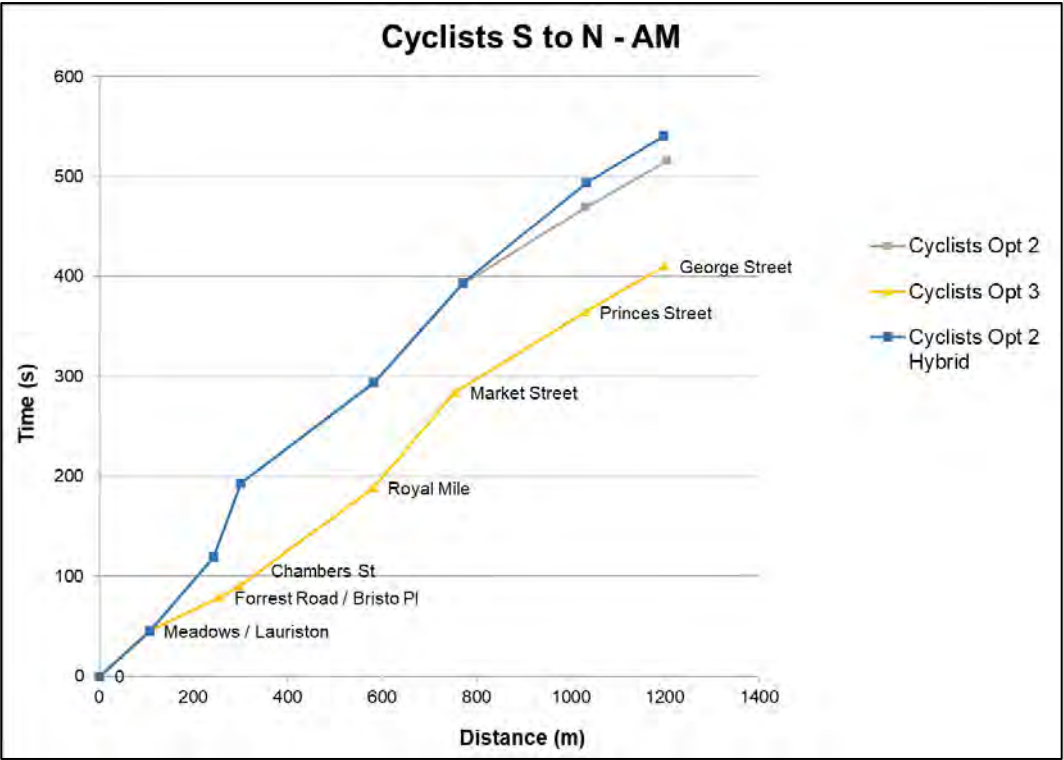


Figure 136:Cyclists Journey Time Northbound AM

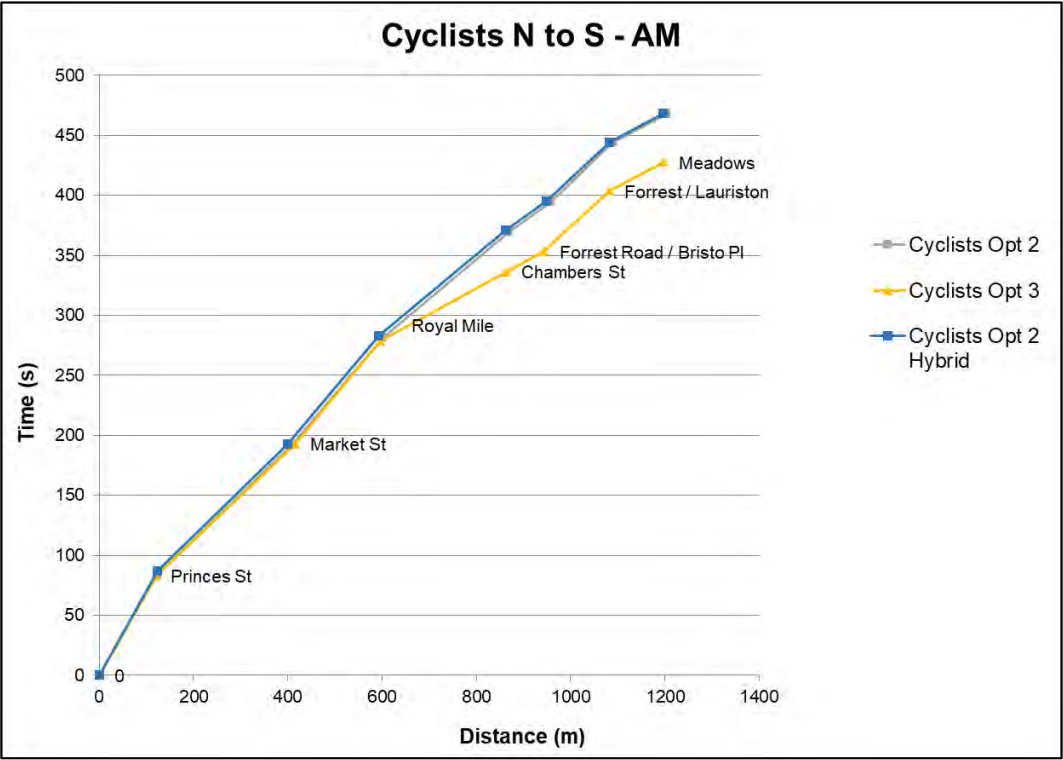


Figure 137: Cyclists Journey Time Southbound AM

Table 23 summarises the journey times for buses in both directions for the AM and PM peak periods, for the following options:

1. Market Street being open to general traffic; and
2. Market Street being closed to general traffic.

The journey time results in Table 23 highlight that the closure of Market Street significantly improves bus journey times in both directions for both AM and PM peak periods for all 3 options, including the new Option 2 Hybrid. The obtained bus journey time results appear sensible and supports the previous journey time results described in section 7 of the main report.

It is important to note that the difference in bus journey time results between Table 23 below and Table 8 in section 7 is caused by the changes to the bus journey time route and introduction of the advanced green time for cyclists at the George IV Bridge / Chambers Street junction. The new bus journey time route starts from the traffic light on Teviot Place and ends after the signalised crossing at the Rose Street / Hanover Street junction, whereas the previous bus journey time routes started from Lauriston Place or Potterow.

Table 23: Bus Journey Time

Route Name	Modelling Option	AM Journey Time (Market Street Open)	AM Journey Time (Market Street Closed)	PM Journey Time (Market Street Open)	PM Journey Time (Market Street Closed)
Meadows – George Street NB	Option 2	00:09:30	00:08:51	00:14:35	00:10:35
	Option 3	00:09:18	00:08:34	00:14:39	00:10:32
	Option 2 Hybrid	00:21:32	00:09:47	00:21:30	00:11:08
George Street – Meadows SB	Option 2	00:08:15	00:07:35	00:10:11	00:07:24
	Option 3	00:08:12	00:07:48	00:10:09	00:07:28
	Option 2 Hybrid	00:08:38	00:07:57	00:10:14	00:07:35

It should be noted that the journey times for buses in the Option 2 Hybrid models are slowed in both directions compared to the journey times in options 2 and 3.

Figure 138 and Figure 139 demonstrate that the closure of Market Street significantly improves bus journey times between Market Street and Princes Street in the Option 2 Hybrid model. With Market Street closed for general traffic, the difference in journey time between Option 2 Hybrid and Option 2 becomes significantly less, particular in the northbound direction, which makes Option 2 Hybrid feasible for further assessment.

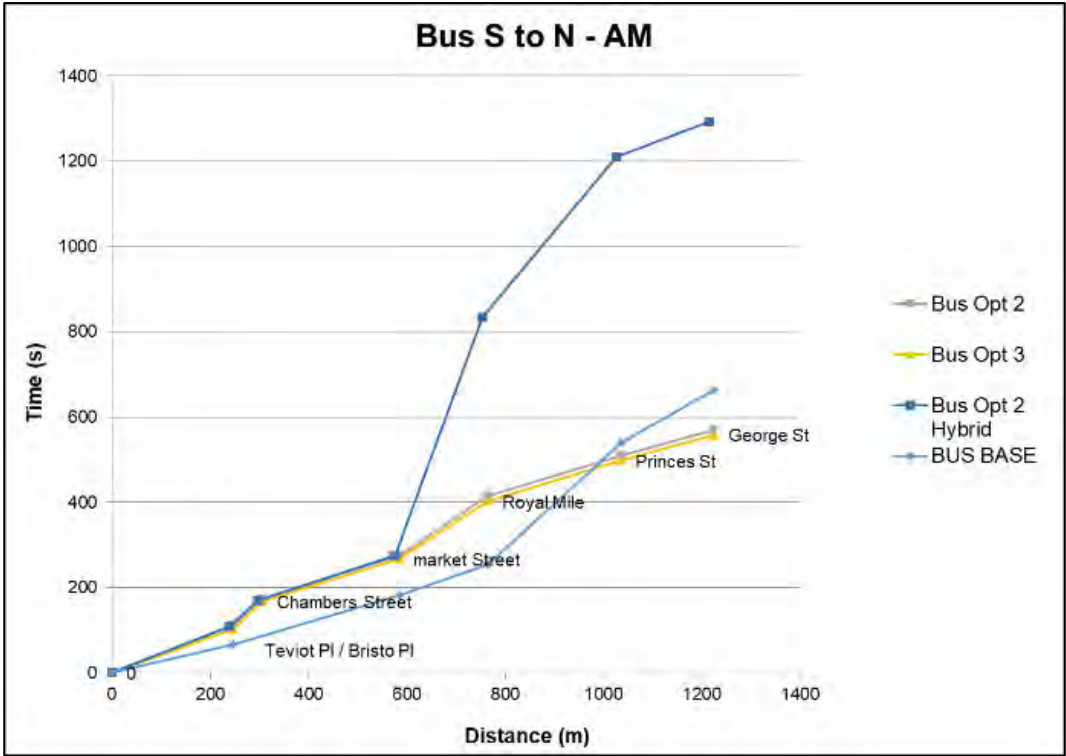


Figure 138: Bus Journey Time (Market Street Open)

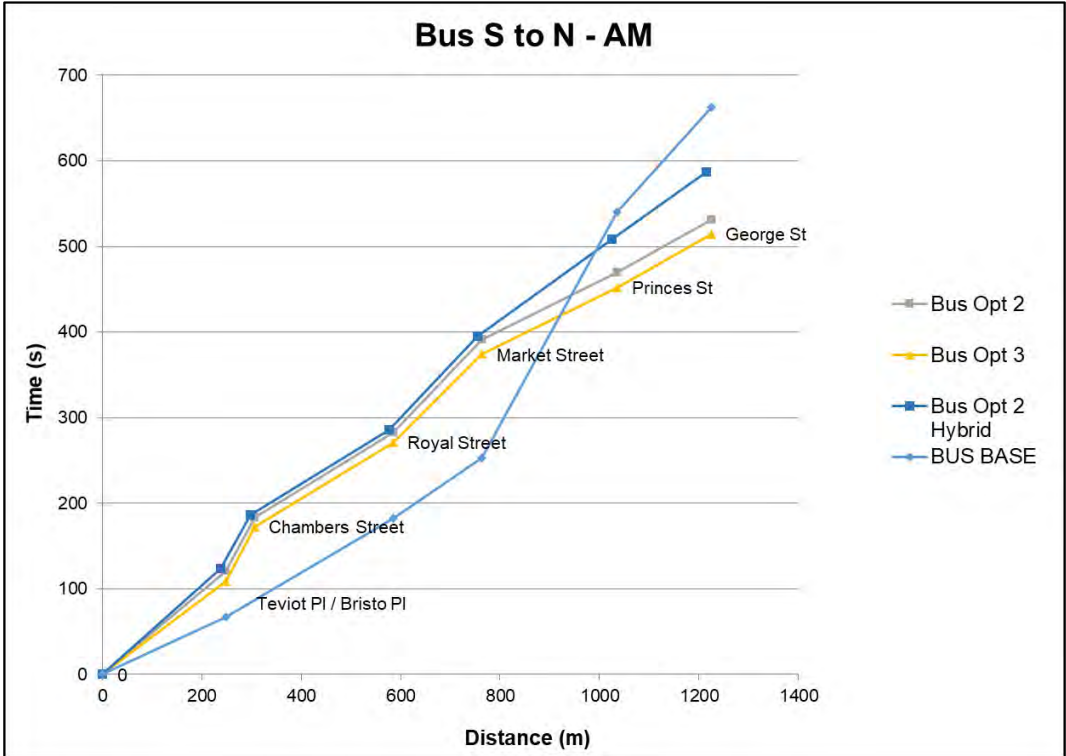


Figure 139: Bus Journey Time (Market Street Closed)

Figure 140 to Figure 143 display bus journey time profiles for the AM and PM peak periods in both directions under the Market Street Closed scenario. The key differences between the options are summarised below:

- In Option 2, buses going northbound in the morning peak period experience a minor additional delay of 2 seconds in comparison to Option 3, caused by cyclists' route choice. In Option 3, all cyclists use Forrest Road to travel northbound, whereas in Option 2 8 cyclists use Bristo Place instead of Forrest Road. These cyclists use the offside lane on Teviot Place to make a right turn onto Bristo Place. As a result, buses travelling northbound can miss the green phase and have to stop at the signals on Teviot Place.
- In Option 2 Hybrid, buses have less green time during the AM and PM peak periods to pass through the Princes Street / The Mound junction in comparison to Option 2 and Option 3, due to the dedicated stage for cyclists.
- In all options, buses travelling northbound experience an additional delay between Royal Mile and Market Street in comparison to the Base, due to the shuttle work.

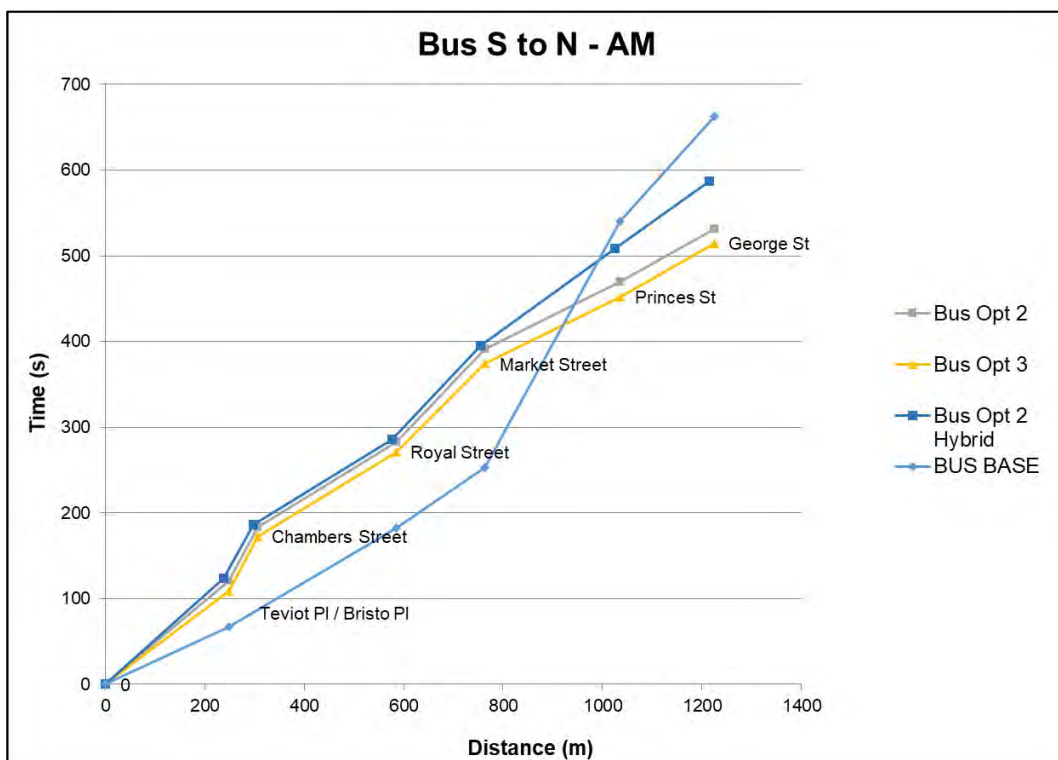


Figure 140: Bus Journey Time AM NB (Market Street Closed)

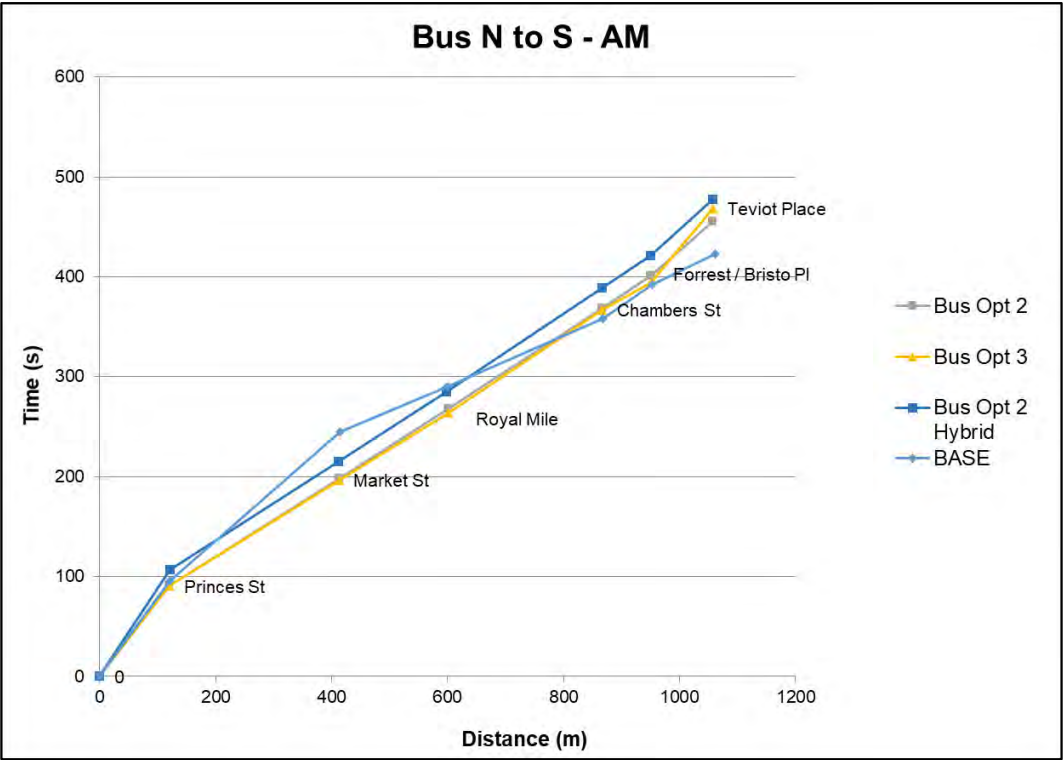


Figure 141: Bus Journey Time AM SB (Market Street Closed)

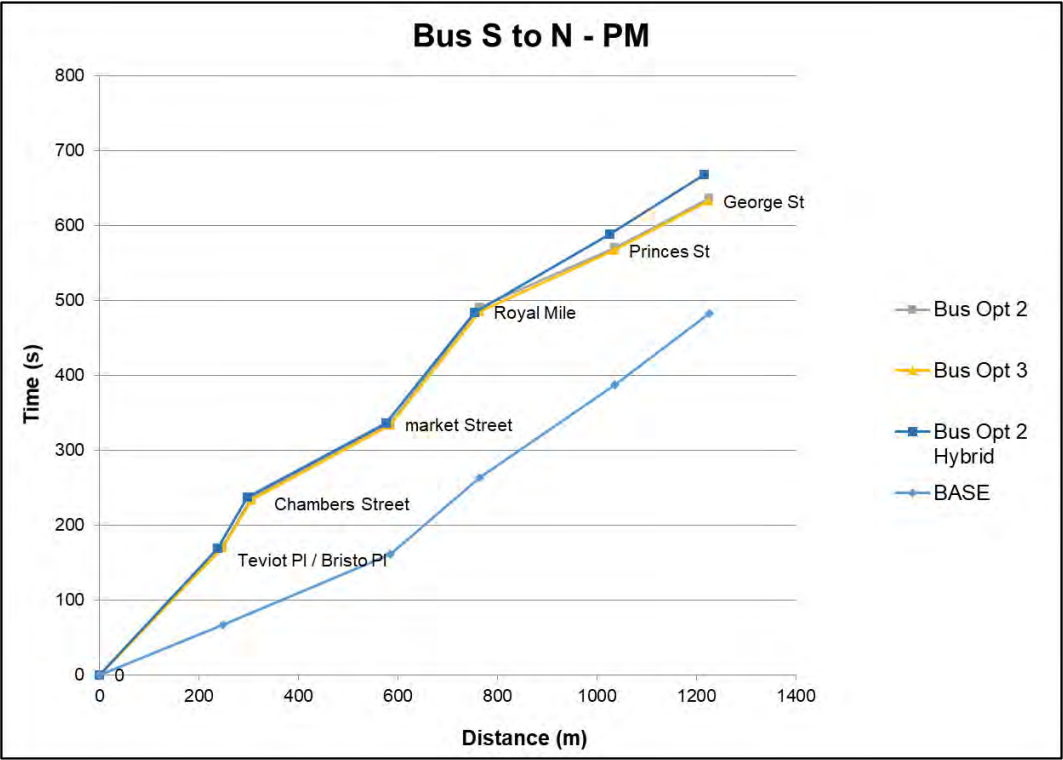


Figure 142: Bus Journey Time PM NB (Market Street Closed)

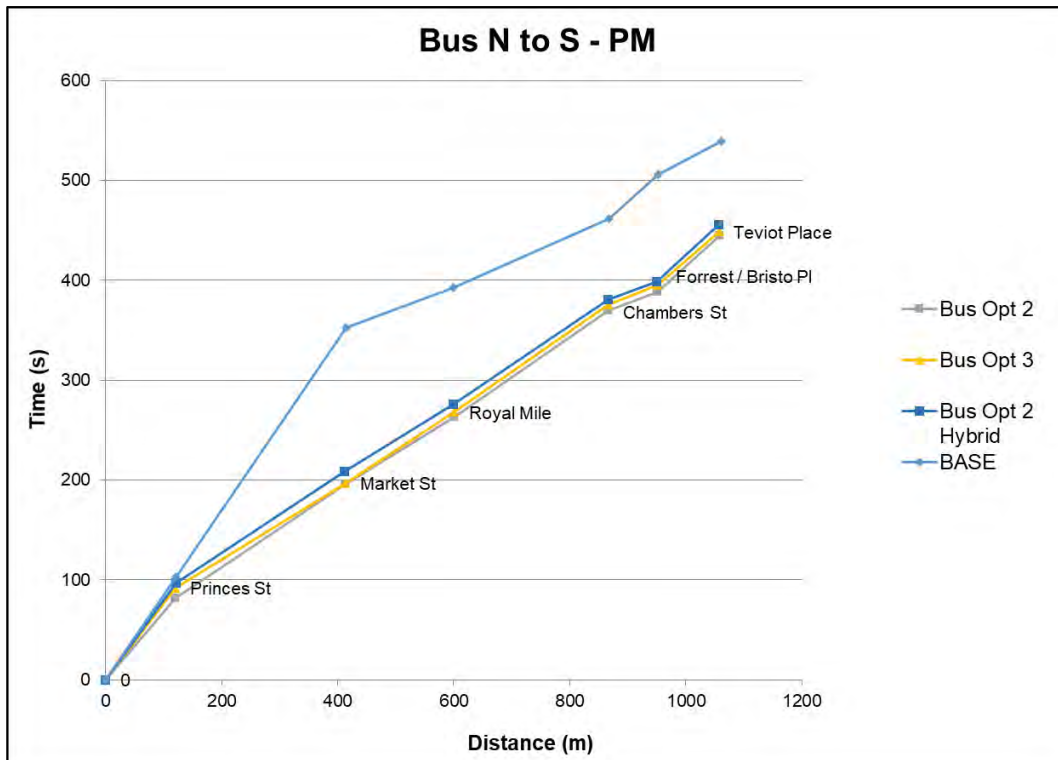


Figure 143: Bus Journey Time PM SB (Market Street Closed)

D.4 Cyclist Sub-Test

The following analysis assesses the journey time for cyclists in Option 2, where cyclists going northbound were forced to use the carriageway on Forrest Road and on George IV Bridge to bypass the signalised crossing across Bristo Place at the top of Forrest Road. Cyclists were forced to use the carriageway rather than the cycleway in order that the difference in journey time could be measured. This was to account for the fact that more experienced cyclists may choose to merge onto George IV Bridge, pass through the traffic signals at Chambers Street and enter the cycleway to the north of Chambers Street. This would avoid the need to wait for the green aspect to appear at the crossing of Bristo Place and for the cycle stage to appear at the George IV Bridge / Chambers Street traffic signals, however they may have to wait for the northbound traffic signals to turn green. This is shown graphically in Figure 144, where the purple dashed line shows the original route whereas the solid orange line shows the alternative route.

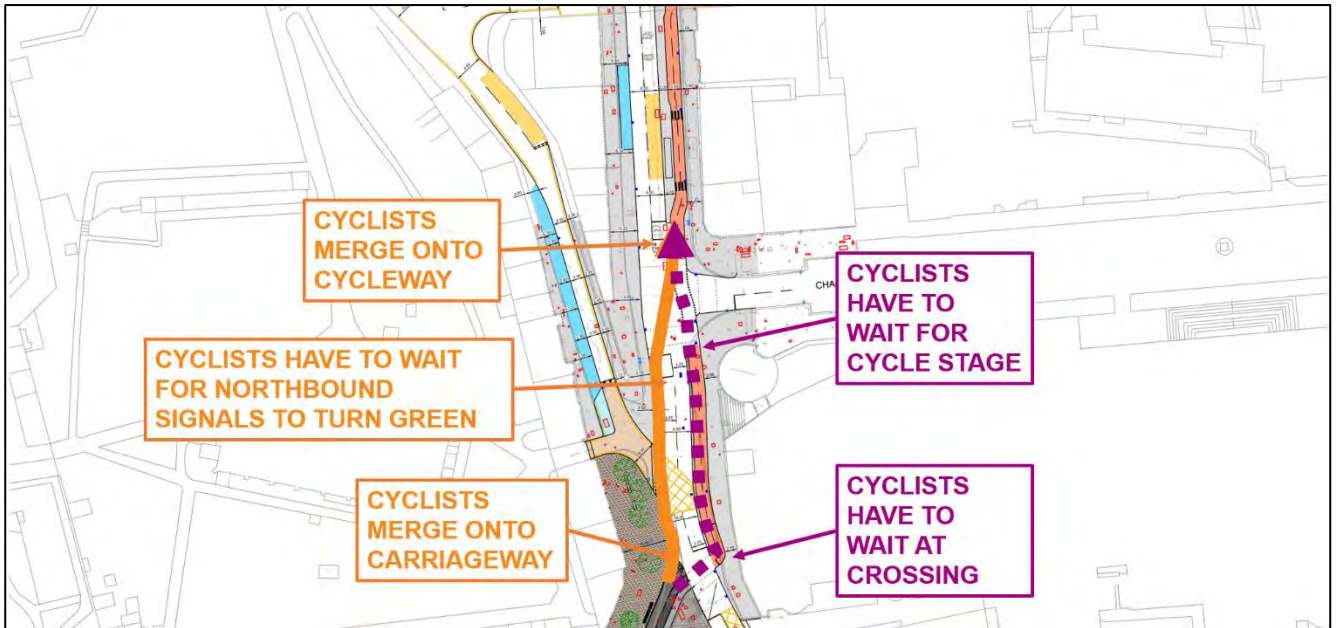


Figure 144: Cyclist Sub-Test

Figure 145 and Figure 146 display the journey time results for Option 2 and Option 2 Sub-Test for both the AM and PM peak periods. In the sub-test option, cyclists going northbound are not delayed by the traffic lights at the Forrest Road / Bristo Place crossing, therefore they have a shorter journey time than in Option 2 and Option 2 Hybrid.

Overall, the journey time for cyclists bypassing the Forrest Road / Bristo Place crossing is 7 minutes 51 seconds, which is 45 seconds less than for cyclists who stop at the Forrest Road / Bristo Place crossing.

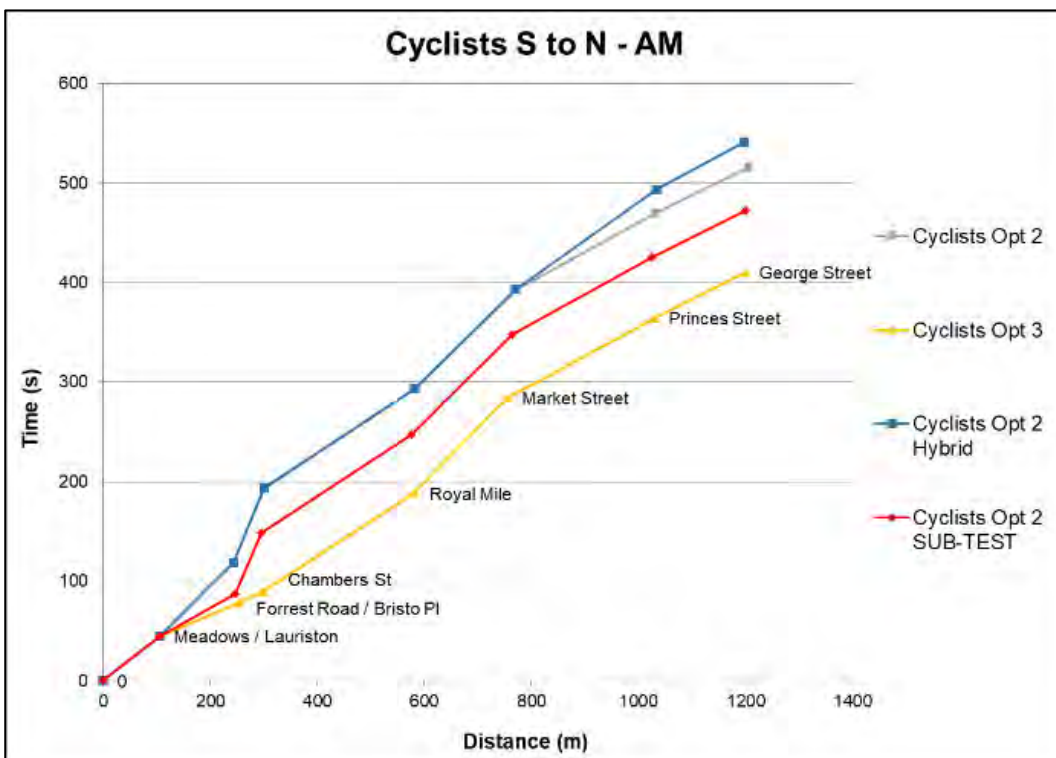


Figure 145: AM Northbound Sub-Test Cyclist Journey Time

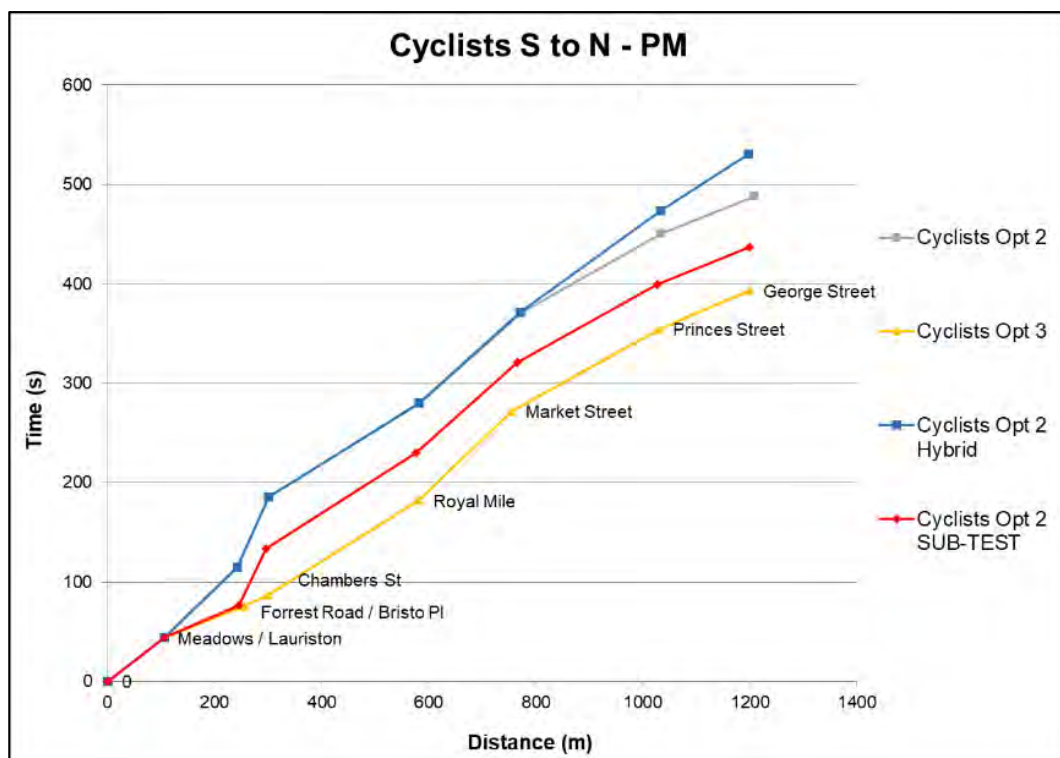


Figure 146: PM Northbound Sub-Test Cyclist Journey Time

D.5 Shuttle Work Sub-Test

The aim of this sub-test was to assess the shuttle work operation between High Street and Market Street in the northbound direction. Travelling northbound, buses experience additional delay due to the limited capacity on Bank Street and the low green time for traffic at The Mound / Princes Street junction.

In the original proposed arrangement, the stop line on the southbound approach would be set back on Bank Street, by approximately 110 metres from the junction, with shuttle working between Bank Street and the junction of George IV Bridge, High Street and Bank Street. The arrangement in the sub-test involved the length over which the shuttle work is in operation being reduced in length to around 50 metres, with the junction of George IV Bridge, High Street and Bank Street operating similarly to how it does currently, albeit with the addition of cycle phases. This arrangement was modelled in LinSig using two stage streams.

Two options of signal timings (Option A and Option B) were created in LinSig for the High Street / George IV Bridge junction. The main difference between the Option A and Option B signal settings is that Option A has a dedicated stage for cyclists, whereas in Option B cyclists get a green time at the same time with traffic on Bank Street. Furthermore, in Option B vehicles get more green time to travel northbound and less to travel southbound at the traffic signals on Bank Street.

Indicative stage diagrams are shown in Figure 147 to Figure 150 to illustrate this.

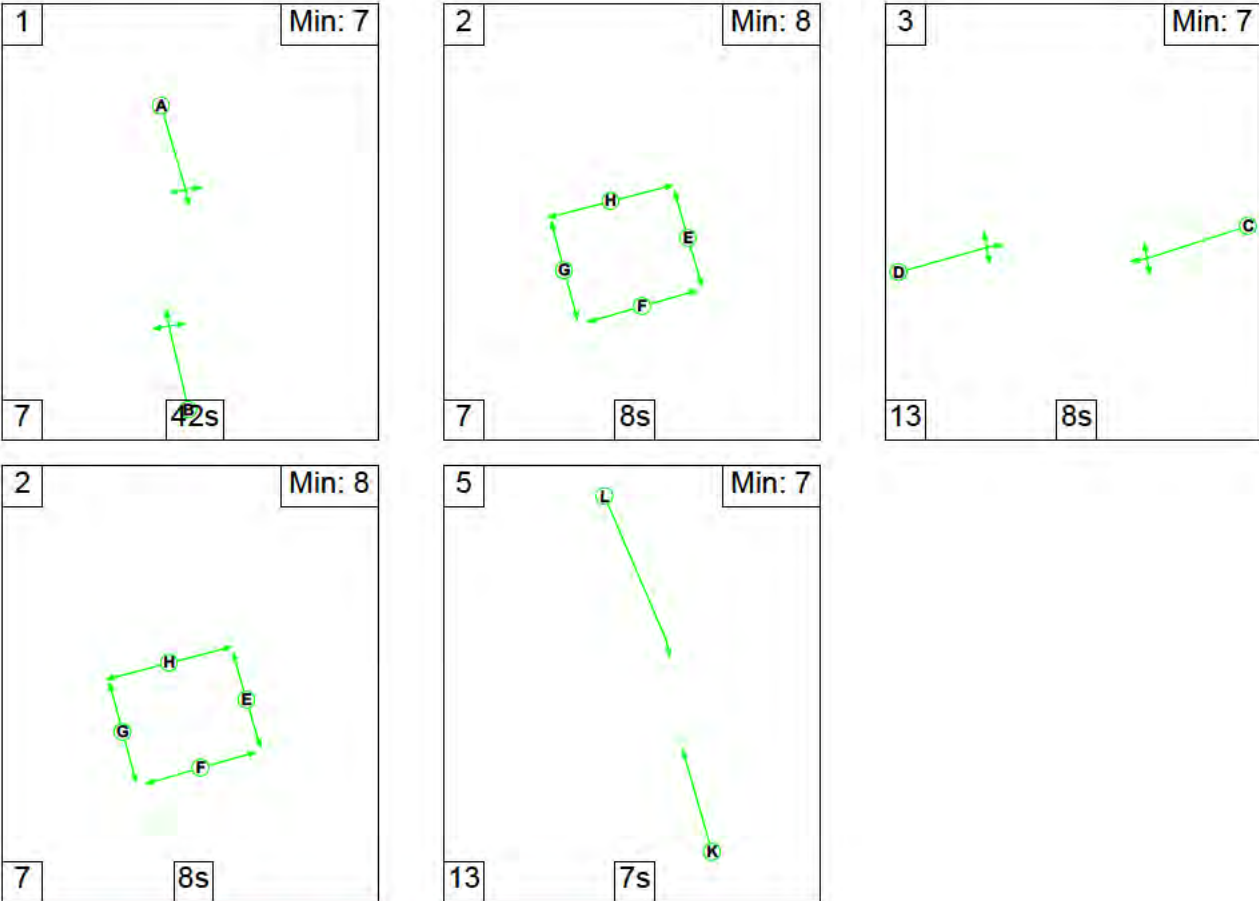


Figure 147: Stage Diagram - Option A (Stream 1)

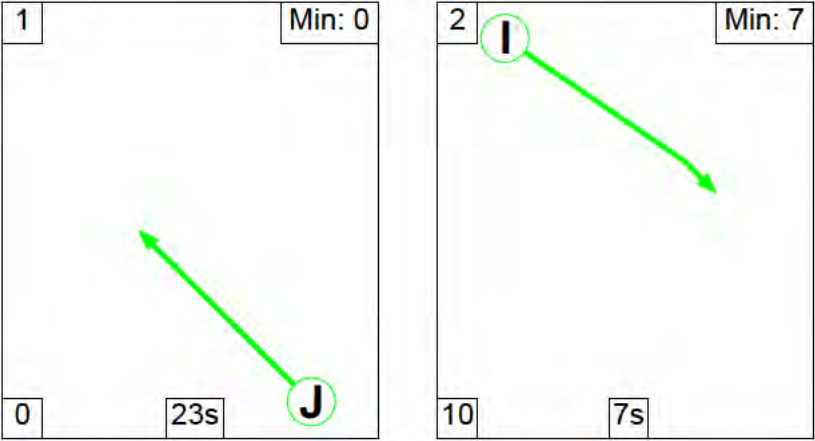


Figure 148: Stage Diagram - Option A (Stream 2)

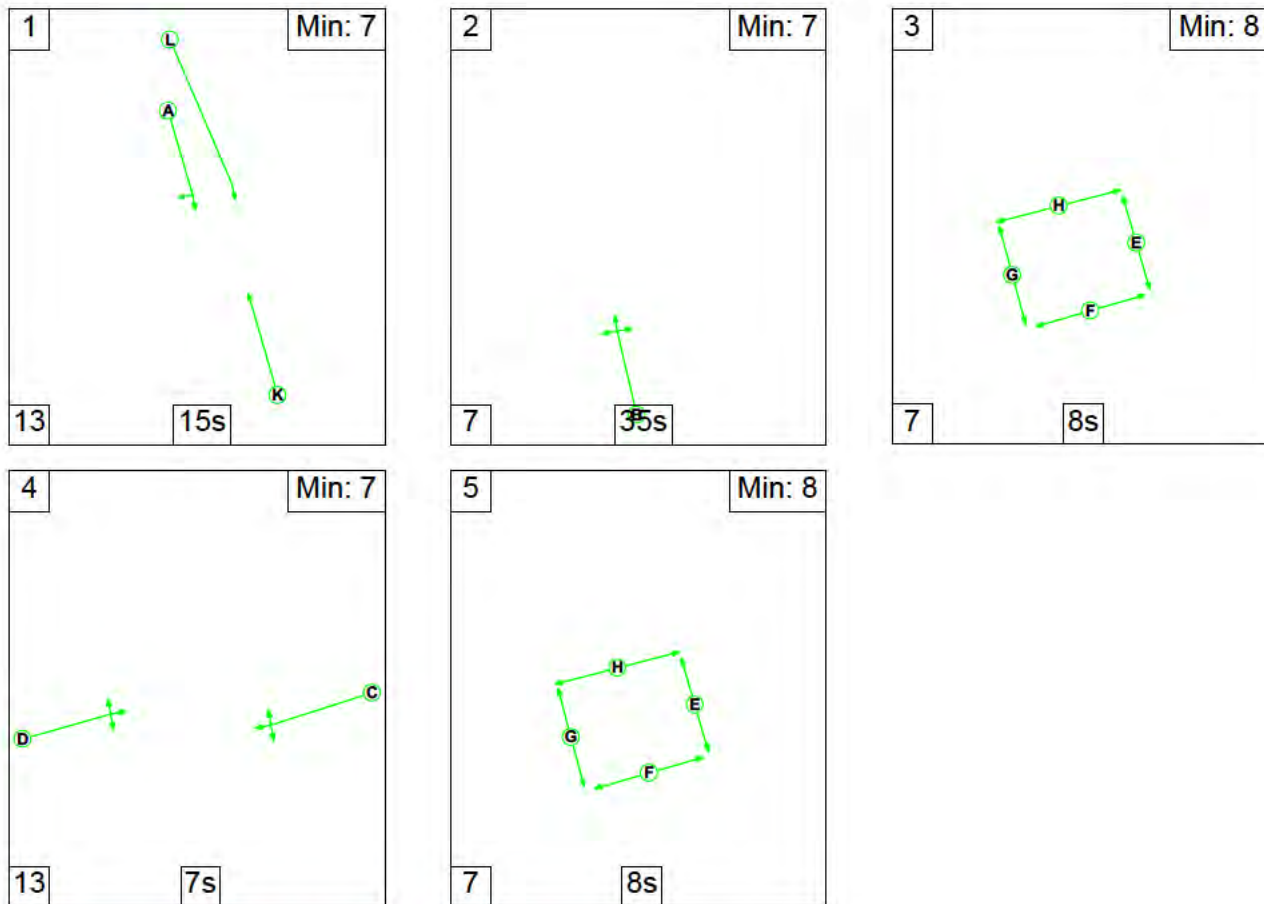


Figure 149: Stage Diagram - Option B (Stream 1)

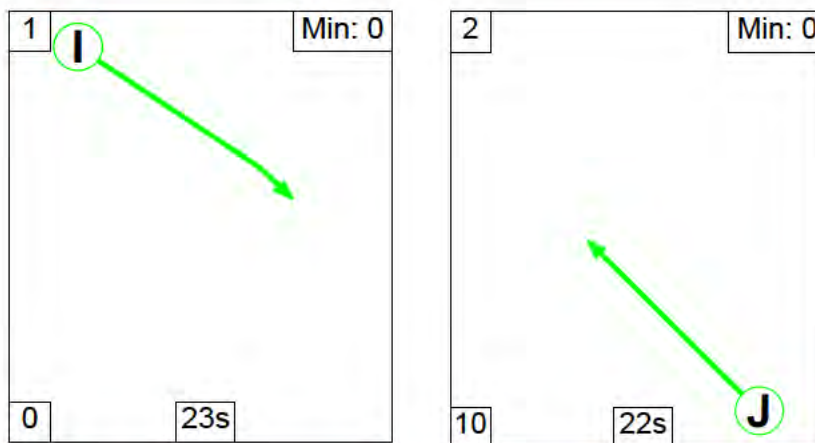


Figure 150: Stage Diagram - Option B (Stream 2)

In addition, new signal timings were produced for The Mound / Market Street junction, to improve coordination between the Market Street / The Mound and High Street / George IV Bridge junctions.

In order to improve the green wave between the High Street / George IV Bridge and The Mound / Market Street junctions, an offset of 20 seconds was set for Option A and an offset of 5 seconds was set for Option B.

Table 24 summarises the journey times for cyclists for the following options:

- Option 2 Hybrid;
- Option 2 Hybrid with Option A signal settings for the High Street / George IV Bridge junction; and
- Option 2 Hybrid with Option B signal settings for the High Street / George IV Bridge junction.

In the remainder of this Appendix Option 2 Hybrid with Option A signal settings will be referred to as “Option A” and Option 2 Hybrid with Option B signal settings will be referred to as “Option B”.

Overall, both options slightly reduce the end-to-end journey time for cyclists in both directions for the AM and PM peak periods in comparison to the Option 2 Hybrid model. In the AM peak, Option A and Option B are 23 to 25 seconds faster in the northbound direction and 6 to 8 seconds faster in the southbound direction than Option 2 Hybrid. Similarly, in the PM peak, Option A and Option B are 34 to 36 seconds faster in the northbound direction and 4 to 13 seconds faster in the southbound direction in comparison to the Option 2 Hybrid model.

The difference in the end-to end journey times between Option A and Option B is marginal. Option A is generally 2 to 7 seconds faster during the AM peak in both directions. In the PM peak Option B is faster than Option A by 2 seconds in the northbound direction and is slower by 9 seconds in the southbound direction.

Most of the cyclists travel northbound in the morning peak (160 cyclists) and southbound in the evening peak (69 cyclists). In the morning, cyclists travelling northbound in Option B pass through the High Street / George IV Bridge junction faster by 8 seconds compared to in Option A. This is because cyclists travelling northbound get more green time at the High Street / George IV Bridge in Option B compared to in Option A.

In the evening, cyclists travelling southbound in Option A require less time to pass through the High Street / George IV Bridge junction. The reason for that is that there is a longer green wave for cyclists between The Mound / Market Street and High Street / George IV Bridge junctions in Option A.

Table 24: Cyclist Journey Time

Direction	From	To	Option 2 Hybrid AM	AM Option A	AM Option B	Option 2 Hybrid PM	PM Option A	PM Option B
NB	Meadows	Meadows / Lauriston	00:00:44	00:00:44	00:00:44	00:00:44	00:00:44	00:00:44
	Meadows / Lauriston	Forrest Road /Bristo Place	00:01:13	00:01:13	00:01:13	00:01:10	00:01:09	00:01:10
	Forrest Road /Bristo Place	Chambers Street	00:01:14	00:01:14	00:01:14	00:01:10	00:01:10	00:01:10
	<u>Chambers Street</u>	<u>Royal Mile</u>	00:01:40	00:01:53	00:01:45	00:01:34	00:01:50	00:01:38
	<u>Royal Mile</u>	<u>Market Street</u>	00:01:39	00:01:52	00:01:07	00:01:31	00:01:43	00:01:50
	Market Street	Princes Street	00:01:40	00:01:47	00:01:47	00:01:42	00:01:40	00:01:42
	Princes Street	George Street	00:00:47	00:00:49	00:00:49	00:00:57	00:00:58	00:00:58
TOTAL	Meadows	George Street	00:08:57	00:08:32	00:08:39	00:08:48	00:08:14	00:08:12
SB	George Street	Princes Street	00:01:26	00:01:26	00:01:26	00:01:16	00:01:16	00:01:16
	<u>Princes Street</u>	<u>Market Street</u>	00:01:45	00:01:49	00:01:44	00:01:47	00:01:54	00:01:55
	<u>Market Street</u>	<u>Royal Mile</u>	00:01:29	00:01:17	00:01:20	00:01:32	00:01:17	00:01:20
	Royal Mile	Chambers Street	00:01:28	00:01:25	00:01:34	00:01:29	00:01:26	00:01:34
	Chambers Street	Forrest Road /Bristo Place	00:00:24	00:00:27	00:00:21	00:00:43	00:00:42	00:00:39
	Forrest Road /Bristo Place	Meadows / Lauriston	00:00:49	00:00:49	00:00:50	00:00:51	00:00:50	00:00:50
	Meadows / Lauriston	Meadows	00:00:23	00:00:23	00:00:23	00:00:24	00:00:24	00:00:24
TOTAL	George Street	Meadows	00:07:44	00:07:36	00:07:38	00:08:02	00:07:49	00:07:58

Figure 151 and Figure 152 show the journey time profiles for cyclists in the northbound direction for Option 2, Option 2 Hybrid and for the two sub-test options – Option A and Option B.

Figure 151 and Figure 152 highlight that cyclists in Option A and Option B travelling in the northbound direction pass through the section from Royal Mile to Market Street faster in comparison to cyclists in Option 2 and Option 2 Hybrid. This is due to the better signal coordination between the Royal Mile and Market Street and hence a longer green wave between the junctions.

As a result of the improved signal coordination between the George IV Bridge / Royal Mile and The Mound / Market Street junctions, more cyclists in Option A and Option B get to The Mound / Princes Street junction and not all of them are able to pass through the Princes Street within one cycle. This means that cyclists must wait until the next cycle to pass through The Mound / Princes Street junction.

Overall, the journey time results that were obtained appear sensible, as cyclists in Option A and Option B can pass through The Mound / Market Street junction faster due to the improved signal settings for the High Street / George IV Bridge junction and The Mound / Market Street junction, but therefore experience a longer delay at The Mound / Princes Street junction. As a result, end-to-end journey times for Option A and Option B are similar to Option 2 but are 8 to 13 seconds less than the cycle journey time in the Option 2 Hybrid model.

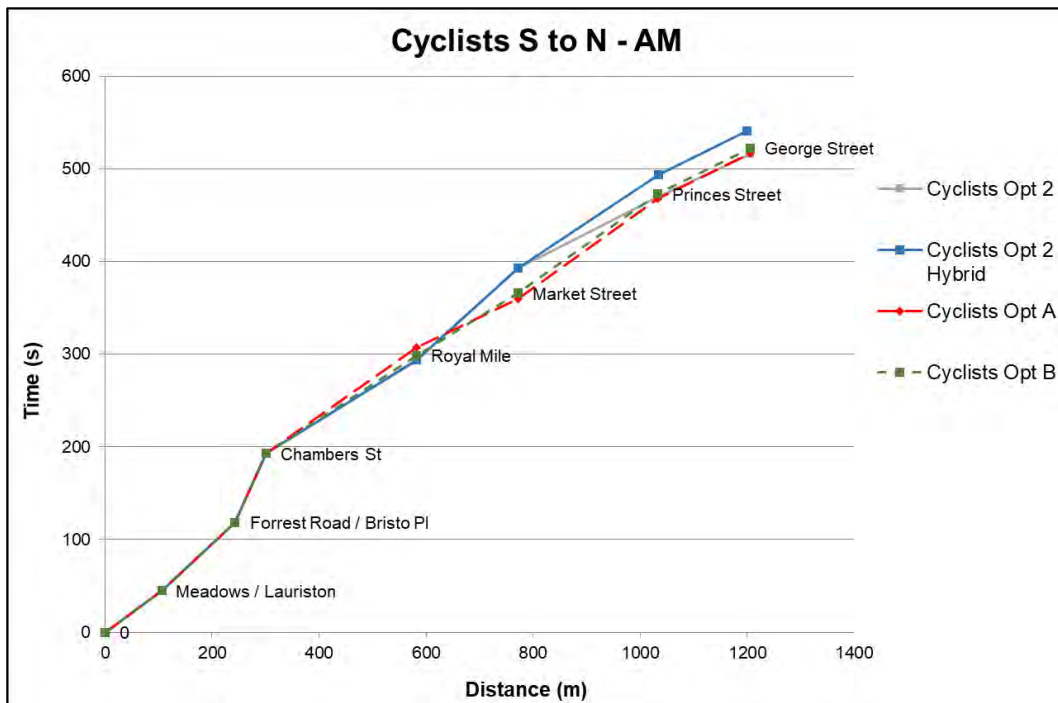


Figure 151: AM Cyclist Journey Time NB

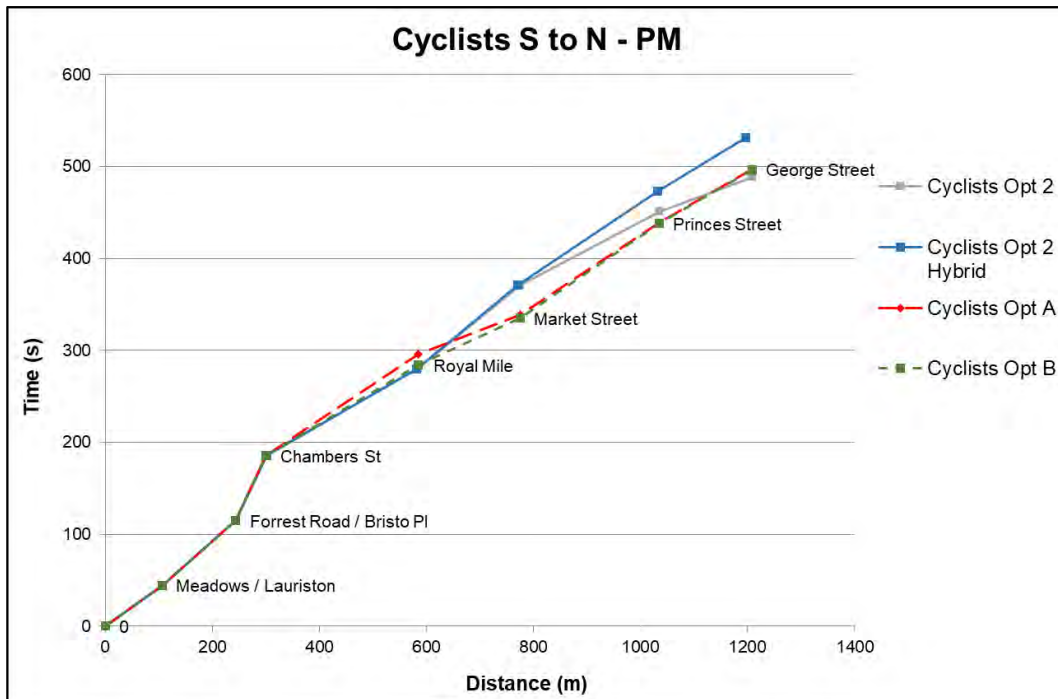


Figure 152: PM Cyclist Journey Time NB

Figure 153 and Figure 154 show cyclist journey time profiles in the southbound direction for Option 2, Option 2 Hybrid, Option A and Option B.

Figure 153 and Figure 154 highlights that the difference in cyclist journey times in the southbound direction is marginal between all of the options for both the AM and PM peak periods. However, for both the AM and PM peak periods, cyclists in Option A and Option B require less time to pass through the section from Market Street to Royal Mile in comparison to cyclists in Option 2 and Option 2 Hybrid. This is due to improved signal coordination between The Mound / Market Street and George IV Bridge / High Street junctions.

Overall, based on the results, it can be said that neither the Option A and Option B signal settings significantly improves the end-to-end cyclists journey times in the southbound direction, albeit there is an improved journey time between Market Street and the Royal Mile.

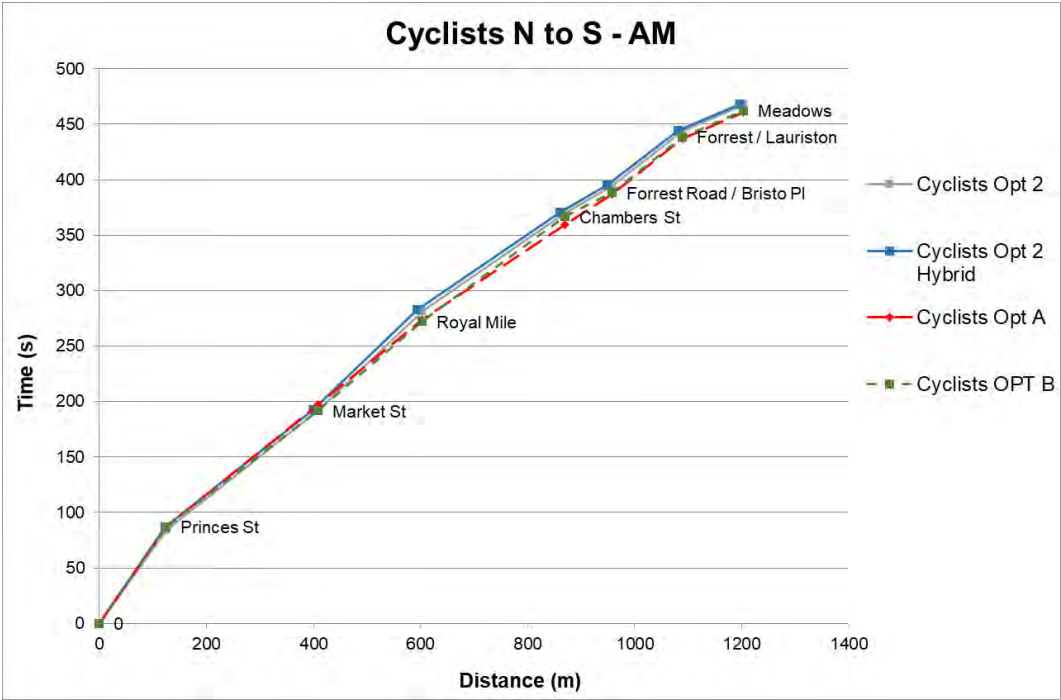


Figure 153: AM Cyclist Journey Time SB

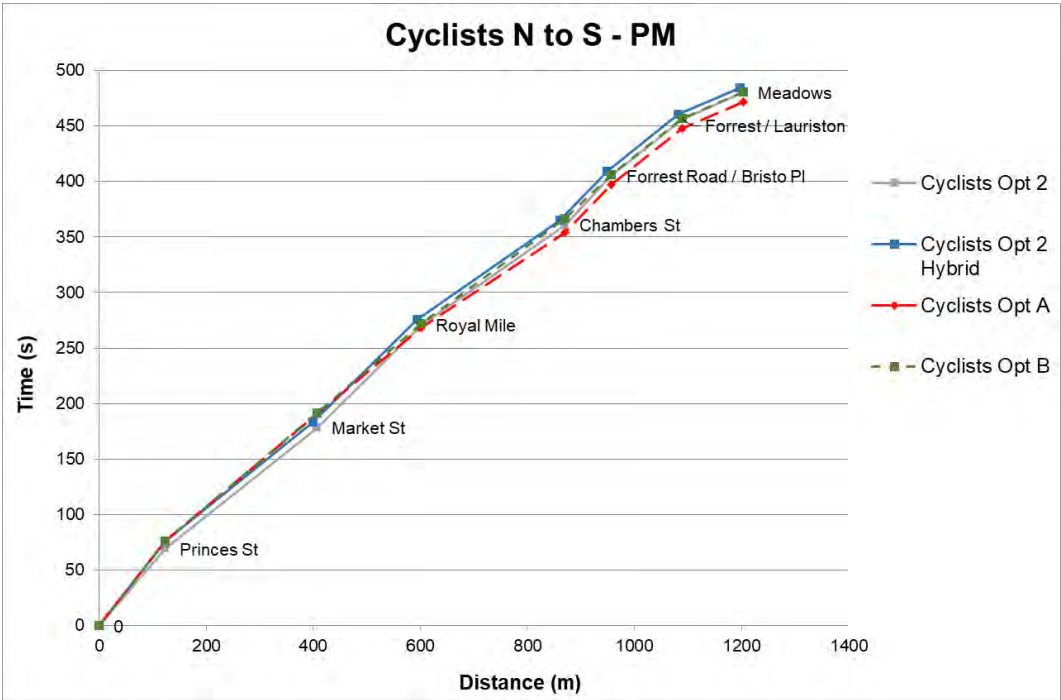


Figure 154: PM Cyclist Journey Time SB

Table 25 summarises the bus journey times for Option 2 Hybrid and the two sub-tests – Option A and Option B.

According to Table 25, Option B shows lower end-to-end journey time for buses travelling southbound in the AM peak and for buses travelling northbound in the PM peak. In the AM peak, the bus journey time in the southbound direction using the Option B signal settings is 7 minutes and 14 seconds, which is 26 seconds faster than bus journey time using the Option A signal settings. In the PM peak, the Option B bus journey time in the northbound direction is 9 minutes and 32 seconds, which is 28 seconds faster than Option A.

However, Option A demonstrates better end-to-end journey time for buses travelling northbound in the AM peak, although this is marginal. Using the Option A signal settings, buses travel from Teviot Place to George Street 4 seconds faster than Option B buses.

Based on the results in Table 25, it can be said that both Option A and Option B have quicker end-to-end journey times in comparison to Option 2 Hybrid.

Table 25: Bus Journey Time

Direction	From	To	Option 2 Hybrid AM	AM Option A	AM Option B	Option 2 Hybrid PM	PM Option A	PM Option B
NB	Teviot Place	Teviot Pl / Bristo Pl	00:02:04	00:02:05	00:02:03	00:02:49	00:02:49	00:02:47
	Teviot Pl / Bristo Pl	Chambers Street	00:01:02	00:01:01	00:01:02	00:01:07	00:01:06	00:01:06
	<u>Chambers Street</u>	<u>Royal Mile</u>	00:01:39	00:01:16	00:01:19	00:01:39	00:01:24	00:01:32
	<u>Royal Mile</u>	<u>Market Street</u>	00:01:48	00:00:59	00:01:05	00:02:26	00:01:33	00:00:58
	Market Street	Princes Street	00:01:52	00:01:55	00:01:56	00:01:44	00:01:43	00:01:49
	Princes Street	George Street	00:01:19	00:01:19	00:01:14	00:01:19	00:01:25	00:01:20
TOTAL	Teviot Place	George Street	00:09:44	00:08:35	00:08:39	00:11:04	00:10:00	00:09:32
SB	George Street	Princes Street	00:01:46	00:01:46	00:01:46	00:01:36	00:01:36	00:01:36
	<u>Princes Street</u>	<u>Market Street</u>	00:01:47	00:01:48	00:01:41	00:01:51	00:01:59	00:02:06
	<u>Market Street</u>	<u>Royal Mile</u>	00:01:10	00:00:58	00:00:50	00:01:07	00:00:53	00:00:45
	Royal Mile	Chambers Street	00:01:43	00:01:43	00:01:33	00:01:45	00:01:48	00:01:45
	Chambers Street	Teviot Pl / Bristo Pl	00:00:32	00:00:32	00:00:31	00:00:17	00:00:17	00:00:20
	Teviot Pl / Bristo Pl	Teviot Place	00:00:55	00:00:53	00:00:53	00:00:56	00:00:56	00:00:57
TOTAL	George Street	Teviot Place	00:07:53	00:07:40	00:07:14	00:07:32	00:07:29	00:07:29

Figure 155 to Figure 158 below show the bus journey time profiles for the AM and PM peak periods. The journey time profiles in Figure 155 and Figure 156 highlight that both Option A and Option B significantly reduce bus journey times in the northbound direction for both the AM and PM peak periods. The reduction in bus journey time is due to the better operation of the shuttle working between the Royal Mile and Market Street.

In the southbound direction, Option A and Option B show less of a reduction in bus journey time in comparison to the northbound direction, as shown in Figure 157 and Figure 158.

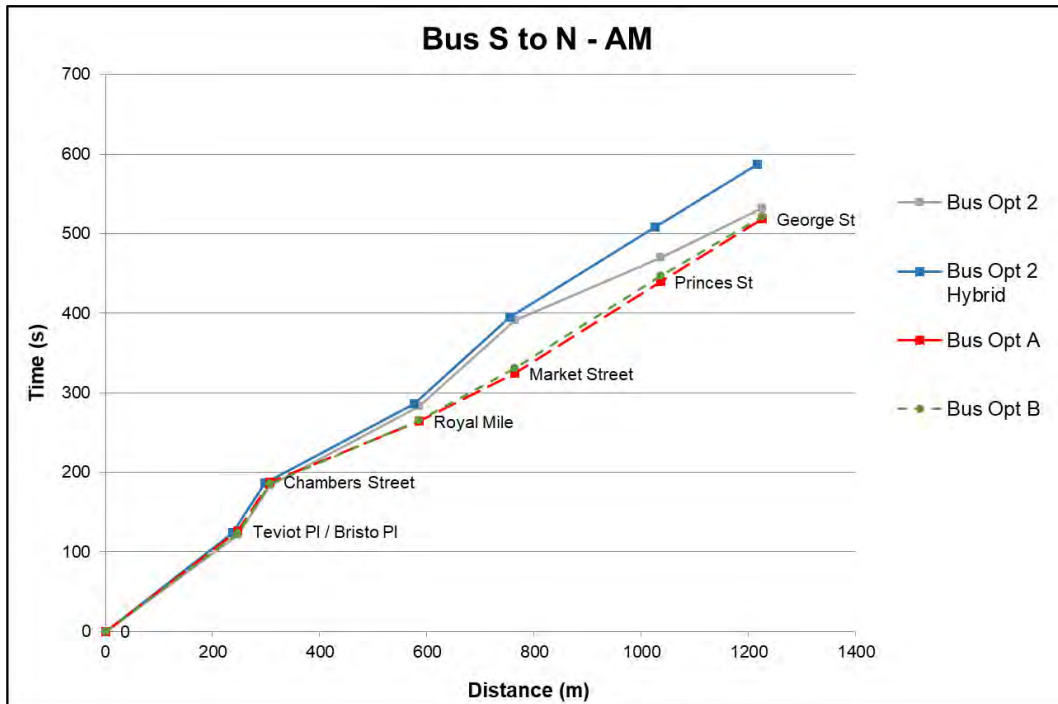


Figure 155: AM Bus Journey Time NB

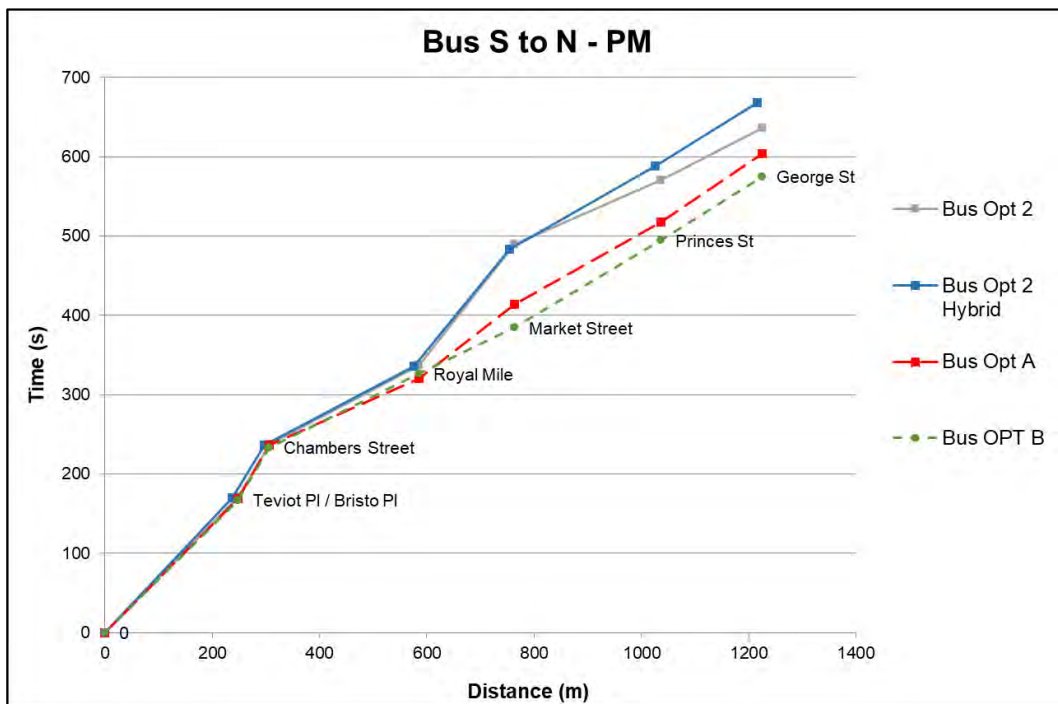


Figure 156: PM Bus journey time NB

Figure 157 and Figure 158 display bus journey time profiles for Option 2, Option 2 Hybrid, Option A and Option B in the southbound direction for both the AM and PM peak periods. The figures below highlight that the Option A bus journey time profiles in the AM and PM peak periods are almost the same as those for Option 2 and

Option 2 Hybrid journey time profiles. Also, the Option B journey time profile in the PM peak is similar to the profiles for Option 2 and Option 2 Hybrid.

However, Option B shows more significant reduction in bus journey time in the southbound direction in the AM peak. The bus journey time when using the Option B signal settings is 39 seconds faster than bus journey time in Option 2 Hybrid.

Overall, journey time profiles in Figure 157 and Figure 158 shows that signal coordination between The Mound / Market Street and George IV Bridge / High Street junctions is less effective in the southbound direction than in the northbound direction.

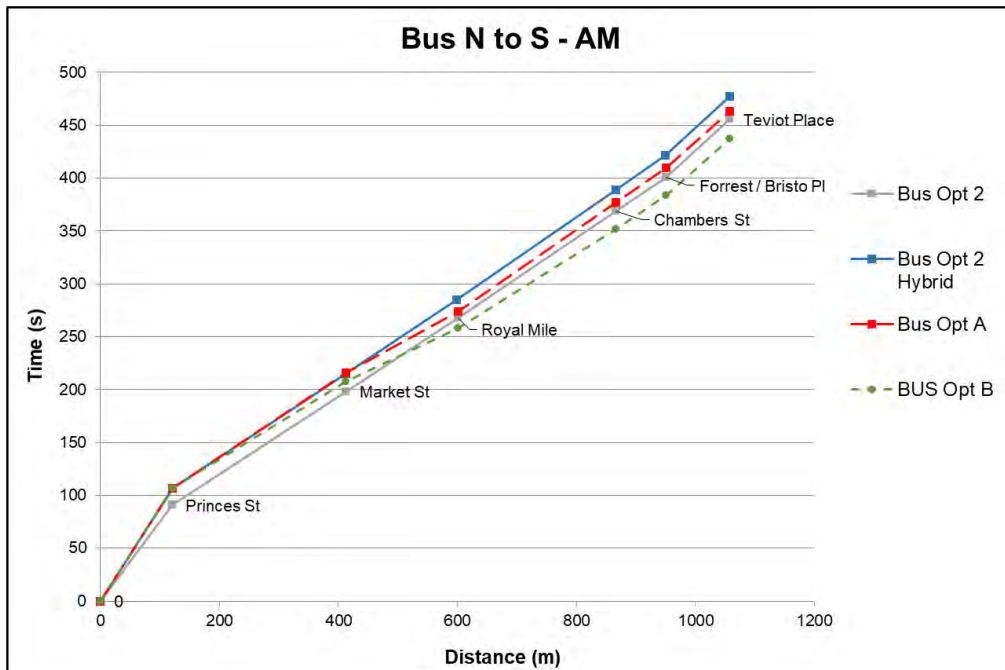


Figure 157: Bus journey time SB

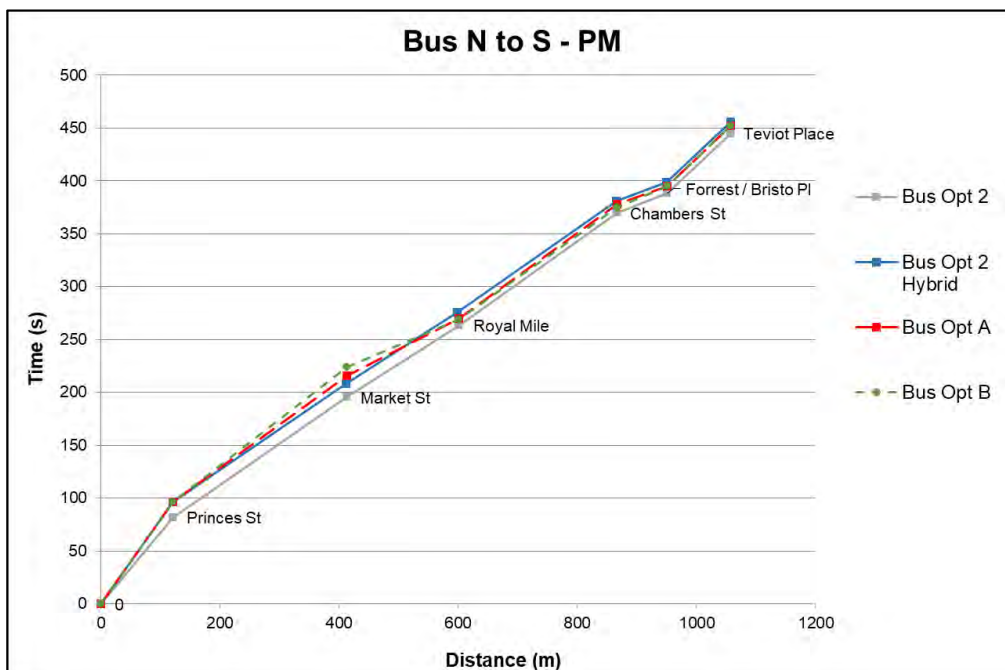


Figure 158: PM Bus journey time SB

D.6 Bus Stop on George IV Bridge Sub-Test

The aim of this sub-test was to assess an impact on traffic caused by the relocation of the southbound “Victoria Street” bus stop closer to the Royal Mile / George IV Bridge junction. At the present time, the southbound “Victoria Street” bus stop is located at George IV Bridge / Victoria street junction approximately 90 metres from the Royal Mile / George IV Bridge junction, however under the new design the bus stop will be located closer to the Royal Mile, approximately 25 metres from the Royal Mile / George IV Bridge junction. Figure 159 below presents existing and proposed locations of the southbound “Victoria Street” bus stop.

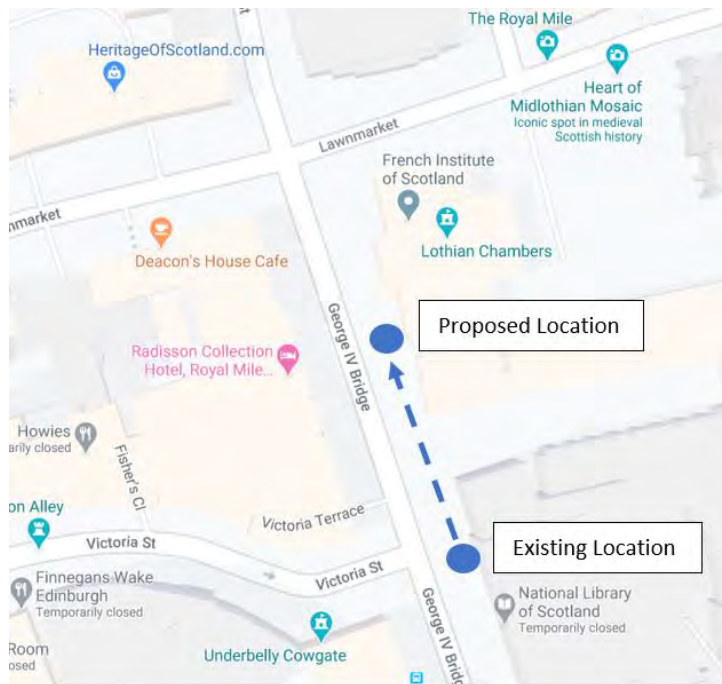


Figure 159: Victoria Street Bus Stop Location

Option B model was chosen to assess an impact of the new location of “Victoria Street” bus stop on George IV Bridge. In the Option B model “Victoria Street” bus stop was moved closer to the George IV Bridge / Royal Mile junction, so that distance to the junction was approximately 25 metres; and distance to the pedestrian crossing on George IV Bridge was approximately 20 metres.

The dwell time in Option B model on “Victoria Street” bus stop was 7 seconds. To have more confidence in the modelling results two additional models with 17 seconds and 27 seconds dwell times were created as part of this sub-test.

In order to assess an impact of the new bus stop location on traffic, queue length data from the “Victoria Street” bus stop to the George IV Bridge / Royal Mile junction was collected. Figure 160 below shows obtained queue length data from all three sub-test models.

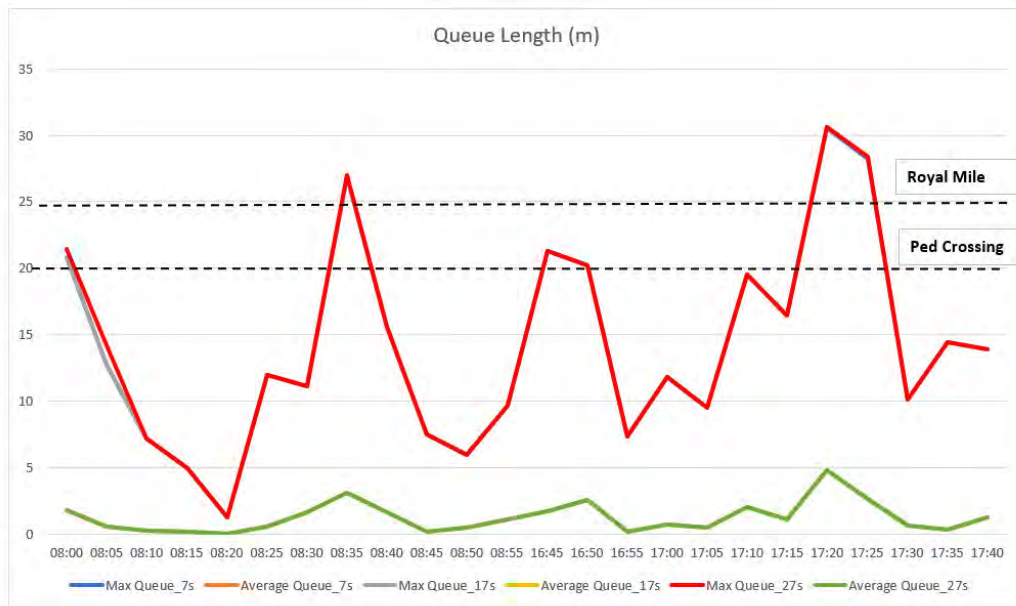


Figure 160: Queue lengths on George IV Bridge

According to Figure 160 above, all three sub-tests shown almost identical queue length results behind the bus on “Victoria Street” bus stop, with a marginal difference in queue length of 1 metre was observed at 08:05. Overall, the average queue length is below 5 metres across AM and PM peak periods. The reason for this is a small number of vehicles using George IV Bridge in the AM and PM peak periods.

However, maximum queues above 20 metres and above 25 metres were observed at 08:00 and 08:35 in the AM peak period and from 16:40 to 16:45 and from 17:20 to 17:25 in the PM peak period. Observed maximum queue above 25 metres long, extends all the way back from the bus stop to the George IV Bridge / Royal Mile junction. Furthermore, observed maximum queue above 20 metres long, means that vehicles are queueing on the pedestrian crossing on George IV Bridge.

Overall under the signal settings arrangement at George IV Bridge / Royal Mile junction in Option B model, observed queue from the bus stop to the junction doesn’t delay traffic on Royal Mile and pedestrians on George IV Bridge, as traffic in the queue have enough time to start movement before the traffic on Royal Mile or pedestrians get green light.

In Option B model, northbound traffic on George IV Bridge gets green at the separate stage after the southbound traffic, which means that the time gap between the southbound traffic and the traffic on Royal Mile stage is 70 seconds in the AM and PM peak periods. In addition, the time gap between the southbound traffic stage and pedestrian stage is 49 seconds in the AM and PM peak periods. It is enough time for traffic in the queue to clear the road section between the bus stop and the junction.

Although, vehicles queueing on George IV Bridge behind the bus on “Victoria Street” bus stop do not delay pedestrians or traffic on Royal Mile, it was decided to shift the bus stop 10 metres down south to get more capacity for queueing traffic on George IV Bridge.

D.7 Summary and Recommendations

Considering the journey time results presented in this Appendix and the initial assessment of the design options described in the main report, it can be concluded that Option 2 Hybrid with Option B signal settings for the High Street / George IV Bridge junction can be considered to be the preferred design option, as it provides the best combination of safety for cyclists and journey time results for both cyclists and buses. The key benefits of the Option 2 Hybrid design are that the cycleway is on the east side of the road and then crosses to the west side of the road at the Hanover Street / Princes Street junction. This design feature and dedicated cycling stage allows

cyclists to cross the tram lines on Princes Street safely, without interacting with traffic. Furthermore, the improved signal settings at High Street / George IV Bridge junction reduce the Option 2 Hybrid journey time results for buses and cyclists. As a result, the end-to-end journey time results for cyclists in the Option 2 Hybrid models are almost equal to the Option 2 results in both directions for both the AM and PM peak periods. Furthermore, with the improved signal settings, Option 2 Hybrid demonstrates significantly lower bus end-to-end journey times than Option 2 in the northbound direction for the PM peak period and slightly lower journey time results for the AM peak period.