



Hagley VISSIM Model

Worcestershire County Council

Options Testing Report - Final Draft

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Hagley VISSIM Model

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Contents

Executive Summary	8
1. Introduction	14
1.1 Background	14
1.2 Purpose of the Report	14
1.3 Structure of the Report	15
1.4 Previous Study	15
1.4.1 Salient findings	15
1.4.1.1 A456 / A491 Stourbridge Road roundabout	15
1.4.1.2 A456 / B4187 Worcester Road	16
1.4.1.3 A456 / A450 Worcester Road	16
1.4.2 Summary	16
2. Option Testing Model Development	17
2.1 Modelled Options	17
3. Model Inputs	21
3.1 Input Data	21
3.2 Traffic Flow from Major Local Plan Developments	21
3.2.1 Stone Hill North	22
3.2.2 Lea Castle	25
4. Model Outputs - Options 1a, 1b and 1c	28
4.1 Model Runs	28
4.2 Junction Flows	28
4.3 Junction Delays	29
4.4 Journey Times	30
5. A456 / B4187 Junction Improvement – Traffic Engineering Feasibility	42
5.1 Existing Layout	42
5.2 Design Speed	42
5.3 Design Constraints	42
5.4 Lane widths	42
5.5 Vehicle Movements	43
5.6 Signalling and Maintenance Bays	43
5.7 Conclusion	43
6. Model Outputs - Options 2 and 3	44
6.1 2036 Results	44
6.2 2019 Results	44
6.2.1 Junction Flows	45
6.2.2 Junction Delays	45
6.2.3 Journey Times	46
7. A491 Kidderminster Rd/ Stourbridge Rd (Cattle Market Junction) Enhancements	57
7.1 Introduction	57
7.2 WCC Option	57

7.3	Alternative Option.....	58
8.	Model Outputs – Options 4 and 4b.....	59
8.1	Model Runs.....	59
8.2	Junction Flows	59
8.2.1	Junction Delays.....	62
8.2.2	Journey Times	64
9.	A456/A491 Hagley Roundabout Enhancements	75
9.1	Introduction	75
9.2	Technical References:.....	75
9.3	Existing Conditions.....	75
9.4	Options	75
9.5	Summary	81
10.	Model Outputs – Options 5a, 5b and 5c	82
10.1	Model Runs.....	82
10.2	2019 Results.....	82
10.2.1	Junction Flows	82
10.2.2	Junction Delays.....	85
10.2.3	Journey Times	86
10.3	2036 Results.....	97
10.3.1	Junction Flows	97
10.3.2	Junction Delays.....	99
10.3.3	Journey Times	101
10.3.4	Vehicles Unable to Enter the Network	112
11.	Summary and Conclusions	114
11.1	Summary	114
11.2	Conclusion.....	114
11.3	Recommendations	119
	Appendix A - A456/B4187 junction scheme drawings (Existing and Proposed layout)	120

List of Figures

Figure 1 Summary graph for Option 1c.....	9
Figure 2 Summary graph for Option 4	11
Figure 3 Summary graph for Option 5a	12
Figure 4 Summary graph for Option 5b	12
Figure 5 Summary graph for Option 5c.....	13
Figure 1-1 Junctions Assessed	14
Figure 2-1 Option 1a layout A456/B4187 Worcester Road junction.....	17
Figure 2-2 Option 1b layout A456/B4187 Worcester Road junction.....	18
Figure 2-3 Option 1c layout A456/B4187 Worcester Road junction.....	18
Figure 2-4 Option 2 layout at A450/A456 and A456/Stakenbridge junction.....	19
Figure 2-5 Option 3 - A450/A456 junction- Gyratory	20
Figure 3-1: Stone Hill North Traffic Flow – 2036 AM Peak	23
Figure 3-2: Stone Hill North Traffic Flow – 2036 PM Peak	24
Figure 3-3: Lea Castle Traffic Flow – 2036 AM Peak	26
Figure 3-4: Lea Castle Traffic Flow – 2036 PM Peak	27
Figure 4-1 Journey Time Routes	31
Figure 4-2: Route 1 NB - 2019 AM Journey Times – Options 1a, 1b and 1c.....	33
Figure 4-3: Route 1 SB - 2019 AM Journey Times – Options 1a, 1b and 1c.....	34
Figure 4-4: Route 2 NB – 2019 AM Journey Times – Options 1a, 1b and 1c.....	35
Figure 4-5: Route 2 SB – 2019 AM Journey Times – Options 1a, 1b and 1c.....	36
Figure 4-6: Route 1 NB - 2019 PM Journey Times – Options 1a, 1b and 1c.....	38
Figure 4-7: Route 1 SB - 2019 PM Journey Times – Options 1a, 1b and 1c.....	39
Figure 4-8: Route 2 NB – 2019 PM Journey Times – Options 1a, 1b and 1c.....	40
Figure 4-9: Route 2 SB – 2019 PM Journey Times – Options 1a, 1b and 1c.....	41
Figure 5-1: Google Streetview Image 1	43
Figure 5-2: Google Streetview Image 2	43
Figure 6-1: Route 1 SB – AM Journey Times – Option 1b (2019) and Option 2 (2036).....	44
Figure 6-2: Route 1 NB – 2019 AM Journey Times – Options 2 and 3	48
Figure 6-3: Route 1 SB – 2019 AM Journey Times – Options 2 and 3	49
Figure 6-4: Route 2 NB – 2019 AM Journey Times – Options 2 and 3	50
Figure 6-5: Route 2 SB – 2019 AM Journey Times – Options 2 and 3	51
Figure 6-6: Route 1 NB – 2019 PM Journey Times – Options 2 and 3	53
Figure 6-7: Route 1 SB – 2019 PM Journey Times – Options 2 and 3	54
Figure 6-8: Route 2 NB – 2019 PM Journey Times – Options 2 and 3	55
Figure 6-9: Route 2 SB – 2019 PM Journey Times – Options 2 and 3	56
Figure 7-1 Highway Boundary data for Cattle market Junction.....	58
Figure 8-1: Route 1 NB – 2019 AM Journey Times – Option 4 and 4b.....	66
Figure 8-2: Route 1 SB – 2019 AM Journey Times – Option 4 and 4b	67
Figure 8-3: Route 2 NB – 2019 AM Journey Times – Option 4 and 4b.....	68
Figure 8-4: Route 2 SB – 2019 AM Journey Times – Option 4 and 4b	69
Figure 8-5: Route 1 NB – 2019 PM Journey Times – Option 4 and 4b.....	71
Figure 8-6: Route 1 SB – 2019 PM Journey Times – Option 4 and 4b	72
Figure 8-7: Route 2 NB – 2019 PM Journey Times – Option 4 and 4b.....	73
Figure 8-8: Route 2 SB – 2019 PM Journey Times – Option 4 and 4b	74
Figure 9-1: Option i - Minor Widening Works	77
Figure 9-2: Option ii - Same improvements as Option i but with Park Road East entry closed	78
Figure 9-3: Option iii - Same improvements as Option i with Park Road East closed for all traffic.....	79
Figure 9-4: Option iv - Same improvements as Option i but increase the width of the A491 circulatory lane	80
Figure 9-5: Option v - A456 Through-About.....	81
Figure 10-1: Route 1 NB – 2019 AM Journey Times – Options 4, 5a, 5b and 5c.....	88
Figure 10-2: Route 1 SB – 2019 AM Journey Times – Options 4, 5a, 5b and 5c	89
Figure 10-3: Route 2 NB – 2019 AM Journey Times – Options 4, 5a, 5b and 5c.....	90
Figure 10-4: Route 2 SB – 2019 AM Journey Times – Options 4, 5a, 5b and 5c	91
Figure 10-5: Route 1 NB – 2019 PM Journey Times – Options 4, 5a, 5b and 5c.....	93
Figure 10-6: Route 1 SB – 2019 PM Journey Times – Options 4, 5a, 5b and 5c	94

Figure 10-7: Route 2 NB – 2019 PM Journey Times – Options 4, 5a, 5b and 5c	95
Figure 10-8: Route 2 SB – 2019 PM Journey Times – Options 4, 5a, 5b and 5c	96
Figure 10-9: Route 1 NB – 2036 AM Journey Times – Options 5a, 5b and 5c	103
Figure 10-10: Route 1 SB – 2036 AM Journey Times – Options 5a, 5b and 5c	104
Figure 10-11: Route 2 NB – 2036 AM Journey Times – Options 5a, 5b and 5c	105
Figure 10-12: Route 2 SB – 2036 AM Journey Times – Options 5a, 5b and 5c	106
Figure 10-13: Route 1 NB – 2036 PM Journey Times – Options 5a, 5b and 5c	108
Figure 10-14: Route 1 SB – 2036 PM Journey Times – Options 5a, 5b and 5c	109
Figure 10-15: Route 2 NB – 2036 PM Journey Times – Options 5a, 5b and 5c	110
Figure 10-16: Route 2 SB – 2036 PM Journey Times – Options 5a, 5b and 5c	111
Figure 10-17: VISSIM Zone Locations	113
Figure 11-1 Summary graph for 2019 Option 1c	115
Figure 11-2 Summary graph for 2019 Option 4	116
Figure 11-3 Summary graph for 2036 with No Improvements at A456 / A491 Roundabout	117
Figure 11-4 Summary graph for Option 5a	118
Figure 11-5 Summary graph for Option 5b	118
Figure 11-6 Summary graph for Option 5c	119

List of Tables

Table 1 Option 1a, 1b and 1c - Journey Times – 2019 AM	9
Table 2 Option 1a, 1b and 1c - Journey Times – 2019 PM	9
Table 3 Option 1c, 2 and 3 - Journey Times – 2019 AM	10
Table 4 Option 1c, 2 and 3 - Journey Times – 2019 PM	10
Table 5 Option 1c, 4 and 4b - Journey Times – 2019 AM	10
Table 6 Option 1c, 4 and 4b - Journey Times – 2019 PM	10
Table 2-1: Summary of Options modelled	20
Table 3-1 2019 to 2036 TEMPro v7.2 Growth	21
Table 3-2: 2036 Forecast Matrix Growth	21
Table 4-1: Options 1a, 1b and 1c - Junction Flows	28
Table 4-2: Options 1a, 1b and 1c - Junction Delays	29
Table 4-3: Journey Time Route Descriptions	30
Table 4-4: 2019 AM Peak Journey Times - Option 1a, 1b and 1c	31
Table 4-5: 2019 PM Peak Journey Times - Option 1a, 1b and 1c	37
Table 6-1: Options 1c, 2 and 3 - Junction Flows	45
Table 6-2: Options 1c, 2 and 3 - Junction Delays	46
Table 6-3: 2019 AM Peak Journey Times - Option 1c, 2 and 3	46
Table 6-4: 2019 PM Peak Journey Times – Options 1c, 2 and 3	52
Table 8-1: Options 1c, 4 and 4b - Junction Flows – 2019 AM Pre-Peak and Peak Hours	59
Table 8-2: Options 1c, 4 and 4b - Junction Flows – 2019 PM Pre-Peak and Peak Hours	60
Table 8-3: Options 1c, 4 and 4b - Junction Flows – 2019 AM and PM Two-Hour Peak Periods	61
Table 8-4: Options 1c, 4 and 4b - Junction Delays	63
Table 8-5: A456 / A491 Signalised Junction Delays	64
Table 8-6: 2019 AM Peak Journey Times - Option 1c, 4 and 4b	64
Table 8-7: 2019 PM Peak Journey Times – Options 1c, 4 and 4b	70
Table 9-1: List of Options	76
Table 10-1: Options 4, 5a, 5b and 5c - Junction Flows – 2019 AM Peak	82
Table 10-2: Options 4, 5a, 5b and 5c - Junction Flows – 2019 AM 2-hour Peak	83
Table 10-3: Options 4, 5a, 5b and 5c - Junction Flows – 2019 PM Peak	84
Table 10-4: Options 4, 5a, 5b and 5c - Junction Flows – 2019 PM 2-hour Peak	84
Table 10-5: Options 4, 5a, 5b and 5b - Junction Delays – 2019 AM Peak	85
Table 10-6: Options 4, 5a, 5b and 5b - Junction Delays – 2019 PM Peak	86
Table 10-7: 2019 AM Peak Journey Times - Option 4, 5a, 5b and 5c	86
Table 10-8: 2019 PM Peak Journey Times – Options 4, 5a, 5b and 5c	92
Table 10-9: Options 5a, 5b and 5c - Junction Flows – 2036 AM Peak	97
Table 10-10: Options 5a, 5b and 5c - Junction Flows – 2036 AM 2-hour Peak	97

Table 10-11: Options 5a, 5b and 5c - Junction Flows – 2036 PM Peak.....	98
Table 10-12: Options 5a, 5b and 5c - Junction Flows – 2036 PM 2-hour Peak.....	99
Table 10-13: Options 5a, 5b and 5c - Junction Delays – 2036 AM Peak	100
Table 10-14: Options 5a, 5b and 5b - Junction Delays – 2036 PM Peak.....	101
Table 10-15: 2036 AM Peak Journey Times – Options 5a, 5b and 5c.....	101
Table 10-16: 2036 PM Peak Journey Times – Options 5a, 5b and 5c.....	107
Table 10-17: Vehicles Unable to Enter the Network.....	112

Executive Summary

Jacobs was commissioned by WCC to develop a micro-simulation traffic model of Hagley in order to evaluate potential highway improvement schemes at four junctions in the network. They are the A456 Kidderminster Rd / A450 Worcester Rd junction; A456 Kidderminster Rd / B4187 Worcester Road junction; the A456/A491 Cattle Market junction; and the A456 Kidderminster Rd / A491 Stourbridge Road/Park Road Roundabout. The A456/Stakenbridge Lane priority junction and A450/Thicknall Lane priority junction were assessed as part of two options developed.

The following options have been tested:

- Option 1a: Amend the A456/B4187 Worcester junction to layout prior to Cala Home developers implementing their scheme in 2016;
- Option 1b: Option 1a but to current standards;
- Option 1c: Option 1b but with a ban on the right turn from A456 Kidderminster Road to B4187 Worcester Rd and a left ban from the B4187 to A456 Kidderminster Road northbound;
- Option 2: Option 1b including converting the A450 Worcester Road to one-way in the southbound direction between the A456 and Thicknall Lane junctions;
- Option 3: Option 1b including introducing a one-way gyratory around the A450, Thicknall Lane and A456;
- Option 4: Option 1c with improvements to the Cattle Market junction (A456/A491 3-arm signalised junction). Change the use of left lane on A456 Kidderminster Rd Eastbound for left turn only towards A491 Stourbridge Road;
- Option 4b: As Option 4 but with retaining the left turn from the B4187 Worcester Road Southbound to A456 Kidderminster Road Eastbound;
- Option 5a: Option 4 with improvements to the A456/A491/Park Road roundabout;
- Option 5b: Option 5a incorporating closure of the entry to the roundabout from Park Road East; and
- Option 5c: Option 5a with the creation of an internal through-about link from the A491 Kidderminster Road Southbound to the A456 Kidderminster Road Westbound.

The modelled options and corresponding junctions are summarised in the table below. No option was specifically developed for the B4187 Worcester Road/Station Road signalised junction as it was the least congested and depended on the performance of other junctions.

Junction	Options Modelled									
	1a	1b	1c	2	3	4	4b	5a	5b	5c
B4187 Worcester Rd / Station Rd / Park Rd	-	-	-	-	-	-	-	-	-	-
A456 / B4187 Worcester Rd / Summervale Rd / Western Rd	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
A456 Kidderminster Rd / A450 Worcester Rd	-	-	-	✓	✓	-	-	-	-	-
A456 Kidderminster Rd / Stakenbridge Ln / Thicknall Ln	-	-	-	✓	✓	-	-	-	-	-
A450 Worcester Rd / Thicknall Ln	-	-	-	✓	✓	-	-	-	-	-
A456 Kidderminster Rd / Park Rd / A491 Stourbridge Rd / Bennett Dr	-	-	-	-	-	-	-	✓	✓	✓
A456 Kidderminster Rd / A456 Birmingham Rd / A491 Stourbridge Rd	-	-	-	-	-	✓	✓	✓	✓	✓

Options 1a and 1b were tested with 2019 levels of traffic and were seen to be very effective in reducing congestion in the northbound direction of the A456 (towards Birmingham). Option 1c was found to provide more significant improvements in journey time and reduced delay for 2019 traffic conditions. This is presented in Table 1. As demonstrated in Figure 1 below, Option 1c leads to improvements at the A456 / Stakenbridge Lane / Thicknall Lane junction, the A456 / A450 signalised junction and the A456 / B4187 Worcester Road signalised junction in the 2019 AM and PM peaks. This is because the improvements at the A456 / B4187 Worcester Road junction reduce traffic blocking back from this junction to the upstream junctions.

Table 1 Option 1a, 1b and 1c - Journey Times – 2019 AM

	Direction	AM Peak (08:00-09:00)				
		Observed Base	Modelled Base	Option 1a	Option 1b	Option 1c
Route 1 – along A456	NB	00:13:11	00:14:49	00:10:59	00:11:04	00:10:09
	SB	00:08:19	00:09:22	00:09:32	00:09:23	00:09:17
Route 2- along A450-A456-B4187 -Park Road -A456	NB	00:14:12	00:15:18	00:11:14	00:11:02	00:10:36
	SB	00:12:54	00:13:01	00:12:13	00:12:10	00:11:59

Table 2 Option 1a, 1b and 1c - Journey Times – 2019 PM

	Direction	PM Peak (17:00-18:00)				
		Observed Base	Modelled Base	Option 1a	Option 1b	Option 1c
Route 1 – along A456	NB	00:11:00	00:10:13	00:08:37	00:08:37	00:08:28
	SB	00:10:01	00:09:03	00:08:49	00:08:42	00:08:37
Route 2- along A450-A456-B4187 -Park Road -A456	NB	00:12:23	00:10:46	00:08:58	00:09:05	00:08:54
	SB	00:10:58	00:11:27	00:10:54	00:10:51	00:10:37



Figure 1 Summary graph for Option 1c

However, the Option 1c improvements lead to an increase in delays at the A456 Kidderminster Road / A491 Stourbridge Road roundabout in the 2019 AM peak. This is because the improvements at the A456 / B4187 Worcester Road junction lead to more traffic being released to the roundabout in the northbound direction.

Options 2 and 3 were initially tested for a 2036 forecast year, but congestion on the A456 southbound approach to the A456/A491 roundabout meant traffic was not being released towards the south of the network and made results unreliable. Therefore, Options 2 and 3 were tested with 2019 levels of traffic but they were not seen to

provide any additional benefits than Options 1a, 1b and 1c alone for 2019 levels of traffic. The journey times for Options 2 and 3 for both AM and PM peak are presented in Table 2 and Table 3 and show that journey times worsen along at least one route in the PM peak in either of the two options. It was therefore concluded that Options 2 and 3 were not required for 2019 traffic levels.

Table 3 Option 1c, 2 and 3 - Journey Times – 2019 AM

	Direction	2019 AM Peak (08:00-09:00)				
		Observed Base	Modelled Base	Option 1c	Option 2	Option 3
Route 1 – along A456	NB	00:13:11	00:14:49	00:10:09	00:11:29	00:11:49
	SB	00:08:19	00:09:22	00:09:17	00:09:48	00:10:07
Route 2- along A450-A456-B4187 -Park Road -A456	NB	00:14:12	00:15:18	00:10:36	00:13:28	00:12:41
	SB	00:12:54	00:13:01	00:11:59	00:10:06	00:10:38

Table 4 Option 1c, 2 and 3 - Journey Times – 2019 PM

	Direction	PM Peak (17:00-18:00)				
		Observed Base	Modelled Base	Option 1c	Option 2	Option 3
Route 1 – along A456	NB	00:11:00	00:10:13	00:08:28	00:22:18	00:09:46
	SB	00:10:01	00:09:03	00:08:37	00:15:44	00:09:25
Route 2- along A450-A456-B4187 -Park Road -A456	NB	00:12:23	00:10:46	00:08:54	00:09:31	00:13:47
	SB	00:10:58	00:11:27	00:10:37	00:11:20	00:12:00

Compared to Option 1c, Option 4 and 4b has been identified to have the added benefit of reducing delays and queues at Cattle Market junction. In both the AM and PM peaks, delays decrease at the Cattle market junction under Options 4 and 4b compared with the base conditions and Option 1c. This is due to the improvements made at this junction under this option. Delays at the A456 / B4187 Worcester Road signalised junction are higher under Option 4b than Option 4 in both the AM and PM peaks. This is due to the left turn from the B4187 Worcester Road onto the A456 being retained under Option 4b leading to the need for a separate pedestrian phase at the signals. This results in less green time for traffic and therefore higher delays at the junction.

For both the AM peak and PM peak, journey times under Option 4 and 4b decrease compared with the modelled base journey times for all routes and across all time periods; and are similar or slightly less than under Option 1c. The journey times are presented in Table 5 and Table 6.

Table 5 Option 1c, 4 and 4b - Journey Times – 2019 AM

	Direction	2019 AM Peak (08:00-09:00)				
		Observed Base	Modelled Base	Option 1c	Option 4	Option 4b
Route 1 – along A456	NB	00:13:11	00:14:49	00:10:09	00:09:56	00:10:33
	SB	00:08:19	00:09:22	00:09:17	00:09:04	00:09:10
Route 2- along A450-A456-B4187 -Park Road -A456	NB	00:14:12	00:15:18	00:10:36	00:10:20	00:10:11
	SB	00:12:54	00:13:01	00:11:59	00:11:44	00:12:04

Table 6 Option 1c, 4 and 4b - Journey Times – 2019 PM

	Direction	PM Peak (17:00-18:00)				
		Observed Base	Modelled Base	Option 1c	Option 4	Option 4b
Route 1 – along A456	NB	00:11:00	00:10:13	00:08:28	00:08:31	00:08:41
	SB	00:10:01	00:09:03	00:08:37	00:08:36	00:08:47
Route 2- along A450-A456-B4187 -Park Road -A456	NB	00:12:23	00:10:46	00:08:54	00:08:56	00:09:04
	SB	00:10:58	00:11:27	00:10:37	00:10:35	00:11:00

The summary graph for Option 4 is demonstrated in Figure 2 indicating performance at all key junctions along the A456 improve under Option 4 or are similar to existing conditions.



Figure 2 Summary graph for Option 4

Figure 3 to Figure 5 demonstrate the performance of junctions in the network for Options 5a-5c for both 2019 and 2036. Options 5a-5c include improvements to the A456/A491/Park Road roundabout along with Option 4 improvements. Options 5a-5c were modelled for 2019 traffic demand as well as 2036 forecast demand.

In 2036, for each of the Options 5a-5c, all junctions in the network experience significant delays in both the 2036 AM and PM peaks. This is because the improvements at the A456 Kidderminster Road / A491 Stourbridge Road roundabout remove the bottleneck at this location, enabling more traffic to travel southbound to downstream junctions. This causes significant delays at the the A456 / B4187 Worcester Road signalised junction resulting in traffic blocking back to upstream junctions along both directions of travel leading to traffic gridlocking. This makes it difficult to assess the performance of Options 5a-5c as it is unclear how well these schemes would operate if there wasn't any blocking back at other downstream junctions.

Whilst the road network is anticipated to face capacity issues in 2036 due to performance of the A456/A491/Park Road roundabout, capacity increases at the roundabout releases traffic downstream that blocks back to roundabout. As a result, all junctions are forecast to perform significantly worse in 2036 than in 2019 due to the gridlocked network during the peak hours and travel times are expected to significantly worsen by 2036.



Figure 3 Summary graph for Option 5a



Figure 4 Summary graph for Option 5b



Figure 5 Summary graph for Option 5c

Based on the analysis discussed, the following are our recommendations:

In the short-term, it is recommended that Option 4 is carried forward as the best option to address congestion issues in Hagley for 2019 traffic levels. Detailed design based on a true topographical survey will however be required for the A456/B4187 junction and the Cattle market junction.

To address the potential network gridlocking scenario in the future, it is recommended that **in the medium-term**, options are explored to:

- Downgrade B4187 Worcester Road to reduce traffic from/to Stourbridge and convert the junction into a priority junction; and
- Restrict/close access to the A456/A491 roundabout from Park Road (East and West)

For the **long-term** forecast conditions, it is suggested that WCC take a strategic view on the performance of the A456 corridor in Hagley exploring further options at the A456/B4187 junction in conjunction with Options 2/3, Option 5.

1. Introduction

1.1 Background

Jacobs was commissioned by Worcestershire County Council (WCC) to develop a micro-simulation model of Hagley. The need for a micro-simulation model was defined at a meeting that took place between Jacobs and WCC to discuss improvement options initially at the A450/A456 junction in Hagley identified as part of the A450 Corridor Enhancement Study. This Hagley Microsimulation model was calibrated and validated for 2019 base year conditions, and the results of this process were reported in the Hagley VISSIM Model Local Model Validation Report (LMVR), submitted to WCC in September 2019.

Jacobs was subsequently commissioned by WCC to use this model to evaluate potential highway improvement schemes at several junctions in the network.

1.2 Purpose of the Report

The purpose of this report is to assess the impacts which the proposed options have on the operation of key junctions and routes in Hagley. There are 5 signalised junctions in Hagley and all of them are included in the microsimulation model. This report focuses on improvement options shown in Figure 1-1 for the A456/B4187 Worcester Road junction, the A456/A450 junction, the 6-arm roundabout and the A491 Stourbridge Rd/A456 Kidderminster Rd/A456 Birmingham Rd junction, the key junctions in Hagley. The A456/Stakenbridge Lane priority junction and A450/Thicknall Lane priority junction were assessed as part of two options developed. No option was specifically developed for the B4187 Worcester Road/Station Road signalised junction as it was the least congested and depended on the performance of other junctions.



Figure 1-1 Junctions Assessed

1.3 Structure of the Report

Following this introduction, the remainder of this report is structured as follows:

- **Section 2: Option Testing Model Development** including details on the modelled scenarios and junction layouts;
- **Section 3: Model Inputs** including details on forecasting methodology;
- **Section 4: Model Outputs of options 1a, b and c** including details on the comparison between journey times and networks performance statistics for the various modelled scenarios;
- **Section 5: A456 / B4187 Junction Improvement - Traffic Engineering Feasibility** of the preferred option;
- **Section 6: Model Outputs of options 2 and 3** including details on the comparison between journey times and networks performance statistics;
- **Section 7: A491 Kidderminster Rd/ Stourbridge Rd (Cattle Market Junction) Enhancements** describing the proposed changes of the scheme;
- **Section 8: Model Outputs of option 4** including details of journey times, junction flows and delays;
- **Section 9: A456/A491 Hagley Roundabout Enhancements** describing the different options developed;
- **Section 10: Model Outputs of options 5a, b and c** including details on the comparison between journey times and networks performance statistics for the various modelled scenarios; and
- **Section 11: Summary and Conclusions** including a summary of the model development process and the network performance under the various proposed options.

1.4 Previous Study

WCC had previously commissioned CH2M (now Jacobs) in 2017 to assess capacities of three junctions in Hagley for 2017 conditions and forecast 2031 traffic conditions. A technical report 'Hagley Junction Modelling' Technical Report was submitted in February 2017. The three junctions in Hagley assessed were:

- A456 Kidderminster Road / A491 Stourbridge Road roundabout;
- A456 / B4187 Worcester Road;
- A456 / A450 Worcester Road.

1.4.1 Salient findings

The existing layouts of these junctions were modelled and validated using 2017 flows. The following options were tested to alleviate the capacity issues for the forecast year 2031 and are as described in section 1.4.1.1 to 1.4.1.3

1.4.1.1 A456 / A491 Stourbridge Road roundabout

- Option A – Adjustments to the lane markings on the A491 Stourbridge Road approach and circulatory markings
- Option B – Widen the A456 Kidderminster Road west exit to two lanes (merge to single lane after approximately 100m).

1.4.1.2 A456 / B4187 Worcester Road

- Option A – Reversion to previous layout

This option looks to adapt the layout of the junction to be as per the previous layout of the junction before the changes to provide two lanes heading towards Kidderminster.

In this layout a single lane is provided in each direction on the A456, with a second lane provided for right turn only on A456 Kidderminster Road approach. The left turn lane is returned to operate as 28.8 m.

- Option B – Revision to pedestrian crossing layout and phasing

This option splits the left turn phase of the B4187 Worcester Road from the right turning traffic, which in turns allows for a staggered pedestrian crossing phase instead of an “all red” phase.

- Option C – Revision to pedestrian phasing within existing kerblines

Option C keeps the layout of the junction the same as the existing layout, but alters the pedestrian phasing in a similar way to Option B. It separates the left turn phase of B4187 Worcester Road from the right turning traffic but would operate with the pedestrian crossing the whole width of the A456 as is current instead of introducing a staggered crossing.

- Option D – Reversion to previous layout, with altered pedestrian phasing

This option looks to adapt the layout of the junction to be similar to the previous layout of the junction before the changes to provide two lanes towards Kidderminster, but a longer left turn filter lane on the A456 Worcester Road eastbound (to the B4187 Worcester) and also with the altered pedestrian phasing from Option C. The left turn lane would be 71m in total, thus any queues longer than this would result in traffic not being able to access this left turn lane.

- Option E – Reversion to previous layout, with staggered pedestrian phasing

Option E is the same as Option D, but incorporates the staggered pedestrian crossing from Option B.

1.4.1.3 A456 / A450 Worcester Road

- Option A – Provide two ahead lanes from the A456 Kidderminster Road South and two exit lanes northbound. Shorten the A456 southbound flare to make the necessary space.
- Option B – Linking of signals at A450/A456 and A456/B4187 junction to the north so that the two junctions operate in tandem.

1.4.2 Summary

The long-term solutions that were suggested after the above options testing are listed below.

- A456/A491 Roundabout: Provide additional exit capacity on exit towards Kidderminster and revise road markings on circulatory and other approached to enhance overall capacity.
- A456/B4187: Option B to be taken forward.
- A456/A450: Option A to be taken forward.

Since the study completion, adjustments to the lane markings have been implemented at the A456/A491 roundabout (Option A) and are part of the 2019 Hagley VISSIM Model.

2. Option Testing Model Development

2.1 Modelled Options

The options considered as part of the 2017 Hagley Junctions Modelling Study were reviewed and the following options considered as part of this study.

- **Option 1a** – Amend the A456/B4187 Worcester junction to layout shown in Figure 2-1 prior to Cala Home developers implementing their scheme in 2016. This provides for one-lane in each direction for the ahead movements on the A456 with a second lane provided for right turn only on A456 Kidderminster Road approach. The dedicated left turn lane is returned to operate as 28.8 m. This is the same as Option 1 for this junction proposed in the 2017 study,



Figure 2-1 Option 1a layout A456/B4187 Worcester Road junction

- **Option 1b** – As Option 1a but to current standards as shown in Figure 2-2. The left turn lane from the A456 to the B4187 under this option is for a longer distance of 80m from the back of taper to junction entry. The A456 northbound will have 3m wide lanes whilst the southbound lane will be 3.5m wide.
- **Option 1c** – As Option 1b but with a ban on the right turn from A456 Kidderminster Road to B4187 Worcester Rd and a left ban from the B4187 to A456 Kidderminster Road northbound as shown in Figure 2-3. This allows for a pedestrian phase on the A456 to run along with the B4187 phase for the right turn movements, thereby reducing number of signal stages required. It further provides for dedicated space for signal maintenance access.



Figure 2-2 Option 1b layout A456/B4187 Worcester Road junction

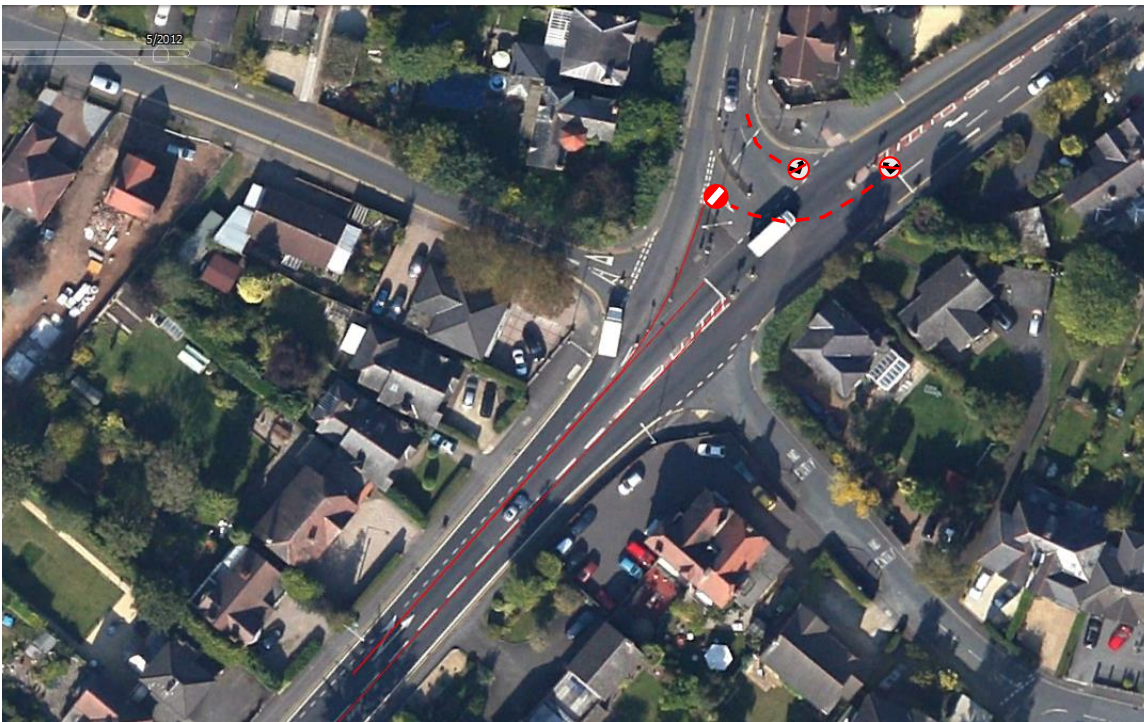


Figure 2-3 Option 1c layout A456/B4187 Worcester Road junction

- **Option 2** – Option 1b at the A456/B4187 junction with introduction of one-way on A450 southbound from A456 to Thicknall Lane as shown in Figure 2-4. The A450 northbound traffic will use the Thicknall Lane to access the A456 at its junction with Stakenbridge Lane. This was one of the recommended options in the A450 corridor enhancement study for this junction. This option requires signalling the A450/Thicknall lane junction and the A456/Thicknall Lane/Stakenbridge Lane junction whilst removing the existing signals at the A456/A450 junction.

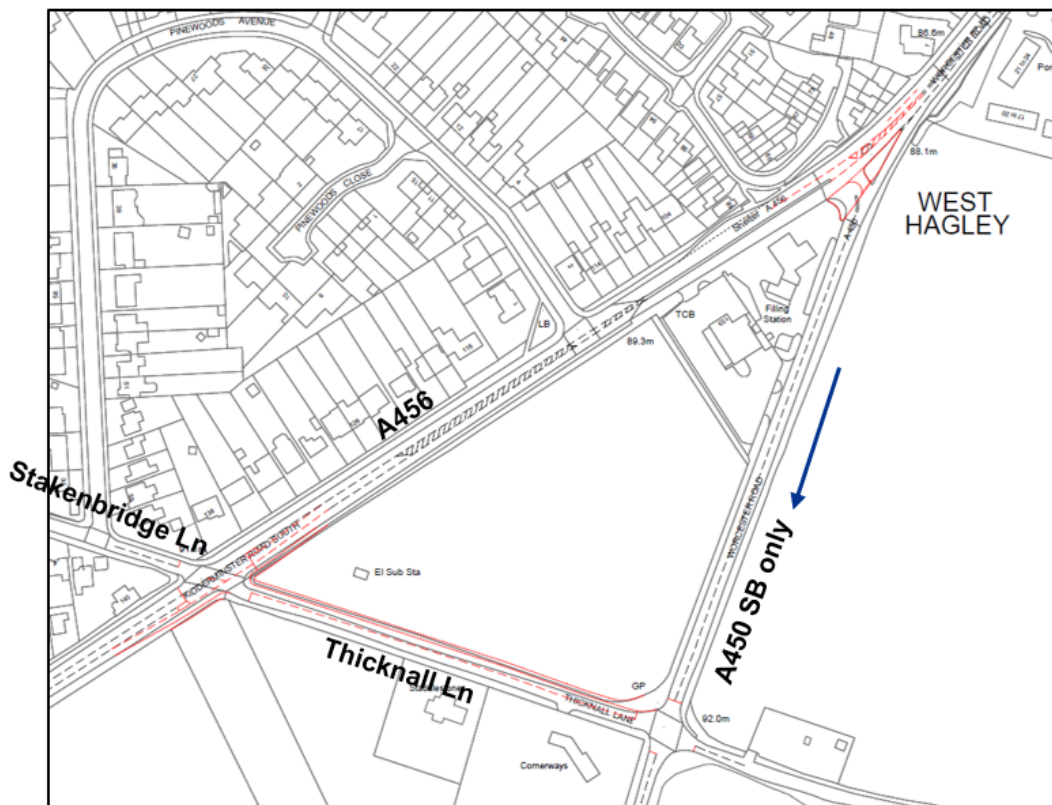


Figure 2-4 Option 2 layout at A450/A456 and A456/Stakenbridge junction

- **Option 3** – Option 1b with introduction of one-way gyratory along the A456/A450, A450/ Thicknall Lane and A456/Thicknall Lane/Stakenbridge Lane junctions as shown in Figure 2-5. This option includes signalling the A450/Thicknall Lane junction; A456/Stakenbridge Lane junction and retaining the signals at the A456/A450 junction with reduced number of stages.

Options 1a, 1b and 1c have been modelled for 2019 demand consistent with the base model. This enables assessment of the short-term impacts as requested by WCC. The model run results are discussed in chapter 4.

Option 2 and Option 3 have been modelled for both 2019 and 2036 demand based on Wyre Forest Local Plan scenarios used to inform the A450 corridor enhancement study. The model run results are discussed in chapter 6.

- **Option 4** – Option 1c with improvements to the Cattle Market junction (A456/A491 3-arm signalised junction)- Change the use of left lane on A456 Kidderminster Rd Eastbound for left turn only towards A491 Stourbridge Road Westbound. Move the stopping line on A456 Kidderminster Road Westbound towards the A456/A491 junction to accommodate higher capacity and reduce queuing. Extend the Southbound 3-lanes layout on A491 Stourbridge Road.

Option 4 has been modelled for 2019 demand consistent with the base model.

- **Option 4b** – As Option 4, but retaining the left turn movement from the B4187 Worcester Road Southbound to A456 Kidderminster Road Eastbound. Similar to Option 4, Option 4b has been modelled for 2019 demand only.
- **Option 5a** – Option 4 with improvements to the A456/A491/Park Road roundabout that includes increasing the roundabout exit from A456 Kidderminster Road Westbound from a single lane to two lanes; move forward the stop line on the circulatory at the A491 Stourbridge Road approach and the stop line on the A491 Stourbridge Road towards the roundabout approach.
- **Option 5b** – Option 5a incorporating closure of the entry to the roundabout from Park Road East.
- **Option 5c** – Option 5a with the creation of an internal through-about link from the A491 Kidderminster Road Southbound to the A456 Kidderminster Road Westbound.

Options 5a, b and c have been modelled for both 2019 and 2036. The model run results for option 4 and 5 are discussed in Chapter 7 to Chapter 9.

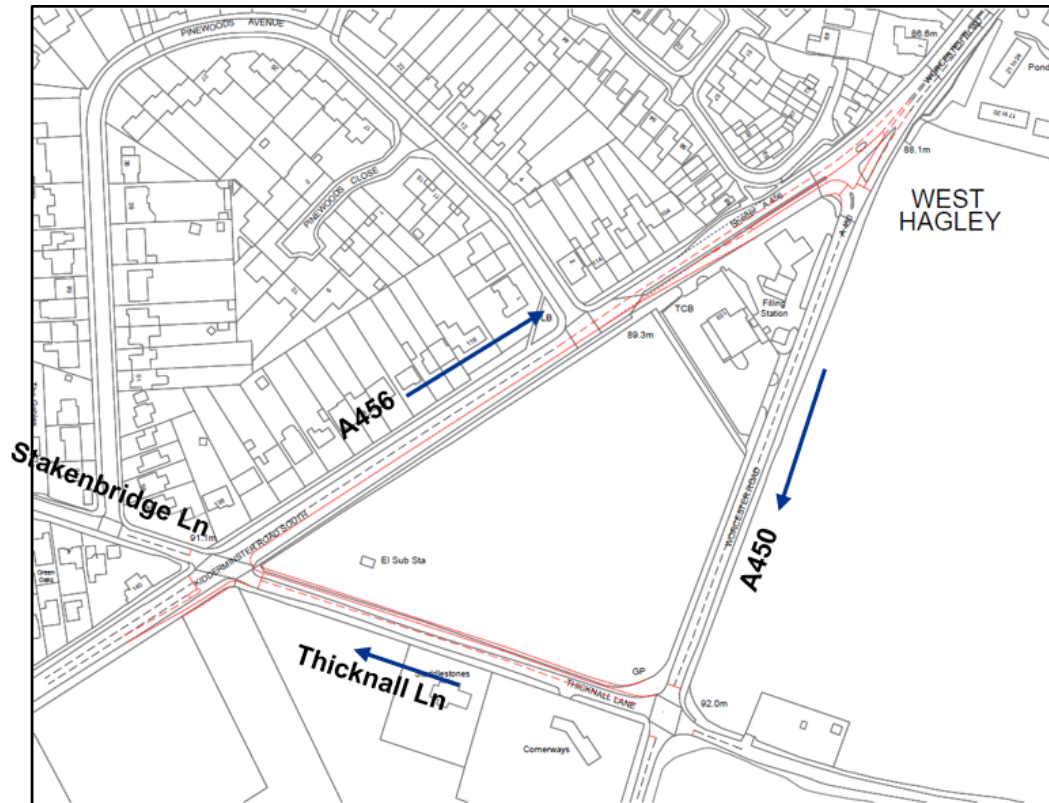


Figure 2-5 Option 3 - A450/A456 junction- Gyratory

The summary of junctions with improvements modelled are summarised in table below.

Table 2-1: Summary of Options modelled

Junction	Options Modelled									
	1a	1b	1c	2	3	4	4b	5a	5b	5c
B4187 Worcester Rd / Station Rd / Park Rd	-	-	-	-	-	-	-	-	-	-
A456 / B4187 Worcester Rd / Summervale Rd / Western Rd	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
A456 Kidderminster Rd / A450 Worcester Rd	-	-	-	✓	✓	-	-	-	-	-
A456 Kidderminster Rd / Stakenbridge Ln / Thicknall Ln	-	-	-	✓	✓	-	-	-	-	-
A450 Worcester Rd / Thicknall Ln	-	-	-	✓	✓	-	-	-	-	-
A456 Kidderminster Rd / Park Rd / A491 Stourbridge Rd / Bennett Dr	-	-	-	-	-	-	-	✓	✓	✓
A456 Kidderminster Rd / A456 Birmingham Rd / A491 Stourbridge Rd	-	-	-	-	-	✓	✓	✓	✓	✓

3. Model Inputs

3.1 Input Data

Forecast matrices for the 2036 forecast model were developed from the Wyre Forest Transport Model (WFTM), developed in VISUM. The 2036 Local Plan scenario assessed through the WFTM and used to inform the A450 corridor enhancement study was used to generate the matrices for the Hagley VISSIM Model.

The Options were run through the 2036 forecast WFTM models and then cordoned to cover the VISSIM micro-simulation model area. The VISUM matrices within the cordoned area were used to calculate the growth in the VISSIM model area between 2019 and 2036. This growth was then applied to the 2019 VISSIM matrices in order to produce 2036 VISSIM matrices for the zones included in the WFTM cordon model (key routes feeding into Hagley). For zones not included in the WFTM, mainly smaller local zones in the VISSIM model, TEMPro (v7.2) growth factors were used. These factors are given in Table 3-1.

Table 3-1 2019 to 2036 TEMPro v7.2 Growth

		2019 to 2036 TEMPro Growth
AM Peak	Origin	5.0%
	Destination	12.5%
PM Peak	Origin	11.7%
	Destination	7.1%

The final matrix totals, along with the growth between 2019 and 2036, can be seen in Table 3-2 for the AM and PM peaks respectively. Flows vary between the various 2036 scenarios due to reassignment impacts in the VISUM model network. It shows that Option 5 has almost twice the increase in demand as compared to Option 2 (i.e., the options at the A456/A450 divert demand away from the Hagley network on to other wider strategic routes).

Table 3-2: 2036 Forecast Matrix Growth

		Matrix Total	2019-2036 Matrix Difference	2019-2036 % Growth
AM Peak	2019 Base	5848	-	-
	2036 Option 2	6384	536	9%
	2036 Option 3	6617	769	12%
	2036 Option 5	6880	1032	18%
PM Peak	2019 Base	6079	-	-
	2036 Option 2	6998	919	15%
	2036 Option 3	6771	692	10%
	2036 Option 5	7172	1093	18%

3.2 Traffic Flow from Major Local Plan Developments

Analysis has been undertaken on the forecast demand on the A456 corridor to identify traffic attributed to proposed Wyre Forest local plan development sites. Two of the biggest development sites proposed have been assessed. These are the Stone Hill North development and the Lea Castle development sites. Stone Hill North has a proposed capacity for 1100 dwelling units. This development site is to be accessed from the A448 to the east of Kidderminster, not far away from the A450 corridor (A448/A450 roundabout). Lea Castle site is between the A449 and A451 Stourbridge Road with proposals for 1400 dwelling units.

3.2.1 Stone Hill North Development Site

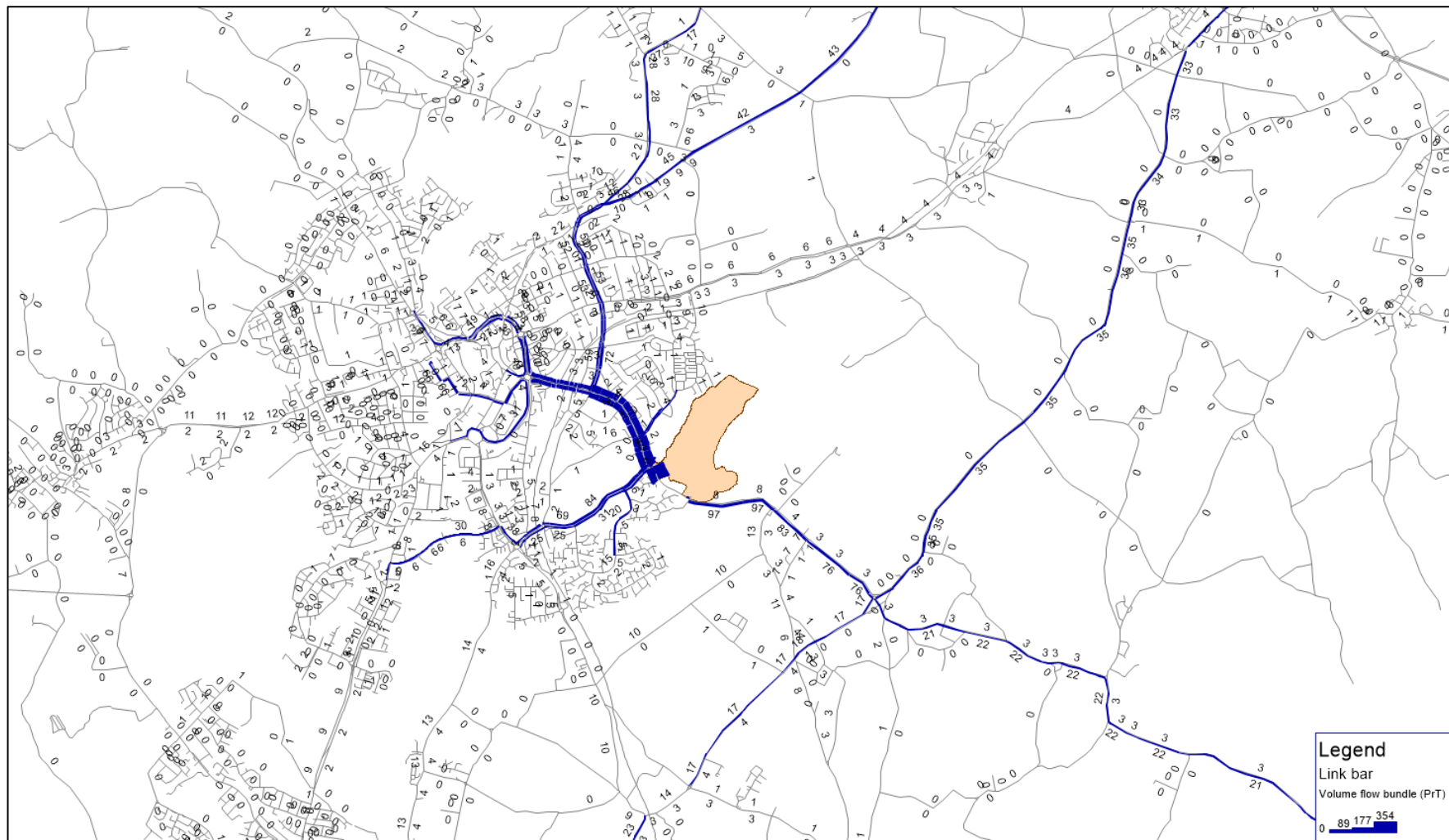
Figure 3-1 and Figure 3-2 show the distribution of the traffic generated by Stone Hill North development for the 2036 AM and PM peaks respectively. The figures show that traffic from the development site distributes towards Kidderminster as well as towards the A450 dispersing to various points on the network.

Approximately 12 vehicles generated by this development approach Hagley via the A456 and 49 approach via the A450 in the 2036 AM peak hour. In the 2036 PM peak hour, approximately 33 vehicles travel through Hagley and along the A450 towards the Stone Hill North development site.

Figure 3-1: Stone Hill North Traffic Flow – 2036 AM Peak



Figure 3-2: Stone Hill North Traffic Flow – 2036 PM Peak



3.2.2 Lea Castle Development Site

Figure 3-3 and Figure 3-4 show the distribution of the traffic generated by the Lea Castle development for the 2036 AM and PM peaks respectively. The figures show that traffic from the development site distributes towards Kidderminster as well as towards Stourbridge via the A449 and the A451 Stourbridge Road. Very little traffic from this site heads towards or through Hagley. In the 2036 AM peak hour, approximately 25 vehicles from the Lea Castle site pass through Hagley. In the PM peak hour, approximately 17 vehicles pass through Hagley.

Figure 3-3: Lea Castle Traffic Flow – 2036 AM Peak

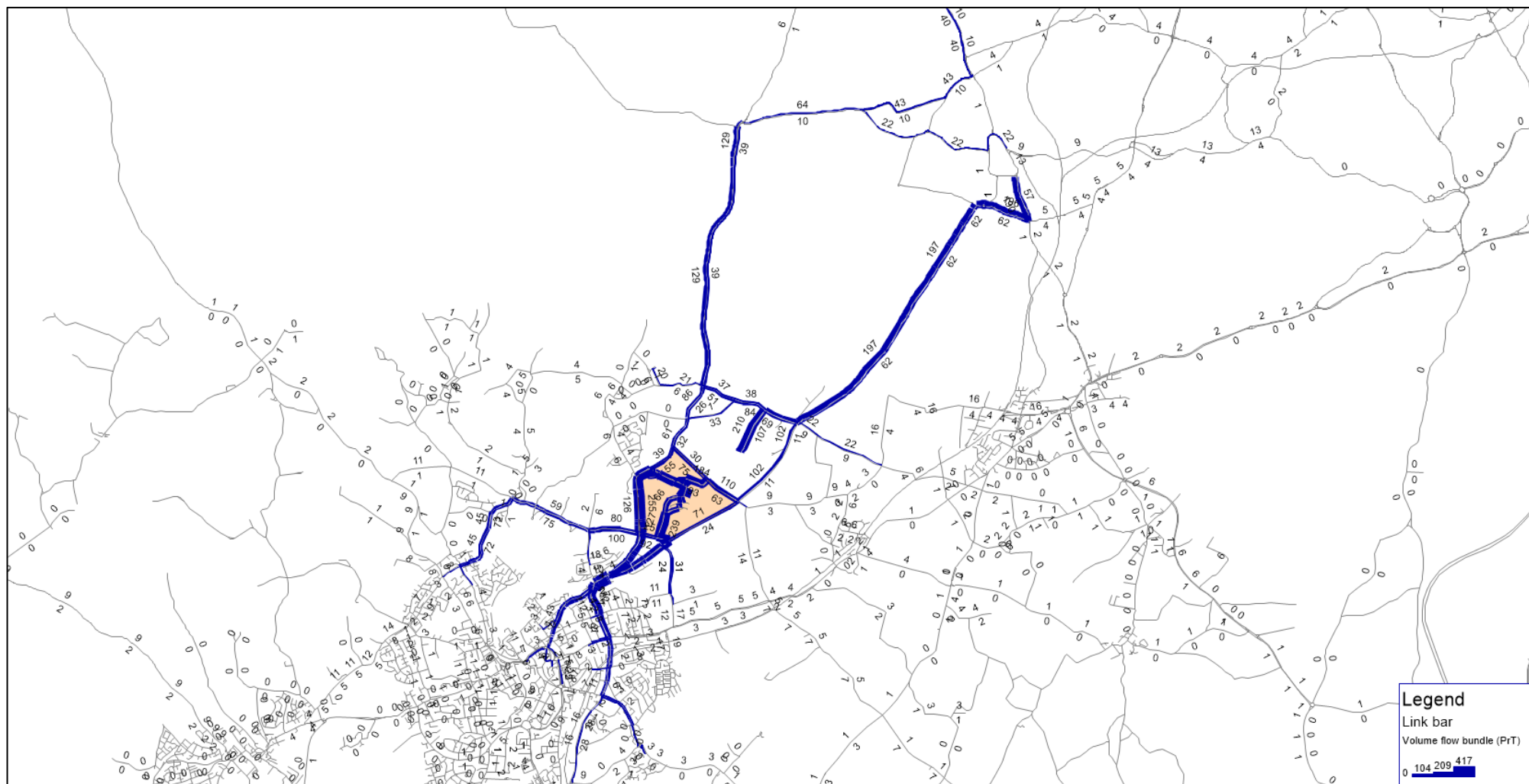
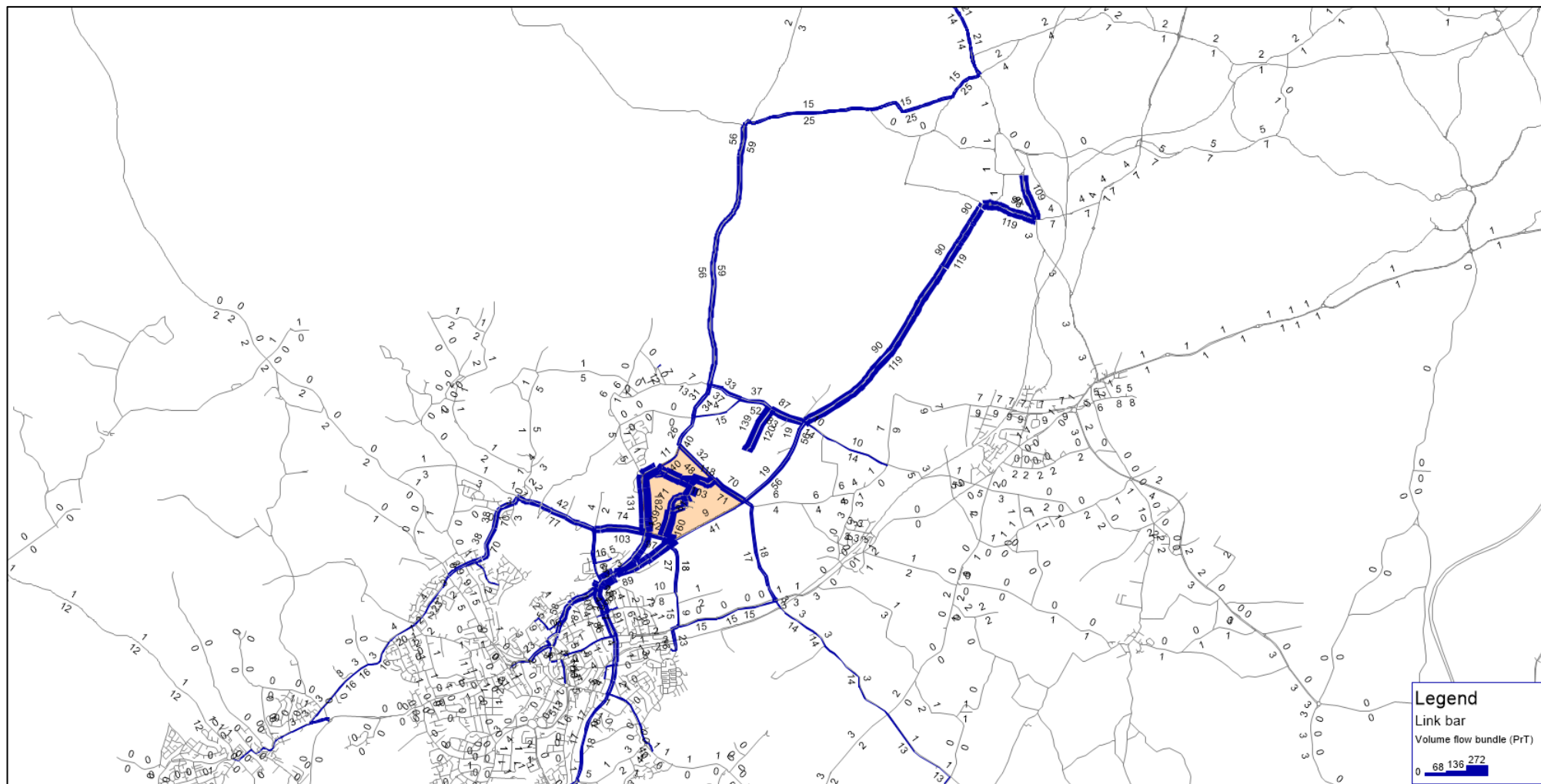


Figure 3-4: Lea Castle Traffic Flow – 2036 PM Peak



4. Model Outputs - Options 1a, 1b and 1c

4.1 Model Runs

The AM and PM peak models for Options 1a-c were each run 10 times with 2019 demand, with each run having a different random seed to represent daily variations in traffic, in line with TfL Traffic Modelling Guidelines (Version 3.0, September 2010). The AM models were run for the period 06:30 to 09:30 whilst the PM model were run for the period 15:30-18:30. All the signalised junctions operate on MOVA and have been modelled in VISSIM using PC-MOVA version 3.0. Junction flows and delays, journey times and vehicle network performance indicators were collected, and the results obtained were averaged over the 10 runs and are reported in the following sections.

4.2 Junction Flows

The total number of vehicles passing through each of the key junctions in the network during the AM and PM peak hours were collected for each option and are presented in Table 4-1. Where flows have increased compared with the base flows, the values are indicated in green whilst red indicates a decrease in throughput compared to the base flows.

Table 4-1: Options 1a, 1b and 1c - Junction Flows

Junction	Junction Throughput (vehicles)							
	2019 AM (08:00-09:00)				2019 PM (17:00-18:00)			
	Base	Op 1a	Op 1b	Op 1c	Base	Op 1a	Op 1b	Op 1c
B4187 Worcester Rd / Station Rd / Park Rd	1488	1412	1410	1442	1279	1316	1317	1345
A456 / B4187 Worcester Rd / Summervale Rd / Western Rd	2438	2438	2441	2270	2441	2548	2554	2440
A456 Kidderminster Rd / A450 Worcester Rd	2110	2070	2064	2193	2336	2367	2371	2432
A456 Kidderminster Rd / Stakenbridge Ln / Thicknall Ln	1258	1246	1245	1240	1542	1538	1534	1455
A450 Worcester Rd / Thicknall Ln	863	862	858	854	881	924	925	927
A456 Kidderminster Rd / Park Rd / A491 Stourbridge Rd / Bennett Dr	3922	3841	3838	3875	3868	3742	3740	3740
Middlefield Ln / A491 Kidderminster Rd	3303	3306	3299	3324	3212	3076	3077	3122
B4187 Worcester Rd / Middlefield Ln	1037	1081	1079	1099	961	978	979	998
A456 Kidderminster Rd / A456 Birmingham Rd / A491 Stourbridge Rd	4035	4018	4012	4020	3909	3759	3760	3761

In the AM peak, flows at the A456 / B4187 Worcester Road junction remain similar in the Option 1a and 1b scenarios as in the base scenario, at 2438 and 2441 vehicles respectively compared with 2438 vehicles in the base. However, flows at this junction decrease to 2270 vehicles in the Option 1c scenario due to two turns being banned at this junction under this scheme.

In the PM peak, flows at the A456 / B4187 Worcester Road junction increase from 2441 vehicles in the base to 2548 in the Option 1a scenario and 2554 vehicles in the Option 1b scenario. This is because the improvement scheme leads to less queueing at the junction and allows more vehicles to pass through. In the Option 1c scenario, the banning of two turns at this junction causes the flow through the junction to be similar to the base scenario.

4.3 Junction Delays

The average delay time for each vehicle passing through the key junctions in the model was collected for the AM and PM peak hours for each scenario and are presented in Table 4-2. Where delays have increased compared with the base delays, the values are indicated in red whilst green indicates the opposite.

Table 4-2: Options 1a, 1b and 1c - Junction Delays

Junction	Average Delay per Vehicle (s)							
	2019 AM (08:00-09:00)				2019 PM (17:00-18:00)			
	Base	Op 1a	Op 1b	Op 1c	Base	Op 1a	Op 1b	Op 1c
B4187 Worcester Rd / Station Rd / Park Rd	44.9	40.4	41.8	47.8	60.8	37.9	40.5	42.5
A456 / B4187 Worcester Rd / Summervale Rd / Western Rd	25.5	20.8	21.0	13.6	30.1	20.1	20.0	14.1
A456 Kidderminster Rd / A450 Worcester Rd	28.8	20.8	21.0	15.6	30.4	19.9	20.0	19.7
A456 Kidderminster Rd / Stakenbridge Ln / Thicknall Ln	15.5	5.1	6.3	3.6	10.1	6.7	6.8	6.7
A450 Worcester Rd / Thicknall Ln	5.9	3.9	3.8	3.4	6.9	2.6	2.7	2.7
A456 Kidderminster Rd / Park Rd / A491 Stourbridge Rd / Bennett Dr	40.1	43.5	41.3	47.0	52.0	54.0	53.0	52.7
Middlefield Ln / A491 Kidderminster Rd	29.7	30.8	30.2	30.4	2.3	1.9	1.9	2.0
B4187 Worcester Rd / Middlefield Ln	3.3	3.4	3.6	3.7	24.0	2.3	2.3	2.4
A456 Kidderminster Rd / A456 Birmingham Rd / A491 Stourbridge Rd	45.6	45.1	45.5	43.8	26.0	22.2	22.1	22.1

In the AM peak, there are average delays of 25.5 seconds per vehicle travelling through the A456 / B4187 Worcester Road signalised junction in the base scenario. This reduces to approximately 21 seconds in the Option 1a and 1b scenarios due to the improvements made at these scenarios. In the Option 1c scenario, delays at this junction reduce further to 13.6 seconds per vehicle. This additional reduction in delay is partly due to a reduction in demand at the junction in the Option 1c scenario due to the banning of two movements at the junction. Additionally, the banning of these two movements leads to a change in signal staging at the junction, allowing the pedestrian phase to run with traffic rather than in a separate stage. This enables additional green time for traffic which contributes to the reduction in delays.

The PM peak follows the same pattern as the AM peak at the A456 / B4187 Worcester Road junction. Delays at this junction are 30.1 seconds per vehicle in the base scenario. The delay decreases to approximately 20 seconds in the Option 1a and 1b scenarios and reduces further to 14.1 seconds in the Option 1c scenario.

In the AM peak, delays at the B4187 Worcester Road / Station Road / Park Road junction increase in the Option 1c scenario compared with the Option 1a and 1b scenarios. Delays at this junction in the Option 1c scenario are 47.8 seconds per vehicle compared with 40.4 seconds and 41.8 seconds in the Option 1a and 1b scenarios respectively. This is due to traffic having to re-route through this junction in the Option 1c scenario. In the Option 1c scenario, the right turn from the A456 Kidderminster Road onto the B4187 Worcester Road is banned. Therefore, traffic which previously made this movement will instead need to access B4187 by turning onto Park Road at the A456/A491 roundabout, towards the B4187 / Station Road / Park Road junction. Additionally, the left turn from the B4187 Worcester Road onto the A456 Kidderminster Road is also banned under the Option 1c scenario. Some of the traffic which was previously making this movement will re-route through the B4187 / Station Road / Park Road junction to access the A456 from Park Road or Middlefield Road instead.

The increase in delays at the B4187 Worcester Road / Station Road / Park Road junction under the Option 1c scenario is less significant in the PM peak. In the PM peak, delay increase from 37.9 seconds in Option 1a and 40.5 seconds in Option 1b to 42.5 seconds in Option 1c.

Similarly, delays at the A456/A491/Bennett Drive roundabout too increase in the AM peak hour under Option 1c to 47 seconds per vehicle compared to 43.5 seconds under Option 1a and 41.3 seconds under Option 1b due to the traffic having to reroute as a result of turn bans at the A456/B4187 junction. The change in delay in the PM peak is less significant and comparable across the three options.

4.4 Journey Times

Average travel times were collected along two key routes in the network for the modelled scenarios. The journey time routes that were collected are described in Table 4-3 and illustrated in Figure 4-1.

Table 4-3: Journey Time Route Descriptions

JT Route 1 (approximately 5.6 km)	A456/B4188 at Blakedown to A456/Wassell Grove Ln Roundabout, along Birmingham Road (A456), Kidderminster Road South(A456), Worcester Road(A456) via Hagley Town Centre.
JT Route 2 (approximately 5.4 km)	A450 /B4188 Intersection to A456/Wassell Grove Ln Roundabout, along Worcester Road (A450), Worcester Road (A456), Worcester Road (B4187), Park Road and Birmingham Road (A456)



Figure 4-1 Journey Time Routes

The journey times for these routes under each of the modelled scenarios, alongside observed journey times are given in Table 4-4 for the 2019 AM peak. Where journey times have increased compared with the modelled base journey times, the values are indicated in red whilst green indicates the opposite.

Table 4-4: 2019 AM Peak Journey Times - Option 1a, 1b and 1c

	Direction	AM Peak (08:00-09:00)				
		Observed Base	Modelled Base	Option 1a	Option 1b	Option 1c
Route 1	NB	00:13:11	00:14:49	00:10:59	00:11:04	00:10:09
	SB	00:08:19	00:09:22	00:09:32	00:09:23	00:09:17
Route 2	NB	00:14:12	00:15:18	00:11:14	00:11:02	00:10:36
	SB	00:12:54	00:13:01	00:12:13	00:12:10	00:11:59

Graphical representations for the two routes in both directions for the 2019 AM peak are given in Figure 4-2 to Figure 4-5.

For Route 1 northbound, all three of the proposed options lead to a decrease in journey time compared with the modelled base journey time. It can be seen in Figure 4-2 that most of this journey time saving occurs between the A456 / Stoney Lane / Broome Lane junction to the A456 / B4187 Worcester Road signalised junction. This is due to the improvements made at the A456 / B4187 Worcester Road junction. It can be seen that the journey time savings in the Option 1c scenario are greater than the Options 1a and 1b scenarios. This is because of the banning of the two movements at the junction means that there is a revised signal staging enabling the pedestrian phase to run with traffic. This gives more green time to the

northbound movement along the A456 through this junction, leading to an additional travel time saving of 55 seconds compared with Option 1b.

For Route 1 southbound, Options 1a and 1b lead to small increases in travel time compared with the modelled base travel time. However, Option 1c leads to a small decrease in travel time compared with the other scenarios due to the banning of the two movements at the A456 / B4187 Worcester Road junction enabling more green time to be given to traffic at this junction.

For Route 2 northbound, as for Route 1 northbound, all three of the proposed schemes lead to a decrease in journey time compared with the modelled base journey time. It can be seen in Figure 4-4 that the majority of this saving occurs on the approach to the A456 / B4187 Worcester Road signalised junction. This route also experiences the lowest travel time in the Option 1c scenario due to the revised staging at the A456 / B4187 Worcester Road junction under this scenario.

For Route 2 southbound, all of the proposed schemes lead to a reduction in travel time compared with the modelled base travel time. It can be seen in Figure 4-5 that most of this saving occurs along the B4187 Worcester Road, on the approach to the A456 / B4187 Worcester Road junction. This is because the schemes lead to a reduction in queueing on the A456 northbound approach to this junction which allows more green time to be allocated to the B4187 approach to the junction.

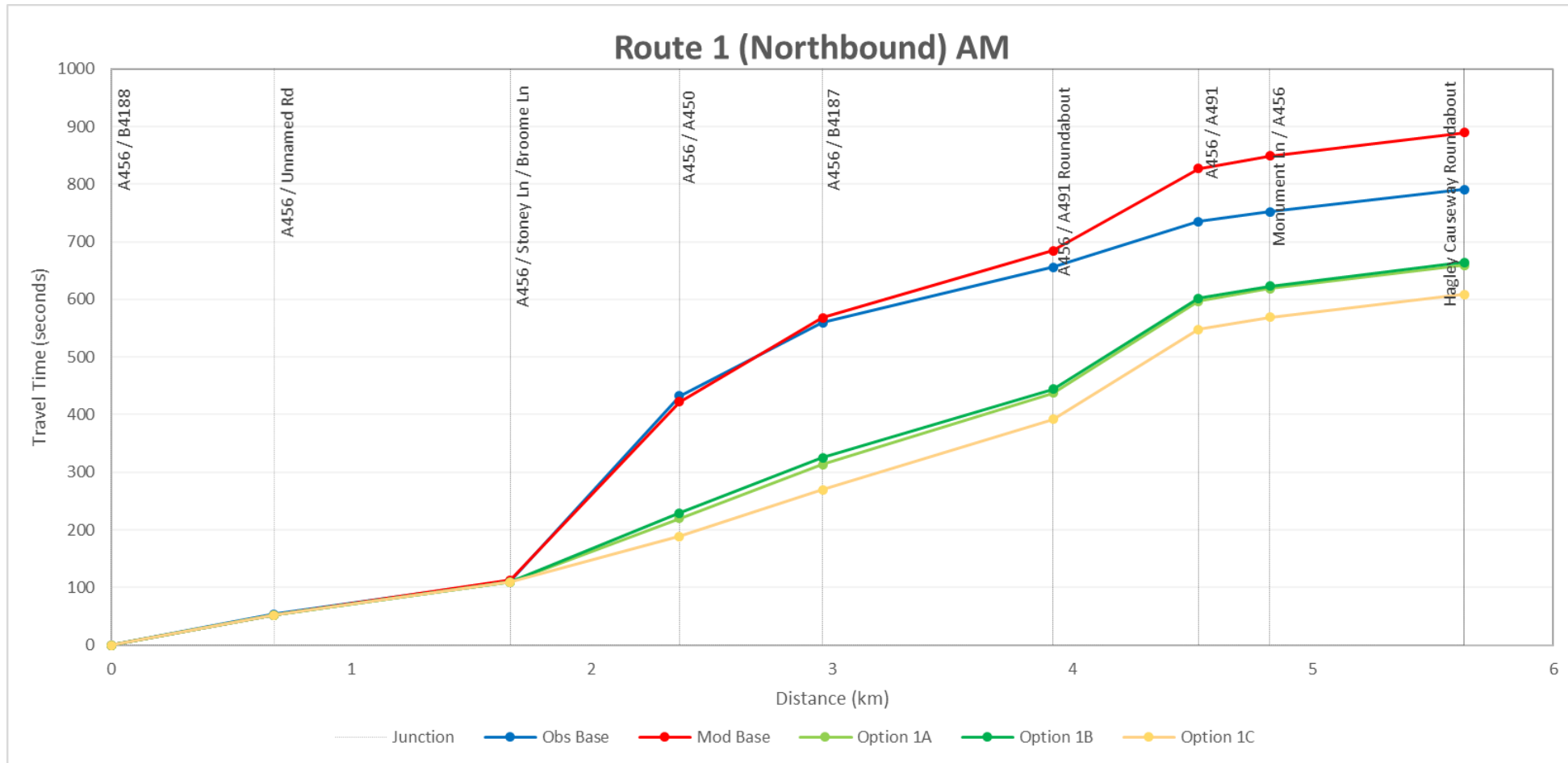


Figure 4-2: Route 1 NB - 2019 AM Journey Times – Options 1a, 1b and 1c

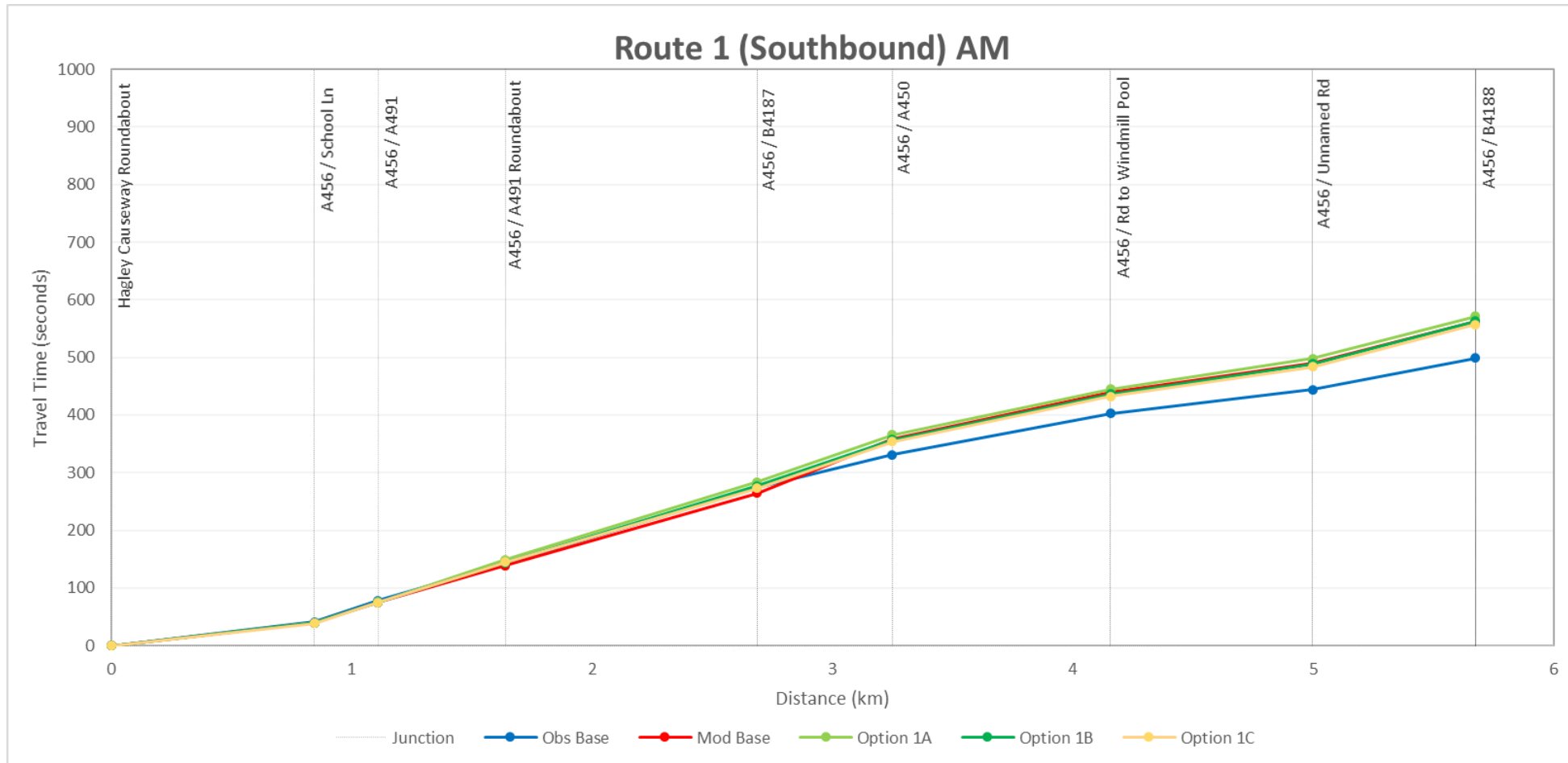


Figure 4-3: Route 1 SB - 2019 AM Journey Times – Options 1a, 1b and 1c

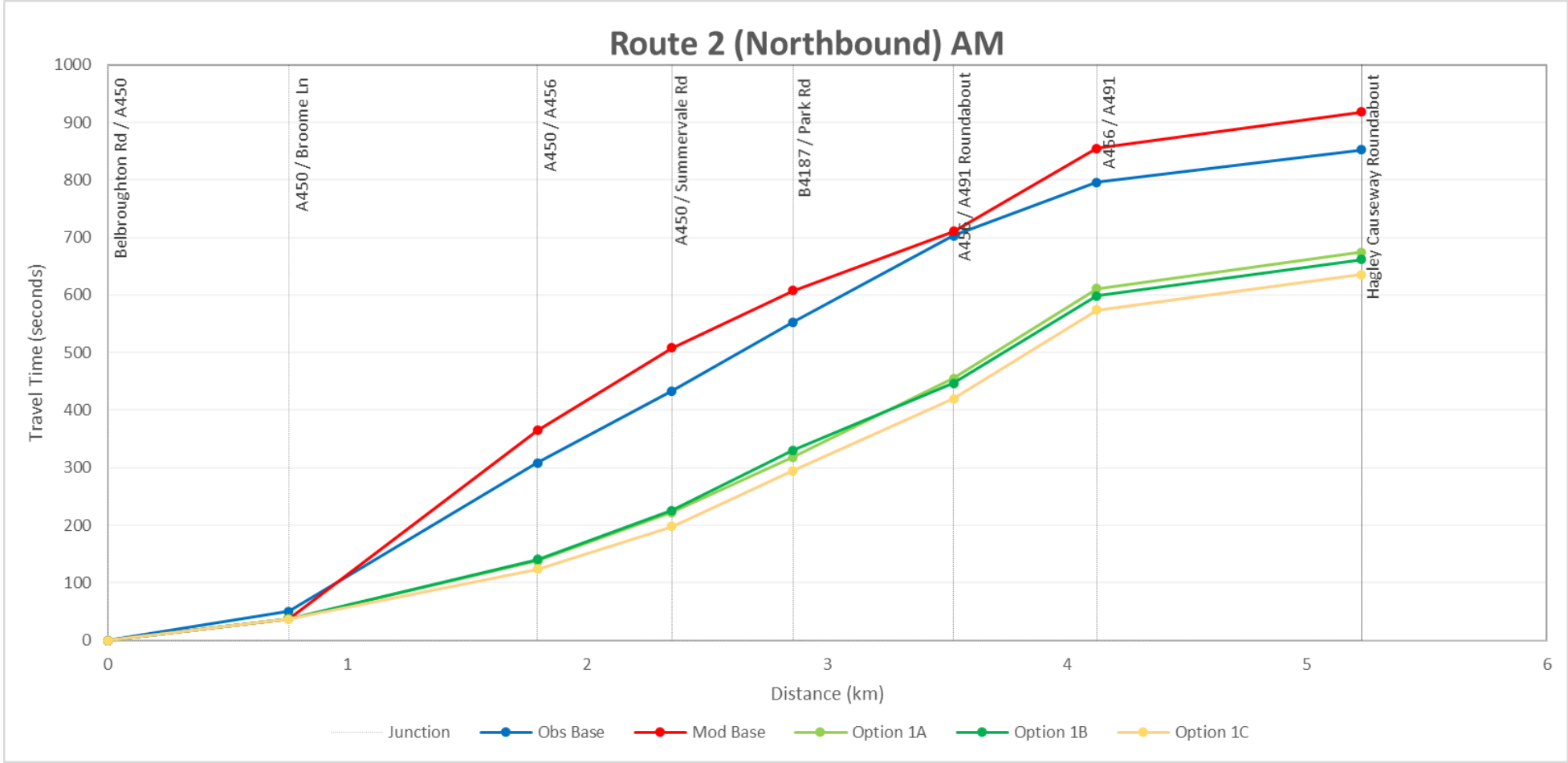


Figure 4-4: Route 2 NB – 2019 AM Journey Times – Options 1a, 1b and 1c

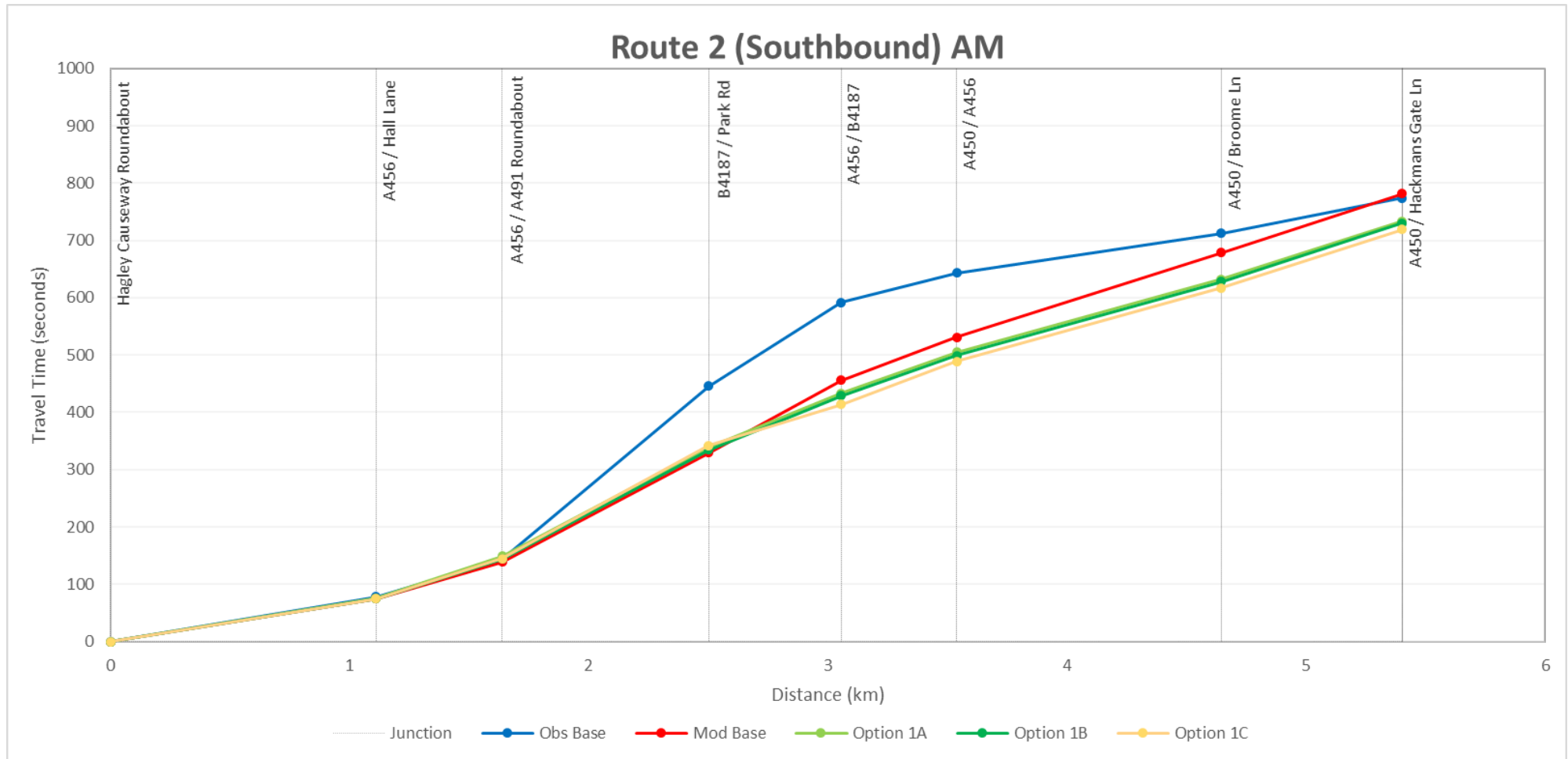


Figure 4-5: Route 2 SB – 2019 AM Journey Times – Options 1a, 1b and 1c

The journey times under each of the modelled scenarios, alongside observed journey times, are given in Table 4-4 for the 2019 PM peak. It shows that journey times decrease along both routes in both directions across all three options.

Table 4-5: 2019 PM Peak Journey Times - Option 1a, 1b and 1c

	Direction	PM Peak (17:00-18:00)				
		Observed Base	Modelled Base	Option 1a	Option 1b	Option 1c
Route 1	NB	00:11:00	00:10:13	00:08:37	00:08:37	00:08:28
	SB	00:10:01	00:09:03	00:08:49	00:08:42	00:08:37
Route 2	NB	00:12:23	00:10:46	00:08:58	00:09:05	00:08:54
	SB	00:10:58	00:11:27	00:10:54	00:10:51	00:10:37

Graphical representations for the two routes in both directions for the 2019 PM peak are given in Figure 4-6 to Figure 4-9.

For Route 1 northbound, all of the proposed options lead to a reduction in travel time compared with the modelled base travel time. As in the AM peak, the majority of this saving occurs between the A456 / Stoney Lane / Broome Lane junction and the A456 / B4187 Worcester Road signalised junction due to the improvements made at this junction. The travel time saving is slightly greater in the Option 1c scenario due to the revised signal staging under this option.

For Route 1 southbound, all of the proposed schemes lead to a reduction in travel time, although the savings are less significant in this direction.

Route 2 northbound follows a similar pattern as Route 1 northbound due to travel time savings on the approach to the A456 / B4187 Worcester Road junction, a section common to both routes.

For Route 2 southbound, all of the proposed options lead to a reduction in travel time compared with the modelled base travel time. This is due to similar reasons as the AM peak. The schemes lead to a reduction in queueing on the A456 northbound approach to this junction which allows more green time to be allocated to the B4187 approach to the junction.

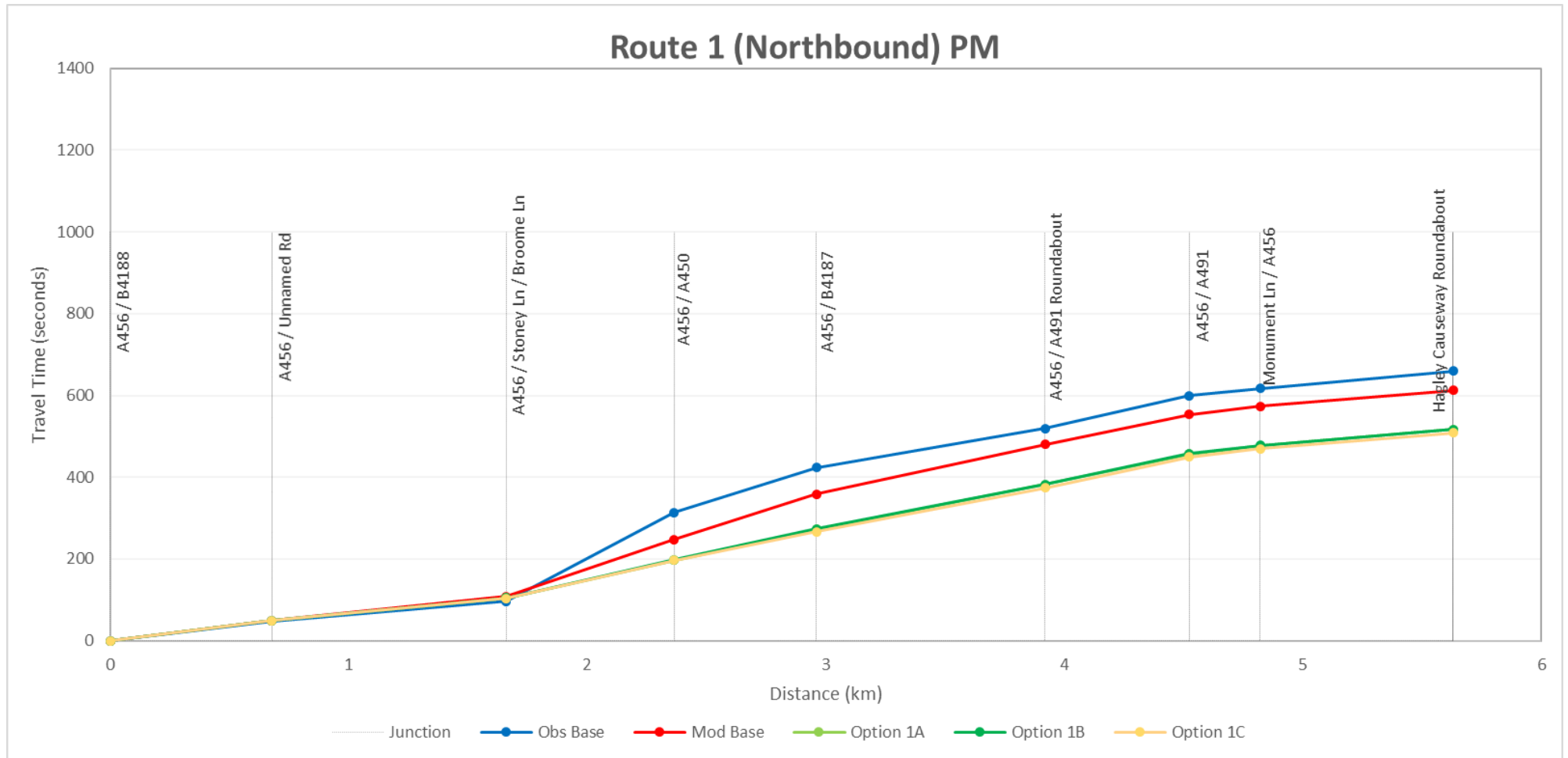


Figure 4-6: Route 1 NB - 2019 PM Journey Times – Options 1a, 1b and 1c

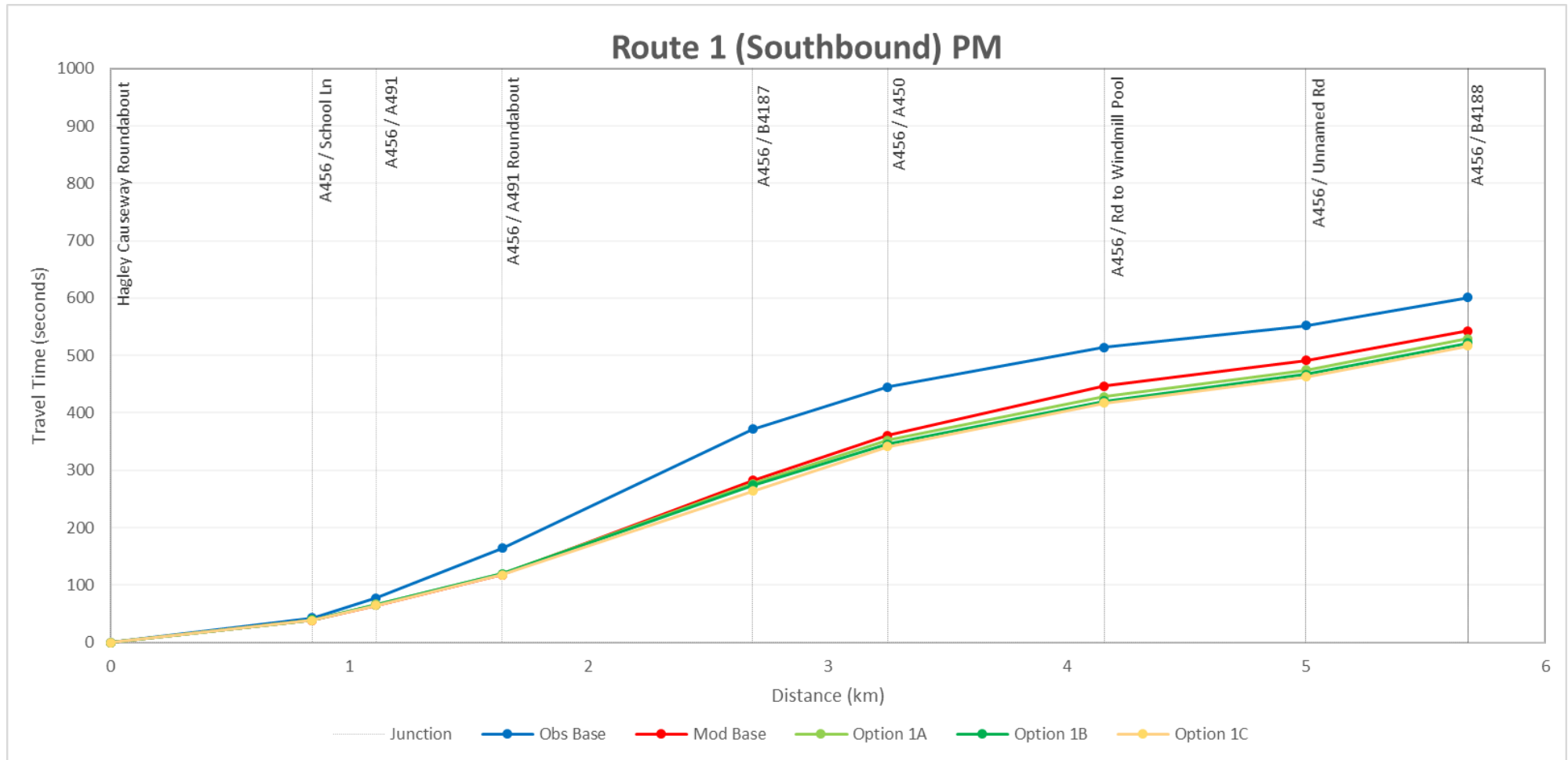


Figure 4-7: Route 1 SB - 2019 PM Journey Times – Options 1a, 1b and 1c

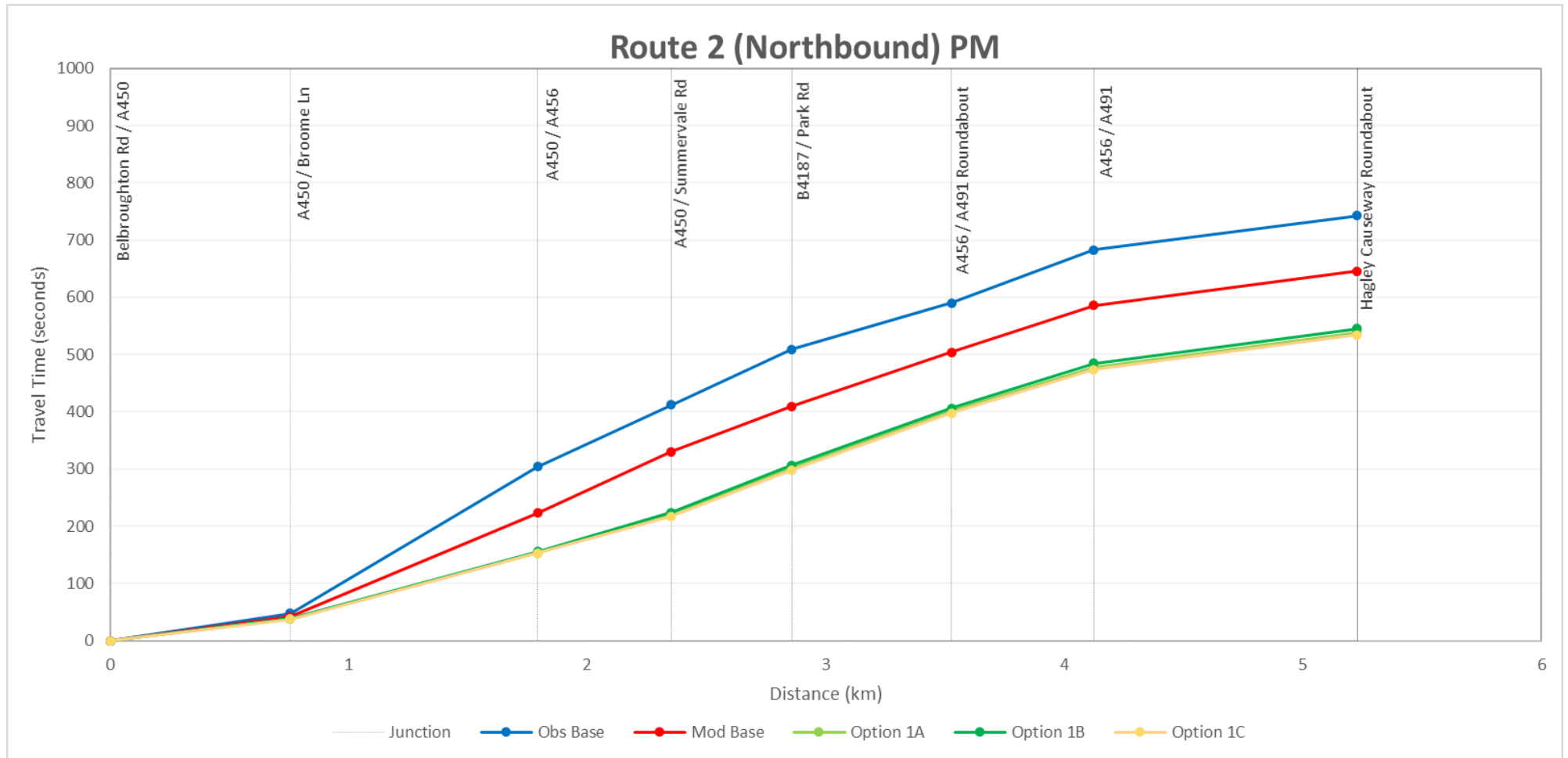


Figure 4-8: Route 2 NB – 2019 PM Journey Times – Options 1a, 1b and 1c

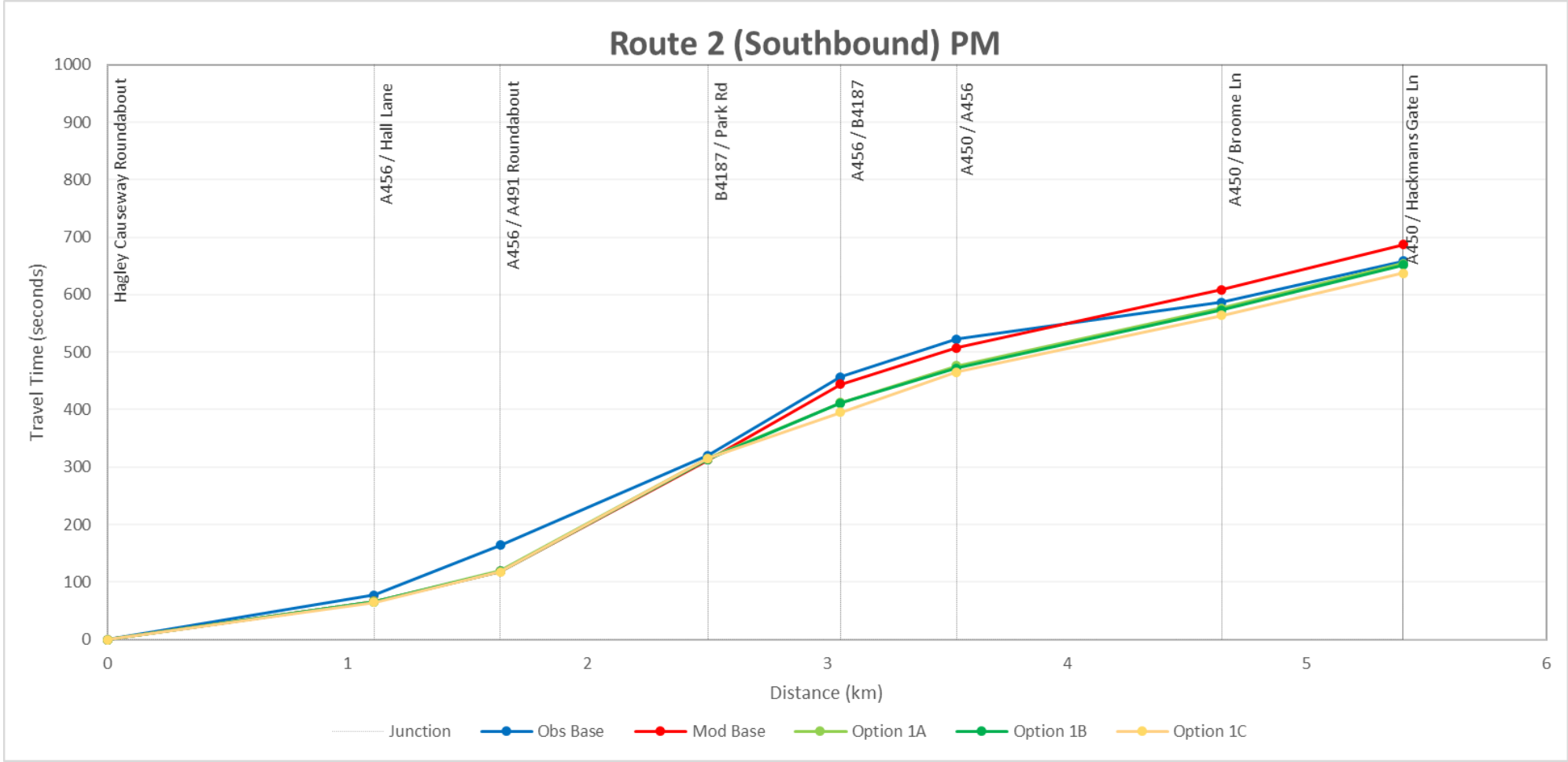


Figure 4-9: Route 2 SB – 2019 PM Journey Times – Options 1a, 1b and 1c

5. A456 / B4187 Junction Improvement – Traffic Engineering Feasibility

The preferred Option 1c provides for one-lane in each direction for the ahead movements on the A456. The left turn lane from the A456 to the B4187 under this option is for a longer distance of 80m from the back of taper to junction entry. The A456 northbound will have 3m wide lanes whilst the southbound lane will be 3.5m wide. It also imposes a ban on the right turn from A456 Kidderminster Road to B4187 Worcester Rd and a left turn ban from the B4187 to A456 Kidderminster Road northbound. This allows for a pedestrian phase on the A456 to run along with the B4187 phase for the right turn movements, thereby reducing signal stages required.

This chapter discusses the engineering feasibility of Option 1c.

5.1 Existing Layout

The Option 1c design has been drawn on an existing road layout extracted from a PDF drawing provided by WCC of the layout produced by Canwell Consultancy Services, Drawing No C/1221/100, issue 3 dated 04/09/14. This drawing is provided in Appendix A. Some details on this drawing such as the length of the splitter island south of the junction do not match Google Earth imagery dated July 2019, however as the island is relocated as part of the Option 1c design these inconsistencies should not be significant.

5.2 Design Speed

The design speed has been taken as 30mph.

5.3 Design Constraints

The junction improvement has been designed in accordance with DMRB CD 123 and is shown on Drawing No. 694944CH-JAC-HGN-ZZ-DR-CH-0001, provided in Appendix A.

The main constraint has been to retain the existing kerb lines and footway extents, only moving the kerbs forming the traffic islands as necessary to accommodate the turning movements at the junction and to remove the right turning facility from the A456 southbound and the left turn movement from the B4187 to the A456 northbound.

The islands between the A456 northbound and the B4187 have merged to form one island with access for maintenance vehicles from both the A456 and the B4187 to be provided by dropped kerbs with a 20mm upstand suitable for vehicular use.

Lane widths/kerb lines have been designed to accommodate turning movements of a refuse vehicle from B4187 through junction to Western Road, HGV's through the junction, from B4187 to A456 southbound and from A456 northbound to B4187. Other movements will be as existing and should not be affected by the design changes.

Pedestrian movements would be as existing across the A456, the refuge island has been widened and moved slightly south as a result of the shift southwards of the ahead movement of the A456 northbound to not conflict with the lane requirements for the A456 northbound to B4187 northbound movement.

Cycle provision is as existing with Advanced Stop Lines on both the northbound and southbound lanes on the A456.

5.4 Lane widths

Lane widths are shown on Drawing No. 694944CH-JAC-HGN-ZZ-DR-CH-0001. In general, they are below desirable width of 3.65m due to the constraints listed above but are a minimum of 3.00m which should be acceptable on the essentially straight through lanes.

On lanes for turning movements the lane widths have been increased as required to accommodate the design vehicles.

The taper from 1 lane to 2 lanes on the A456 northbound south of the scheme has been designed at 1:30 for 30mph in accordance with TD 27/05, Table 4-2.

5.5 Vehicle Movements

Vehicle movements are shown in Drawing No. 694944CH-JAC-HGN-ZZ-DR-CH-0002, provided in Appendix A. There is an existing restriction on HGV's making a right turn from the A456 southbound to the B4187 (see Figure 5-1), due to the turning movement required being impossible with the current geometry.

There is also an existing restriction on HGV's from the A456 northbound to the B4187 (Figure 5-2). Earlier Google StreetView imagery dated 2014 show this was previously permitted for access only.

There appears to be no restriction from HGV's using the B4187 southbound and turning into the A456 northbound or southbound at this junction.



Figure 5-1: Google Streetview Image 1



Figure 5-2: Google Streetview Image 2

5.6 Signalling and Maintenance Bays

The signal arrangement is as existing for the most part and is not the subject of this indicative design.

Provision for a maintenance bay is provided within the extended island on the north side of the junction with dropped kerb access from the A456 (within the junction) and the B4187. This is made feasible due to the right turn ban from the A456 to the B4187.

The area within the extended island is in the Junction Intervisibility Zone, and so vehicles parked here could obstruct visibility between the A456 northbound stop line and the B4187 stop line and vice versa. Engineers will have to cross the B4187 approach to reach the control cabinet, potentially while the signals are inoperable.

Alternative parking bay locations are shown on Drawing No. 694944CH-JAC-HGN-ZZ-DR-CH-0001.

An on-street parking facility can be provided on the B4187 southbound approximately 40m north of the junction, between direct accesses, made feasible due to the left turn ban from the B4187 to the A456. Positioning the parking bay closer to the junction could result in conflicts with turning movements of vehicles on the approach to the junction immediately before the tight left-hand bend into the junction. Additionally, this parking bay would have to be prevented from being used by the general public.

The other alternative parking location is on the footway close to the cabinet. Access for this will be by overrunning the kerb and the vehicle will block pedestrian use of the footway. Vehicles may intrude into the Junction Intervisibility Zone and block visibility from the B4187 approach and the A456 southbound.

5.7 Conclusion

The junction should be able to be modified as proposed under Option 1c, however this will need to be confirmed with a more detailed design based on a true topographical survey.

6. Model Outputs - Options 2 and 3

6.1 2036 Results

The Option 2 and 3 models were initially run for a 2036 forecast year. Option 2 includes Option 1b at the A456/B4187 junction with introduction of one-way on A450 southbound from A456 to Thickenall Lane; Option 3 includes Option 1b with introduction of one-way gyratory along the A456/A450, A450/ Thickenall Lane and A456/Thickenall Lane/Stakenbridge Lane junctions.

However, it was noted that there was significant congestion in some areas of the network for this forecast year resulting in traffic unable to get through to other junctions downstream. This results in reduced demand at downstream junctions and may lead to assessment of the operation of Options 2 and 3 being unreliable, as these junctions don't experience any change in delays compared to the base year.

Figure 6-1 shows the travel time along Route 1 southbound for the 2036 AM peak under Option 2. It can be seen that there is a significant increase in journey time compared with the 2019 scenarios. This increase in journey time occurs on the southbound approach to the A456 /A491/Park Road roundabout. This means that there is a lot of traffic being held at the roundabout that is not able to reach downstream junctions in west Hagley. Therefore, the assessment for these junctions would not be reliable.

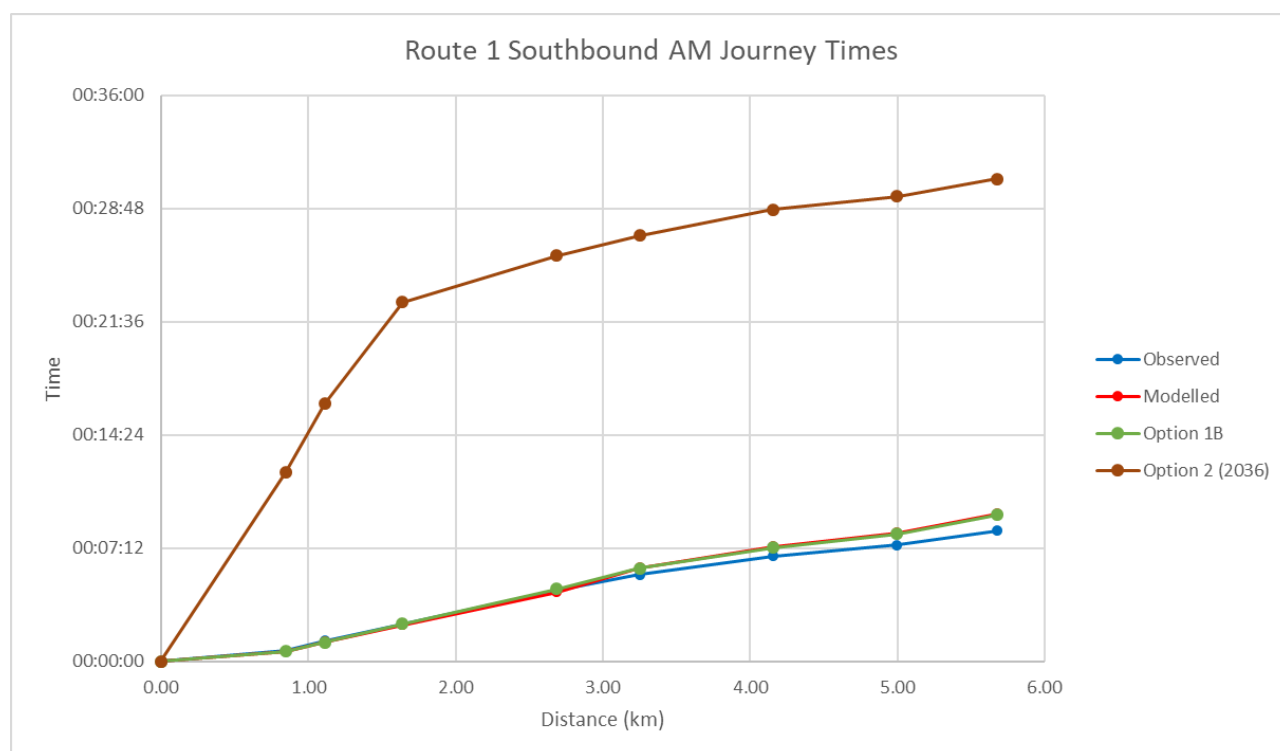


Figure 6-1: Route 1 SB – AM Journey Times – Option 1b (2019) and Option 2 (2036)

6.2 2019 Results

The Option 2 and 3 scenarios were instead run with 2019 traffic in order to obtain more reliable results on the likely operation of the network under the proposed schemes. Details of these results are given in the sections below.

6.2.1 Junction Flows

The total number of vehicles passing through each of the key junctions in the network during the AM and PM peak hours were collected for each scenario and are presented in Table 6-1. Where flows have increased compared with the base flows, the values are indicated in green whilst red indicates the opposite. As Option 1c was the best performing variant under Option 1, it has been included in the table for comparison.

Table 6-1: Options 1c, 2 and 3 - Junction Flows

Junction	Junction Throughput							
	2019 AM (08:00-09:00)				2019 PM (17:00-18:00)			
	Base	Op 1c	Op 2	Op 3	Base	Op 1c	Op 2	Op 3
B4187 Worcester Rd / Station Rd / Park Rd	1488	1442	1404	1463	1279	1345	1267	1420
A456 / B4187 Worcester Rd / Summervale Rd / Western Rd	2438	2270	2445	2447	2441	2440	2407	2519
A456 Kidderminster Rd / A450 Worcester Rd	2110	2193	2060	2143	2336	2432	2191	2380
A456 Kidderminster Rd / Stakenbridge Ln / Thicknall Ln	1258	1240	1573	1557	1542	1455	1786	1897
A450 Worcester Rd / Thicknall Ln	863	854	836	1515	881	927	836	1735
A456 Kidderminster Rd / Park Rd / A491 Stourbridge Rd / Bennett Dr	3922	3875	3850	3844	3868	3740	2827	3840
Middlefield Ln / A491 Kidderminster Rd	3303	3324	3313	3336	3212	3122	2313	3204
B4187 Worcester Rd / Middlefield Ln	1037	1099	1070	1118	961	998	988	980
A456 Kidderminster Rd / A456 Birmingham Rd / A491 Stourbridge Rd	4035	4020	4030	4023	3909	3761	3004	3856

In both the AM and PM peaks, flows at the A456 Kidderminster Road / Stakenbridge Lane / Thicknall Lane junction increase under both the Option 2 and Option 3 scenarios compared with the base and Option 1c. This is because traffic which travels along the A450 northbound towards Hagley now has to re-route via the A456 / Stakenbridge Lane / Thicknall Lane junction in order to access the A456 due to the conversion of the section of the A450 to one-way under both Options 2 and 3.

Flows at the A450 Worcester Road / Thicknall Lane junction increase significantly under Option 3 in both the AM and PM peaks. This is because traffic can no longer travel southbound along the A456 between the A456 / A450 junction and the A456 / Stakenbridge Lane / Thicknall Lane junction under this option. This traffic instead has to re-route via the A450 / Thicknall Lane junction.

6.2.2 Junction Delays

The average delay time for each vehicle passing through each of the key junctions in the model was collected for the AM and PM peak hours for each scenario and are presented in Table 6-2. Where delays have increased compared with the base delays, the values are indicated in red whilst green indicates the opposite.

Table 6-2: Options 1c, 2 and 3 - Junction Delays

Junction	Average Delay per Vehicle (s)							
	2019 AM (08:00-09:00)				2019 PM (17:00-18:00)			
	Base	Op 1c	Op 2	Op 3	Base	Op 1c	Op 2	Op 3
B4187 Worcester Rd / Station Rd / Park Rd	44.9	47.8	41.9	42.3	60.8	42.5	35.6	57.1
A456 / B4187 Worcester Rd / Summervale Rd / Western Rd	25.5	13.6	21.0	22.3	30.1	14.1	34.9	35.4
A456 Kidderminster Rd / A450 Worcester Rd	28.8	15.6	7.6	15.2	30.4	19.7	18.2	8.7
A456 Kidderminster Rd / Stakenbridge Ln / Thicknall Ln	15.5	3.6	42.5	36.1	10.1	6.7	73.3	37.5
A450 Worcester Rd / Thicknall Ln	5.9	3.4	6.4	28.5	6.9	2.7	2.8	46.4
A456 Kidderminster Rd / Park Rd / A491 Stourbridge Rd / Bennett Dr	40.1	47.0	44.8	44.1	52.0	52.7	89.3	51.7
Middlefield Ln / A491 Kidderminster Rd	29.7	30.4	34.9	32.1	2.3	2.0	5.5	2.1
B4187 Worcester Rd / Middlefield Ln	3.3	3.7	4.4	3.0	24.0	2.4	2.3	2.5
A456 Kidderminster Rd / A456 Birmingham Rd / A491 Stourbridge Rd	45.6	43.8	46.6	44.8	26.0	22.1	19.1	25.7

In both the AM and PM peaks, delays increase significantly at the A456 Kidderminster Road / Stakenbridge Lane / Thicknall Lane junction under the Options 2 and 3 scenarios. This is not only because flows at this junction increase significantly under these options, as shown in Table 6-1 but also the signalisation of the junction intrinsically adds to vehicle delays.

Similarly, delays increase significantly at the A450 Worcester Road / Thicknall Lane junction under the Option 3 scenario in both the AM and PM peaks due to the increase in demand at this junction in this scenario and its signalisation.

6.2.3 Journey Times

The journey times for these routes under Options 2 and 3, alongside observed journey times under Option 1c are given in Table 6-3 for the 2019 AM peak. Where journey have increased compared with the modelled base journey times, the values are indicated in red whilst green indicates the opposite.

Table 6-3: 2019 AM Peak Journey Times - Option 1c, 2 and 3

	Direction	2019 AM Peak (08:00-09:00)				
		Observed Base	Modelled Base	Option 1c	Option 2	Option 3
Route 1	NB	00:13:11	00:14:49	00:10:09	00:11:29	00:11:49
	SB	00:08:19	00:09:22	00:09:17	00:09:48	00:10:07
Route 2	NB	00:14:12	00:15:18	00:10:36	00:13:28	00:12:41
	SB	00:12:54	00:13:01	00:11:59	00:10:06	00:10:38

The table shows that except for Route 1 southbound journey times, all other journey time routes demonstrate travel time savings compared to the corresponding base modelled journey times. However, the time savings are lower than those under Option 1c.

Graphical representations for the two routes in both directions for the 2019 AM peak are given in Figure 6-2 to Figure 6-5.

For Route 1 northbound, all three of the proposed options lead to a decrease in journey time compared with the modelled base journey time. However, Options 2 and 3 lead to an increase in journey time compared with Option 1c. It can be seen in Figure 6-2 that most of this journey time increase occurs on the approach to the A456 / A450 signalised junction. This is because there is an increase in traffic on the approach to this junction under both of these options due to traffic which previously accessed the junction from the A450 instead having to re-route along the A456 northbound due to the conversion of this section of the A450 to one-way.

For Route 1 southbound, both Options 2 and 3 lead to an increase in travel time compared to the base and Option 1c scenarios. It can be seen in Figure 6-3 that the majority of this increase occurs after the A456 / A450 signalised junction. In Option 2, this is due to the signalisation of the A456 / Stakenbridge Lane / Thicknall Lane junction. Under Option 3, the increase in travel time is due to traffic no longer being able to travel via the A456 southbound between the A456 / A450 junction and the A456 / Stakenbridge Lane / Thicknall Lane junction after the introduction of the one-way gyratory. Instead, traffic has to re-route along the A450 and Thicknall Lane, leading to an increase in travel distance and travel time.

For Route 2 northbound, all three of the proposed options lead to a decrease in journey time compared with the modelled base journey time. However, Options 2 and 3 lead to an increase in journey time compared with Option 1c. Figure 6-4 shows that the majority of this increase occurs on the approach to the A456 / A450 signalised junction. Under both options, this is due to the conversion of the A450 between the A456 / A450 and A456 / Thicknall Lane junctions to one-way in the southbound direction. Therefore, vehicles previously travelling along this section now instead have to re-route along Thicknall Lane and the A456, making the route longer in distance and time.

For Route 2 southbound, all three of the proposed options lead to a decrease in journey time compared with the modelled base journey time. For this route, Options 2 and 3 lead to an improvement in journey time compared with Option 1c. Figure 6-5 shows that the majority of this travel time saving occurs after the A456 / A450 junction. This is because under both Options 2 and 3, the A450 is converted to two lanes in the southbound direction between the A456 / A450 junction and the A450 / Thicknall Lane junction. This increased capacity leads to a lower journey time on this section.

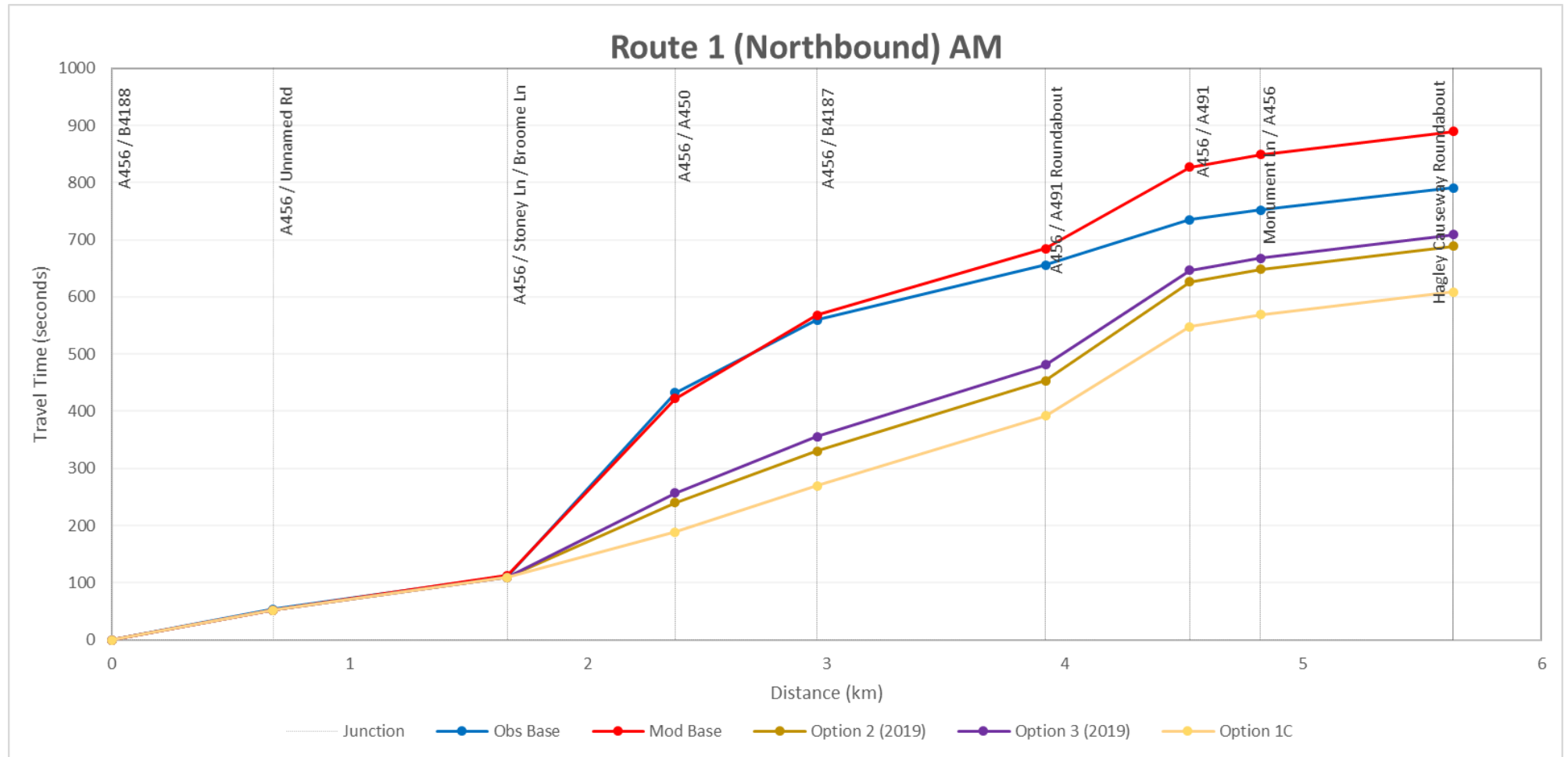


Figure 6-2: Route 1 NB – 2019 AM Journey Times – Options 2 and 3

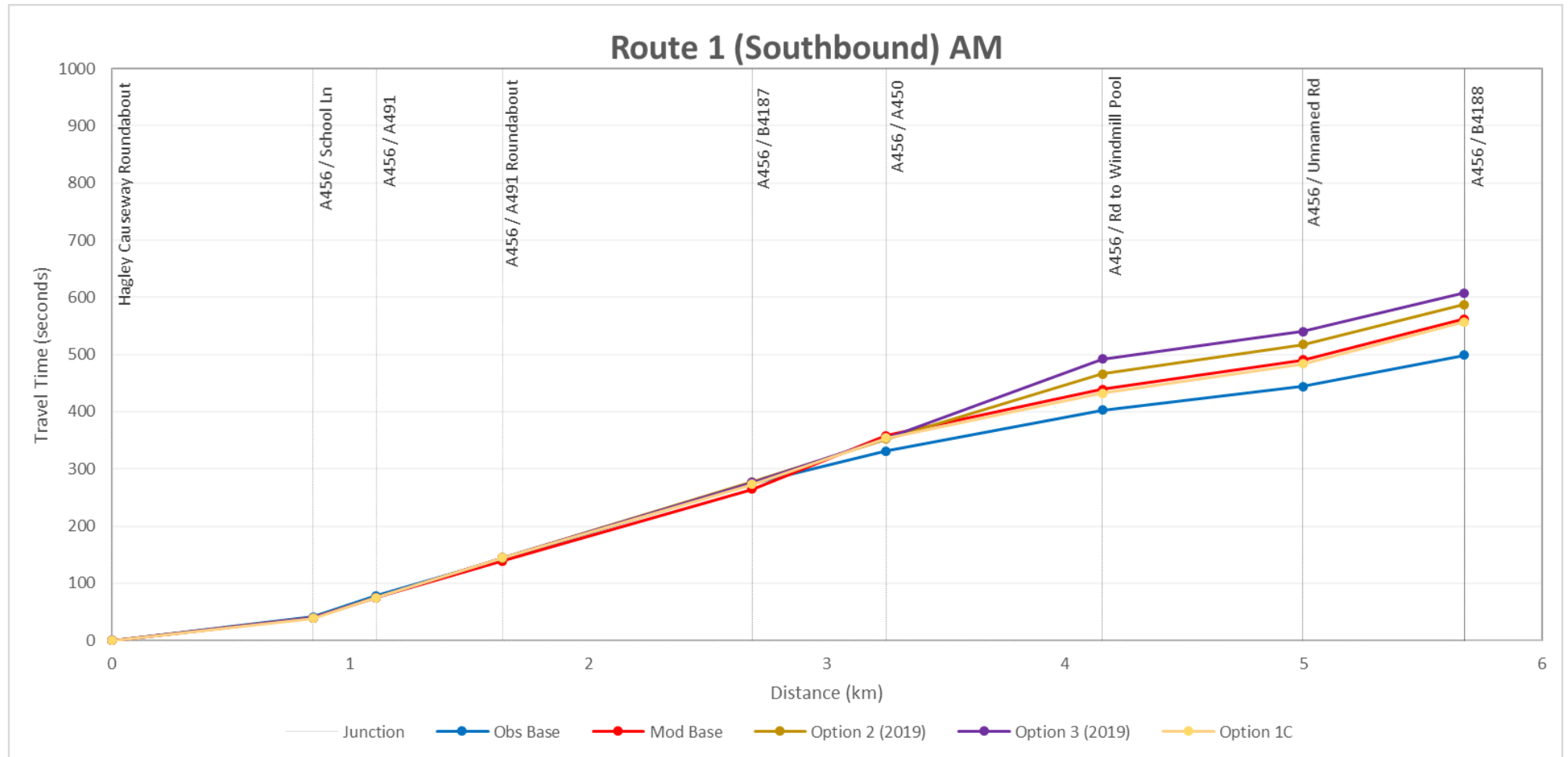


Figure 6-3: Route 1 SB – 2019 AM Journey Times – Options 2 and 3

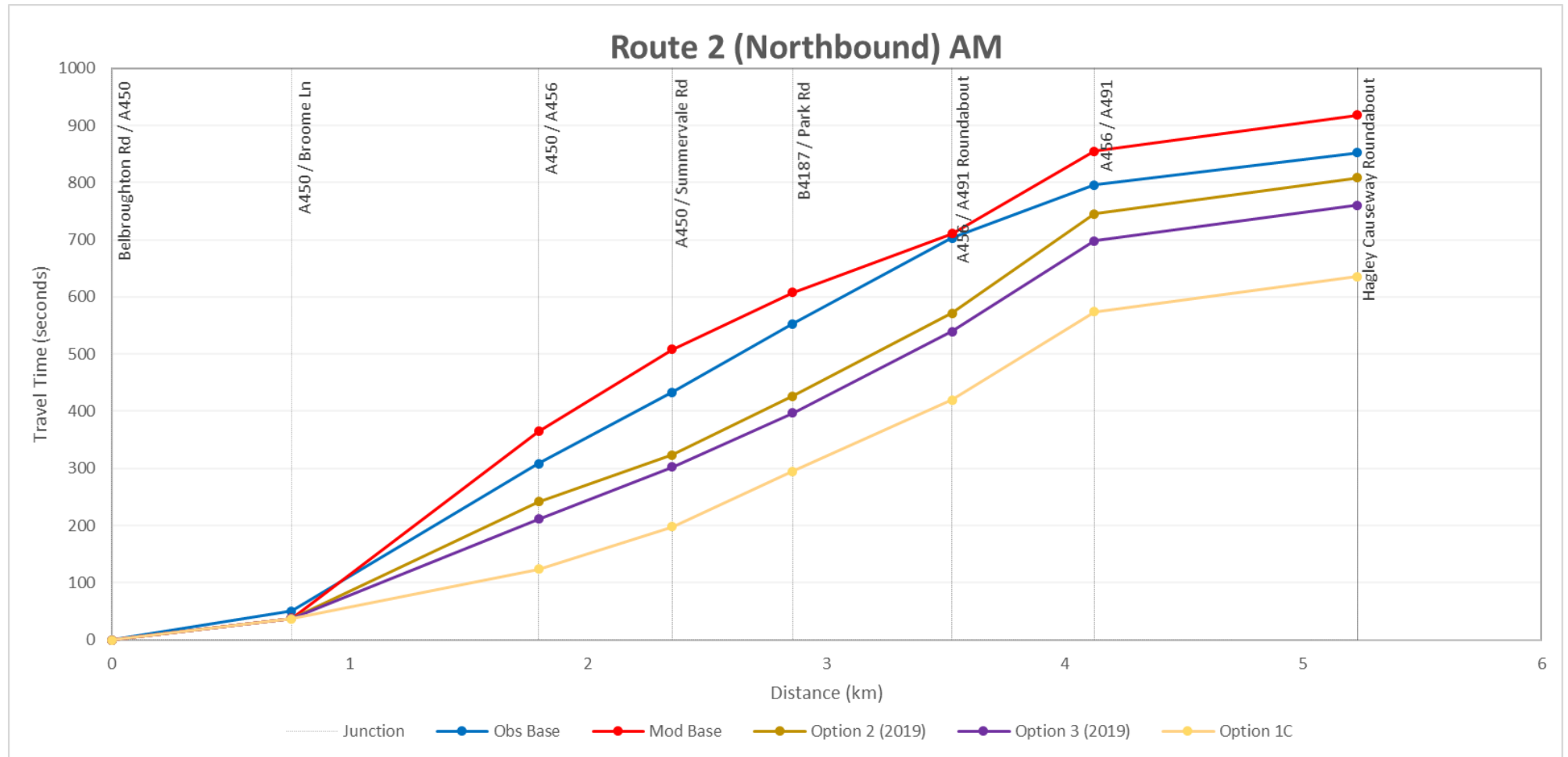


Figure 6-4: Route 2 NB – 2019 AM Journey Times – Options 2 and 3

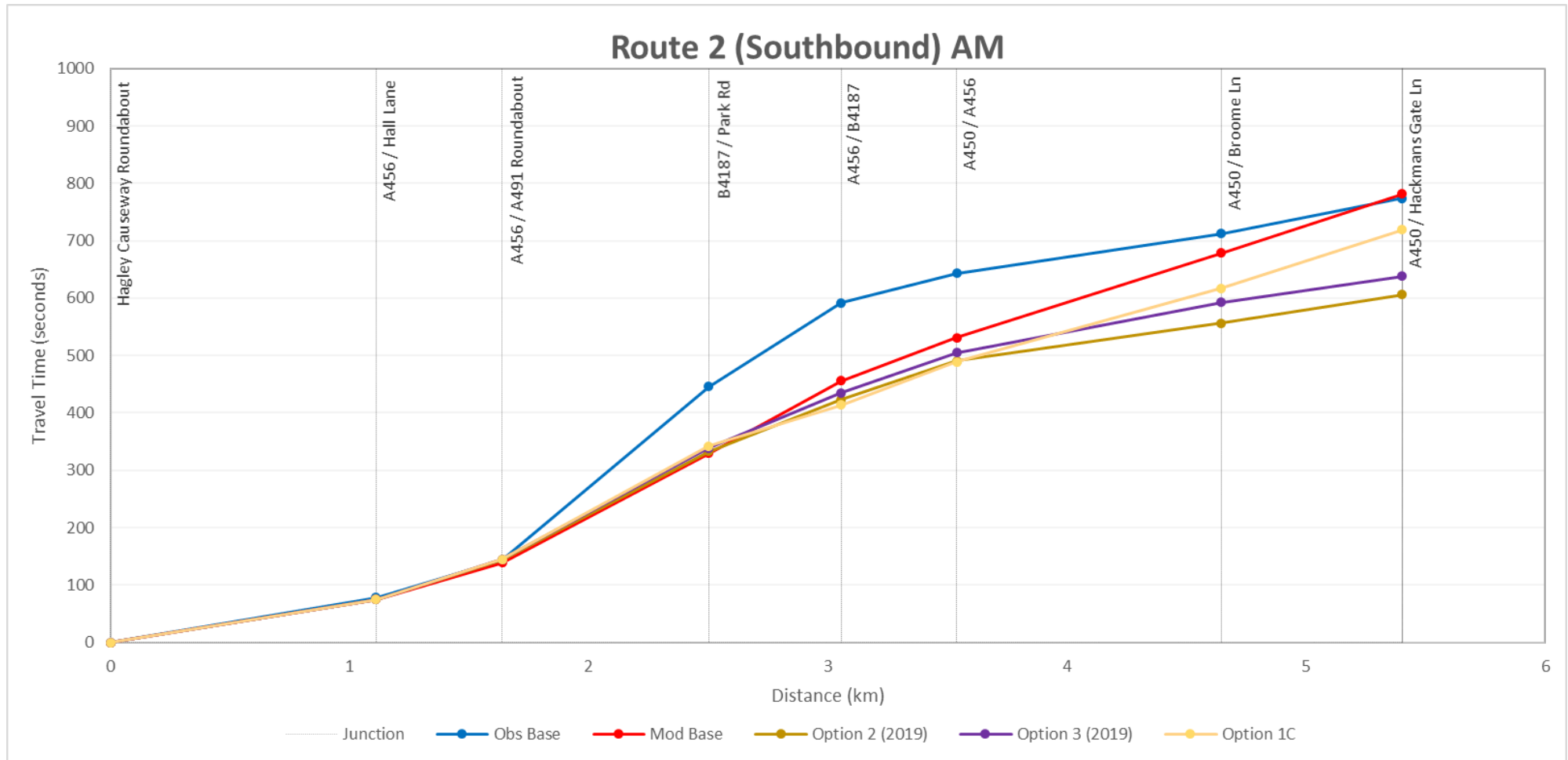


Figure 6-5: Route 2 SB – 2019 AM Journey Times – Options 2 and 3

The journey times under each of the modelled scenarios, alongside observed journey times, are given in Table 6-4 for the 2019 PM peak. Where journey times have increased compared with the modelled base journey times, the values are indicated in red whilst green indicates the opposite.

Table 6-4: 2019 PM Peak Journey Times – Options 1c, 2 and 3

	Direction	PM Peak (17:00-18:00)				
		Observed Base	Modelled Base	Option 1c	Option 2	Option 3
Route 1	NB	00:11:00	00:10:13	00:08:28	00:22:18	00:09:46
	SB	00:10:01	00:09:03	00:08:37	00:15:44	00:09:25
Route 2	NB	00:12:23	00:10:46	00:08:54	00:09:31	00:13:47
	SB	00:10:58	00:11:27	00:10:37	00:11:20	00:12:00

Graphical representations for the two routes in both directions for the 2019 PM peak are given in Figure 6-6 to Figure 6-9.

For Route 1 northbound, Options 3 leads to a decrease in journey time compared with the modelled base journey time. However, Option 3 has a higher journey time than Option 1c. This increase occurs on the approach to the A456 / A450 signalised junction as there is an increase in traffic on this approach under the Option 3 scenario due to traffic no longer being able to access this junction via the A450 and instead having to re-route along Thicknall Lane and the A456 due to the introduction of the one-way gyratory.

Option 2 leads to a significant increase in travel time along Route 1 northbound compared with the other scenarios. Figure 6-6 shows that this increase occurs on the approach to the A456 / A450 signalised junction as there is an increase in traffic on this approach under the Option 2 scenario due to traffic having to re-route along Thicknall Lane and the A456. The increase in travel time under Option 2 is much more significant than under Option 3 as the affected section of the A456 has two lanes in the northbound direction under the Option 3 scenario but only one lane under Option 2.

For Route 1 southbound, both Options 2 and 3 lead to an increase in travel time compared to the base and Option 1c scenarios. The most significant increase occurs under Option 2. It can be seen in Figure 6-7 that this increase occurs between the A456 / A491 roundabout and the A456 / Windmill Pool junction. This is due to the signalisation of the A456 / Stakenbridge Lane / Thicknall Lane junction under this option.

For Route 2 northbound, Option 2 leads to a decrease in journey time compared with the modelled base journey time. However, Option 2 has a higher journey time than Option 1c. It can be seen in Figure 6-8 that the majority of this increase occurs on the approach to the A456 / A450 junction as traffic has to travel along Thicknall Lane to this junction leading to a longer journey time in terms of both distance and time.

Under Option 3, Route 2 northbound experiences an increase in travel time compared with the other scenarios. As in Option 2, this is due to traffic having to re-route along Thicknall Lane and the A456 in this option.

For Route 2 southbound, Option 2 leads to a decrease in journey time compared with the modelled base journey time. However, Option 2 has a higher journey time than Option 1c for this route. Figure 6-9 shows that this increase occurs on the approach to the A456 / A450 junction. Option 3 has a higher journey time than the other three scenarios, the increase journey time under this scenario occurs on the approach to the A456 / B4187 Worcester Road signalised junction.

The above analysis shows that Option 1c provides higher journey time savings and reduced delay than Options 2 and 3 and is therefore preferable for 2019 traffic conditions.

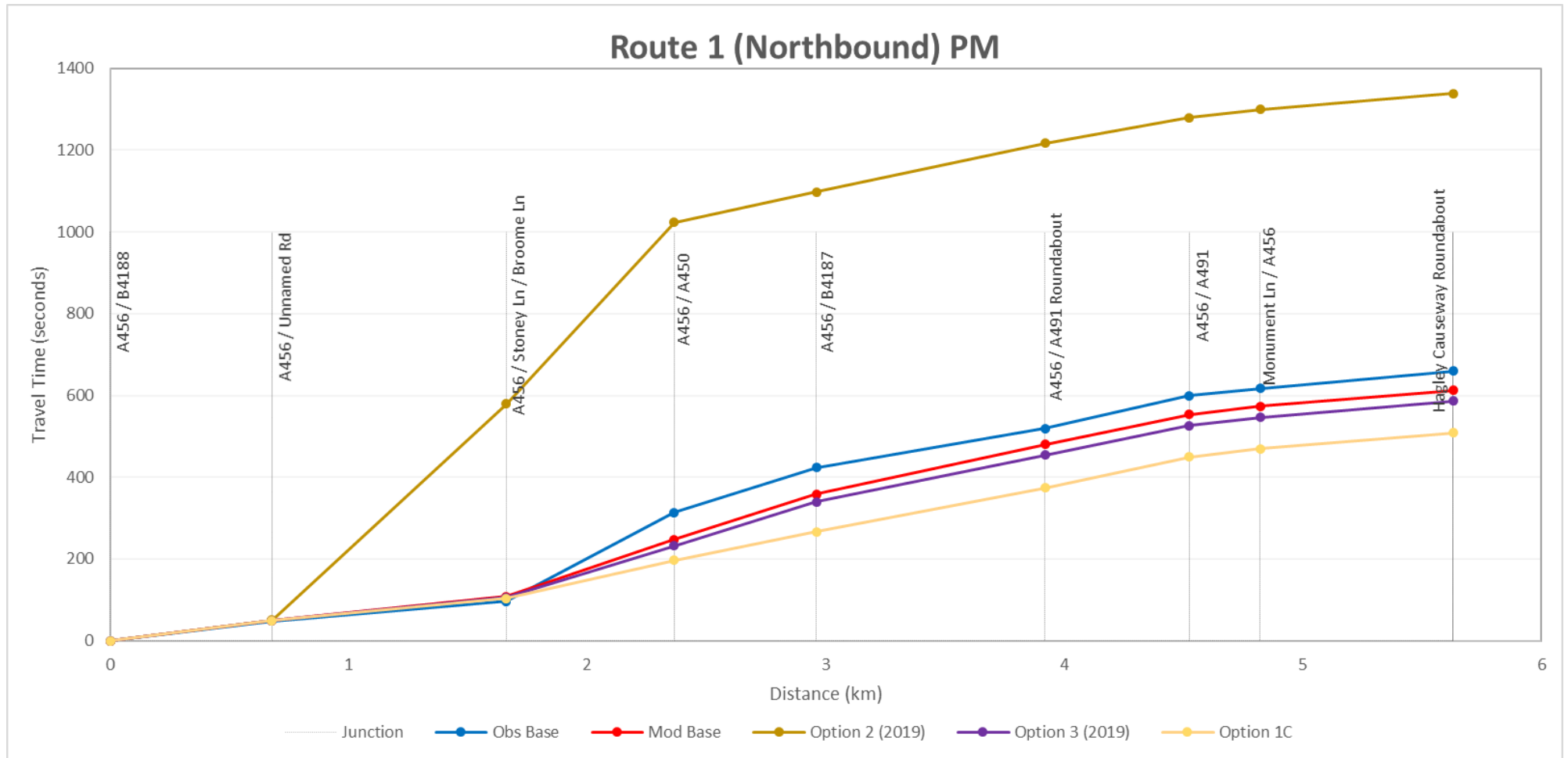


Figure 6-6: Route 1 NB – 2019 PM Journey Times – Options 2 and 3

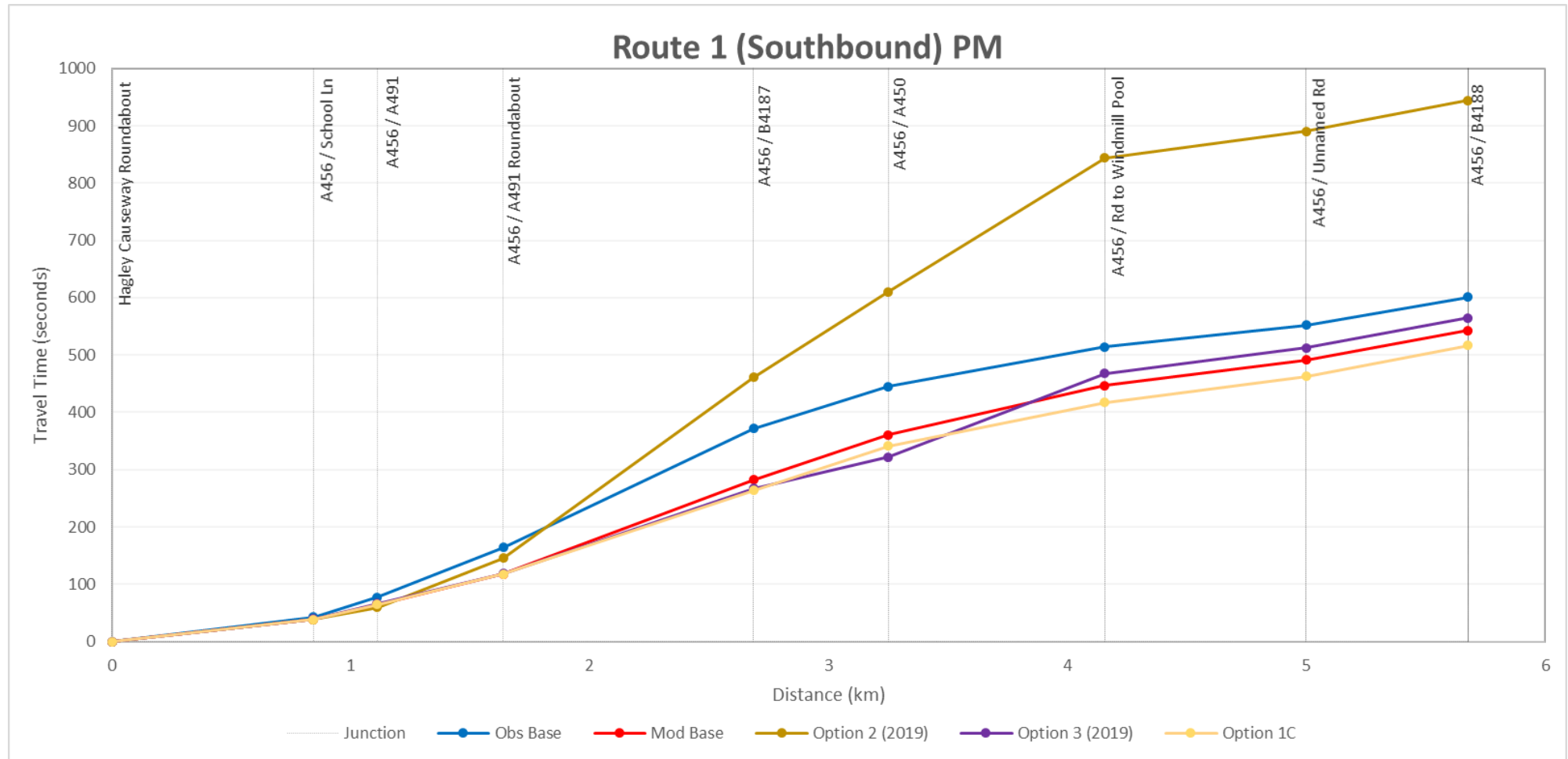


Figure 6-7: Route 1 SB – 2019 PM Journey Times – Options 2 and 3

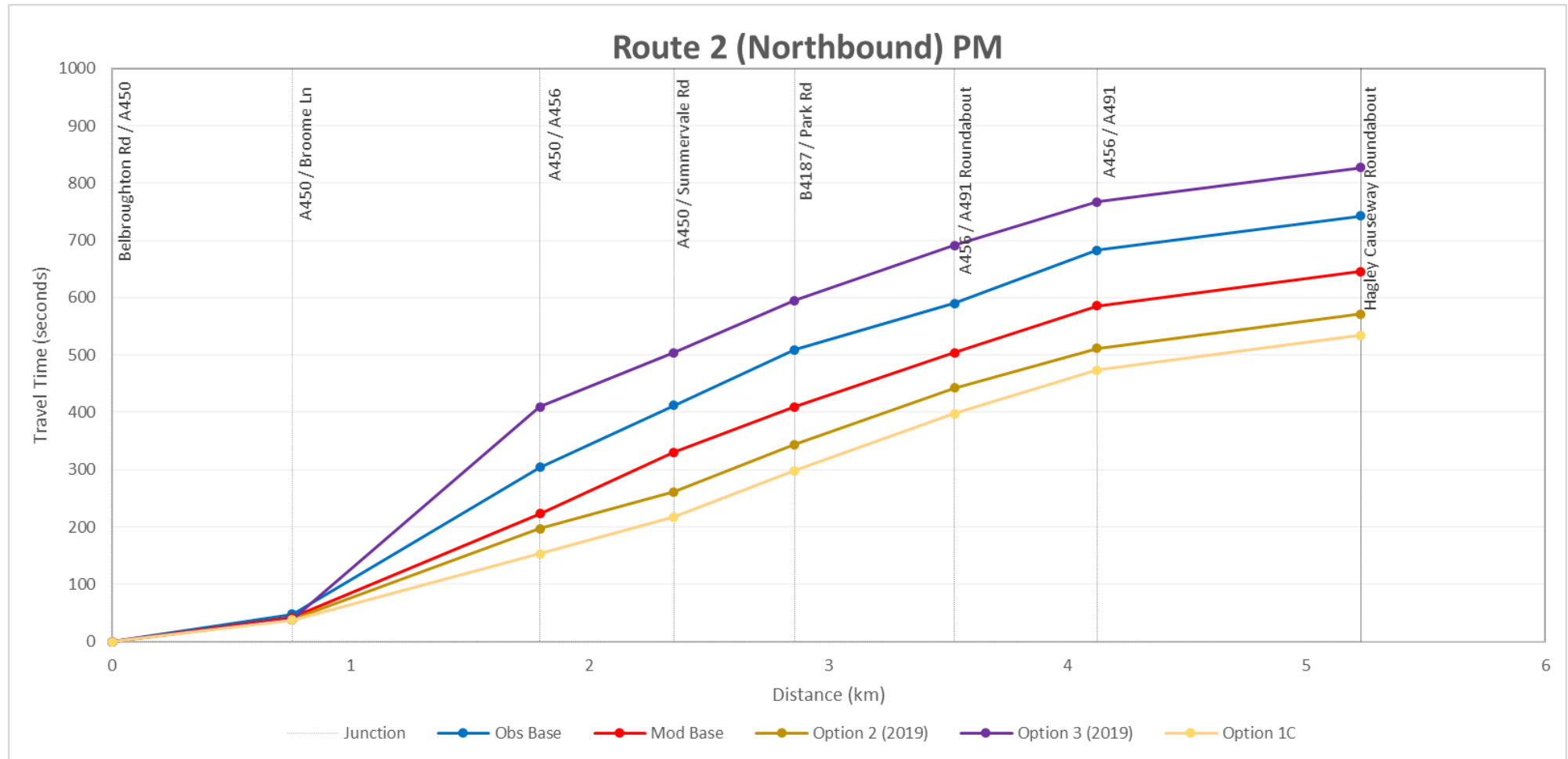


Figure 6-8: Route 2 NB – 2019 PM Journey Times – Options 2 and 3

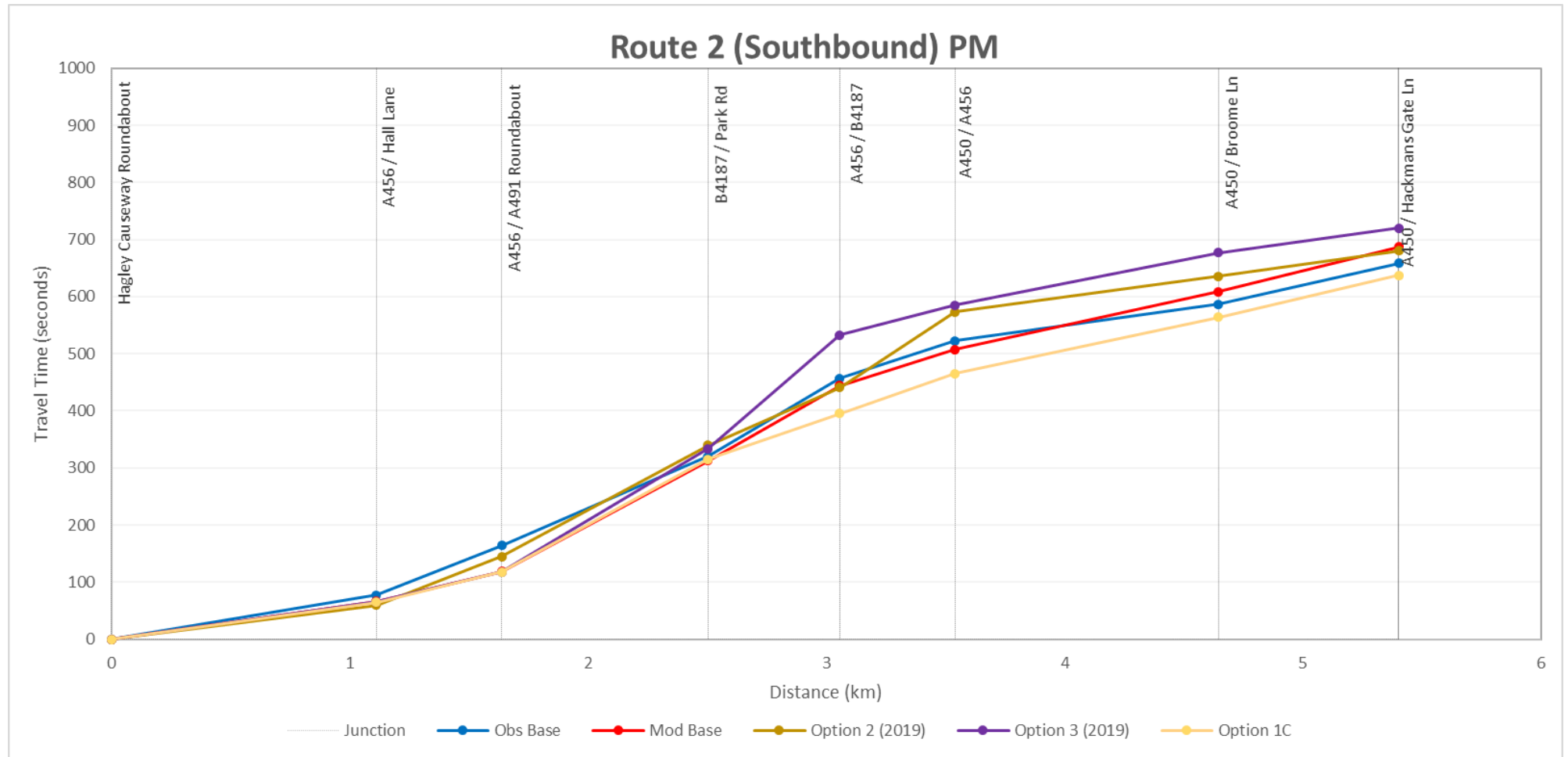


Figure 6-9: Route 2 SB – 2019 PM Journey Times – Options 2 and 3

7. A491 Kidderminster Rd/ Stourbridge Rd (Cattle Market Junction) Enhancements

7.1 Introduction

This chapter investigates a scheme to improve the performance of the A491 Kidderminster Rd/ Stourbridge Rd signalised 'T' junction, also known as 'Cattle Market junction'.

The outcome of this work will be used to define infrastructure requirements at the junction alongside other improvement options at junctions that currently suffer congestion on the A456 corridor in Hagley.

7.2 WCC Option

The junction has been identified in the past by the Parish Council as a congestion hotspot and a request for improvements by widening the approach lanes from the south has been suggested. This is to resolve problems with left turning traffic travelling from the A456 Kidderminster Road to Stourbridge Road which are currently being blocked from exiting the junction by queueing traffic at the signals. The left turn slip is about 35 metres from the signals stop-line and therefore 6 pcu's waiting at the stop-line blocks left turning traffic which then increases the length of the queue and increased delays at the junction.

The proposed widened work could facilitate a longer left turn lane from the south and consequently reduce the level of queues and delays observed on the southern arm of the junction.

The 2019 validated VISSIM (micro-simulation) has been used to identify the problem and this confirms significant queueing on the southern arm largely due to straight ahead traffic queueing at the signals blocking the left turners from entering the left turn slip lane.

The feasibility of widening work has been investigated using highway boundary data obtained from WCC. It is considered that the widening work would need to be contained within highway land otherwise the scheme could become cost prohibitive and generate objections from the impacted adjacent land owners. The boundary data shows limited highway land available to provide widening works in this location. The highway boundary data is given in Figure 7-1:



Figure 7-1 Highway Boundary data for Cattle market Junction

7.3 Alternative Option

Whilst widening work would improve the overall capacity at the junction, land constraints make this option difficult to provide. Instead, an alternative option has been developed to improve the performance of the junction described as follows:

- A456 Kidderminster Road (from south), re-configure lane markings - provide a left turn only lane and ahead lane up to the left turn slip access, then flare out the ahead lane to two lanes just past the left-turn slip.
- A456 Birmingham Road (from east), move the stop-line forward on the Birmingham Road (for ahead movements) this will increase the queuing capacity before right turn lane becomes blocked and will reduce the intergreen time. This should increase the throughput and therefore the capacity of the junction.
- Extend the Southbound 3-lanes approach on A491 Stourbridge Road by 80m.

This option has been modelled using the 2019 VISSIM model with Option 1c improvements to determine the journey time impacts of the proposals compared with the existing layout. A variant of Option 1c that retains the left turn movement from B4187 Worcester Road to the A456 Kidderminster Road has been modelled as Option 4b with the layout shown in Drawing No. 694944CH-JAC-HGN-ZZ-DR-0001, provided in Appendix A.

2036 forecasts have not been modelled as congestion at the A456/491/Park Road roundabout blocks back impacting the performance of Cattle Market junction and other junction to provide reliable results as mentioned in 6.1.

8. Model Outputs – Options 4 and 4b

8.1 Model Runs

The AM and PM peak models for Options 4 and 4b were each run 10 times with 2019 demand similar to previous options. Junction flows and delays, journey times and vehicle network performance indicators were collected, and the results obtained were averaged over the 10 runs and are reported in the following sections.

8.2 Junction Flows

The total number of vehicles passing through each of the key junctions in the network during the AM and PM pre-peak and peak hours were collected for Options 4 and 4b and are presented in Table 8-1 to Table 8-3. Where flows have increased compared with the base flows, the values are indicated in green whilst red indicates the opposite. As Option 1c was the best performing variant of the previous options tested, it has been included in the table for comparison.

Table 8-1: Options 1c, 4 and 4b - Junction Flows – 2019 AM Pre-Peak and Peak Hours

Junction	Junction Throughput							
	2019 AM (07:00-08:00)				2019 AM (08:00-09:00)			
	Base	Op 1c	Op 4	Op 4b	Base	Op 1c	Op 4	Op 4b
B4187 Worcester Rd / Station Rd / Park Rd	1154	1127	1125	1109	1488	1442	1442	1421
A456 / B4187 Worcester Rd / Summervale Rd / Western Rd	2180	2221	2218	2200	2438	2270	2272	2363
A456 Kidderminster Rd / A450 Worcester Rd	2043	2172	2173	2146	2110	2193	2193	2212
A456 Kidderminster Rd / Stakenbridge Ln / Thicknall Ln	1186	1208	1208	1195	1258	1240	1238	1246
A450 Worcester Rd / Thicknall Ln	908	912	915	905	863	854	853	860
A456 Kidderminster Rd / Park Rd / A491 Stourbridge Rd / Bennett Dr	3766	3755	3772	3753	3922	3875	3865	3838
Middlefield Ln / A491 Kidderminster Rd	3171	3196	3221	3224	3303	3324	3301	3298
B4187 Worcester Rd / Middlefield Ln	805	845	843	837	1037	1099	1099	1102
A456 Kidderminster Rd / A456 Birmingham Rd / A491 Stourbridge Rd	3866	3873	3913	3914	4035	4020	3992	3986

Table 8-2: Options 1c, 4 and 4b - Junction Flows – 2019 PM Pre-Peak and Peak Hours

Junction	Junction Throughput							
	2019 PM (16:00-17:00)				2019 PM (17:00-18:00)			
	Base	Op 1c	Op 4	Op 4b	Base	Op 1c	Op 4	Op 4b
B4187 Worcester Rd / Station Rd / Park Rd	1086	1211	1201	1199	1279	1345	1338	1331
A456 / B4187 Worcester Rd / Summervale Rd / Western Rd	2437	2527	2529	2531	2441	2440	2446	2506
A456 Kidderminster Rd / A450 Worcester Rd	2340	2427	2431	2429	2336	2432	2440	2449
A456 Kidderminster Rd / Stakenbridge Ln / Thicknall Ln	1492	1434	1431	1432	1542	1455	1454	1458
A450 Worcester Rd / Thicknall Ln	943	956	957	955	881	927	932	940
A456 Kidderminster Rd / Park Rd / A491 Stourbridge Rd / Bennett Dr	3694	3695	3731	3722	3868	3740	3780	3804
Middlefield Ln / A491 Kidderminster Rd	3165	3181	3198	3187	3212	3122	3126	3186
B4187 Worcester Rd / Middlefield Ln	789	842	828	827	961	998	997	1000
A456 Kidderminster Rd / A456 Birmingham Rd / A491 Stourbridge Rd	4016	3978	4007	4001	3909	3761	3785	3838

Table 8-3: Options 1c, 4 and 4b - Junction Flows – 2019 AM and PM Two-Hour Peak Periods

Junction	Junction Throughput							
	2019 AM (07:00-09:00)				2019 PM (16:00-18:00)			
	Base	Op 1c	Op 4	Op 4b	Base	Op 1c	Op 4	Op 4b
B4187 Worcester Rd / Station Rd / Park Rd	2642	2569	2567	2530	2365	2556	2539	2530
A456 / B4187 Worcester Rd / Summervale Rd / Western Rd	4618	4491	4490	4563	4878	4967	4975	5037
A456 Kidderminster Rd / A450 Worcester Rd	4153	4365	4366	4358	4676	4859	4871	4878
A456 Kidderminster Rd / Stakenbridge Ln / Thicknall Ln	2444	2448	2446	2441	3034	2889	2885	2890
A450 Worcester Rd / Thicknall Ln	1771	1766	1768	1765	1824	1883	1889	1895
A456 Kidderminster Rd / Park Rd / A491 Stourbridge Rd / Bennett Dr	7688	7630	7637	7591	7562	7435	7511	7526
Middlefield Ln / A491 Kidderminster Rd	6474	6520	6522	6522	6377	6303	6324	6373
B4187 Worcester Rd / Middlefield Ln	1842	1944	1942	1939	1750	1840	1825	1827
A456 Kidderminster Rd / A456 Birmingham Rd / A491 Stourbridge Rd	7901	7893	7905	7900	7925	7739	7792	7839

In the 2019 AM peak, most junctions experience a decrease in throughput under Options 4 and 4b compared with the base scenario for the peak hour of 08:00-09:00. However, in the pre-peak, all expect one junction experience an increase in throughput compared with the base scenario.

Table 8-3 shows that overall, for the two-hour modelled AM period, four junctions experience a reduction in throughput whilst five experience an increase under Option 4. Throughput under Option 4 in the 2019 AM peak is very similar to that under Option 1c, differing by a maximum of 12 vehicles for any junction. Under Option 4b, there is an increase in throughput of 73 vehicles at the A456 / B4187 Worcester Road signalised junction compared with Option 4. This is due to the left turn from the B4187 Worcester Road onto the A456 being allowed under this option.

In the 2019 PM peak, as in the AM peak, most junctions experience an increase in throughput during the pre-peak under Options 4 and 4b compared with the base. As in the AM peak, for the two-hour modelled PM period, four junctions experience a reduction in throughput under Options 4 and 4b compared with the base whilst five experience an increase. Throughput at the A456 Kidderminster Road / A491 Stourbridge Road signalised junction increases under Options 4 and 4b compared with Option 1c, from 7739 vehicles to 7792 and 7839 vehicles respectively. As in the AM peak, the re-introduction of the left turn from the B4187 Worcester Road onto the A456 under Option 4b leads to an increase in throughput at this junction of 62 vehicles compared with Option 4.

8.2.1 Junction Delays

The average delay time for each vehicle passing through each of the key junctions in the model was collected for the AM and PM peak hours for each scenario and are presented in Table 8-4. Where delays have increased compared with the base delays, the values are indicated in red whilst green indicates the opposite.

Table 8-4: Options 1c, 4 and 4b - Junction Delays

Junction	Average Delay per Vehicle (s)							
	2019 AM (08:00-09:00)				2019 PM (17:00-18:00)			
	Base	Op 1c	Op 4	Op 4b	Base	Op 1c	Op 4	Op 4b
B4187 Worcester Rd / Station Rd / Park Rd	44.9	47.8	45.4	45.9	60.8	42.5	47.6	44.5
A456 / B4187 Worcester Rd / Summervale Rd / Western Rd	25.5	13.6	13.8	20.4	30.1	14.1	13.6	22.2
A456 Kidderminster Rd / A450 Worcester Rd	28.8	15.6	16.1	20.1	30.4	19.7	19.5	19.7
A456 Kidderminster Rd / Stakenbridge Ln / Thicknall Ln	15.5	3.6	3.5	6.6	10.1	6.7	7.0	7.2
A450 Worcester Rd / Thicknall Ln	5.9	3.4	3.4	3.4	6.9	2.7	2.5	2.6
A456 Kidderminster Rd / Park Rd / A491 Stourbridge Rd / Bennett Dr	40.1	47.0	39.7	37.2	52.0	52.7	52.8	52.5
Middlefield Ln / A491 Kidderminster Rd	29.7	30.4	18.0	12.8	2.3	2.0	2.1	2.2
B4187 Worcester Rd / Middlefield Ln	3.3	3.7	3.2	3.4	24.0	2.4	3.4	3.1
A456 Kidderminster Rd / A456 Birmingham Rd / A491 Stourbridge Rd	45.6	43.8	37.0	36.2	26.0	22.1	20.5	20.7

In both the AM and PM peaks, delays decrease at the A456 Kidderminster Road / A491 Stourbridge Road signalised junction under Options 4 and 4b compared with the base and Option 1c. This is due to the improvements made at this junction under this option. Delays at this junction are similar under Options 4 and 4b. In the AM peak, delays reduce from 43.8 seconds under Option 1c to 37 and 36.2 seconds under Options 4 and 4b respectively. Delays in the PM peak reduce from 22.1 seconds to 20.5 and 20.7 seconds.

In the AM peak, delays at the A456 Kidderminster Road / A491 Stourbridge Road roundabout also decrease under Options 4 and 4b, from 47 seconds in Option 1c to 39.7 and 37.2 seconds. This is because the Option 4 scheme reduces the northbound traffic blocking back from the signalised junction to the roundabout.

It can be seen that delays at the A456 / B4187 Worcester Road signalised junction are higher under Option 4b than Option 4 in both the AM and PM peaks. In the AM peak, delays at this junction under Option 4 are 13.8 seconds and rise to 20.4 seconds under Option 4b. In the PM peak, delays increase from 13.6 seconds under Option 4 to 22.2 seconds under Option 4b. This is due to the left turn from the B4187 Worcester Road onto the A456 being allowed under Option 4b. This means that the signal staging at this junction has to be revised under Option 4b to allow for a separate pedestrian phase thereby leaving less green time for traffic and therefore higher delays at the junction.

Table 8-5 gives a breakdown of the delays at the A456 Kidderminster Road / A491 Stourbridge Road signalised junction by movement.

Table 8-5: A456 / A491 Signalised Junction Delays

Junction	From	To	AM Peak				PM Peak			
			Base	Op 1c	Op 4	Op 4b	Base	Op 1c	Op 4	Op 4b
A456 Kidderminster Road / Birmingham Road / A491 Stourbridge Road	A456 Birmingham Rd Westbound	A456 Birmingham Rd Westbound	21.58	21.97	12.43	12.80	15.09	13.43	10.72	11.15
		A491 Stourbridge Rd Northbound	70.54	67.1	61.49	62.07	41.5	37.02	37.03	37.51
	A491 Stourbridge Rd Southbound	A456 Birmingham Rd Westbound	52.44	50.34	56.44	54.90	40.27	35.4	34.92	35.12
		A456 Birmingham Rd Eastbound	16.73	16.18	17.35	16.89	10.89	8.75	10.27	12.39
	A456 Birmingham Rd Eastbound	A491 Stourbridge Rd Northbound	32.99	31.46	18.76	17.13	15.54	8.28	9.66	8.79
		A456 Birmingham Rd Eastbound	72.44	69.42	52.98	52.00	35.94	28.84	26.08	27.70

In the AM peak, the Option 4 improvements lead to a reduction in delays overall at the A456 / A491 signalised junction. The movement which experiences the greatest reduction in delay compared with Option 1c is the left turn from the A456 Birmingham Road to the A491 Stourbridge Road, reducing from approximately 31 seconds to 17-19 seconds under Options 4 and 4b. This is due to this movement being assigned a dedicated lane under Option 4.

In the PM peak, the reduction in delays at this junction under Option 4 are less significant. The movement which experiences the greatest decrease in delay compared with Option 1c is the straight-ahead movement along the A456 eastbound through the junction. This is due to the reallocation of lanes on this approach under Option 4.

8.2.2 Journey Times

The journey times in the network under Option 4 and 4b, alongside observed journey times as well as under Option 1c are given in Table 8-6 for the 2019 AM peak. Journey times decrease compared with the modelled base journey times for all routes and across all time periods; and are similar or slightly less than under Option 1c.

Table 8-6: 2019 AM Peak Journey Times - Option 1c, 4 and 4b

	Direction	2019 AM Peak (08:00-09:00)				
		Observed Base	Modelled Base	Option 1c	Option 4	Option 4b
Route 1	NB	00:13:11	00:14:49	00:10:09	00:09:56	00:10:33
	SB	00:08:19	00:09:22	00:09:17	00:09:04	00:09:10
Route 2	NB	00:14:12	00:15:18	00:10:36	00:10:20	00:10:11
	SB	00:12:54	00:13:01	00:11:59	00:11:44	00:12:04

Graphical representations for the two routes in both directions for the 2019 AM peak are given in Figure 8-1 to Figure 8-4.

For Route 1 northbound, the travel time reduces from 10 minutes 9 seconds under Option 1c to 9 minutes 56 seconds under Option 4. Figure 8-1 shows that this journey time saving occurs on the approach to the A456 Kidderminster Road / A491 Stourbridge Road signalised junction due to the Option 4 improvements

made on the northbound approach to this junction. The Option 4b travel time for this route is 10 minutes 33 seconds, higher than both the Option 1c and Option 4 travel times. It can be seen in Figure 8-1 that this increase in travel time occurs on the approach to the A456 / B4187 Worcester Road signalised junction. This is due to the left turn from the B4187 Worcester Road onto the A456 being allowed under Option 4b resulting in additional pedestrian stage at the signals and reducing available green time for traffic leading to higher delays at the junction.

For Route 1 southbound, the travel time reduces by 13 seconds under Option 4 compared with Option 1c. Figure 8-2 shows that most of this travel time saving occurs at the beginning of the route on the approach to the A456 Kidderminster Road / A491 Stourbridge Road signalised junction. This is because the A456 southbound stopline is moved forward under Option 4, allowing better signal efficiency and increased stacking capacity on this approach and leading to a reduction in delays and therefore travel time. Option 4b has a similar travel time to Option 4 for this route, at 9 minutes 10 seconds.

Route 2 northbound experiences a 14 second reduction in travel time under Option 4 compared with Option 1c. This saving occurs on the same section as for Route 1 northbound, the approach to the A456 Kidderminster Road / A491 Stourbridge Road signalised junction. For Option 4b, the travel time is higher than for Option 4 up until the A456 / B4187 Worcester Road signalised junction. This is on the same section as for Route 1 northbound. However, after this point, the Option 4b travel time reduces compared with Option 4 due to reduction in traffic heading north on B4187 (as left turn to A456 Kidderminster Road is open) leading to the overall travel time being 9 seconds less.

Route 2 southbound experiences a 15 second reduction in travel time under Option 4 compared with Option 1c, from 11 minutes 59 seconds to 11 minutes 44 seconds. This journey time saving mostly occurs on the approach to the A456 Kidderminster Road / A491 Stourbridge Road signalised junction. However, Option 4b leads to a 5 second increase in travel time compared with Option 1c. This increase occurs on the approach to the A456 / B4187 Worcester Road signalised junction. This is due to an increase in demand on this section of the route due to the left turn from the B4187 Worcester Road onto the A456 being allowed under Option 4b.

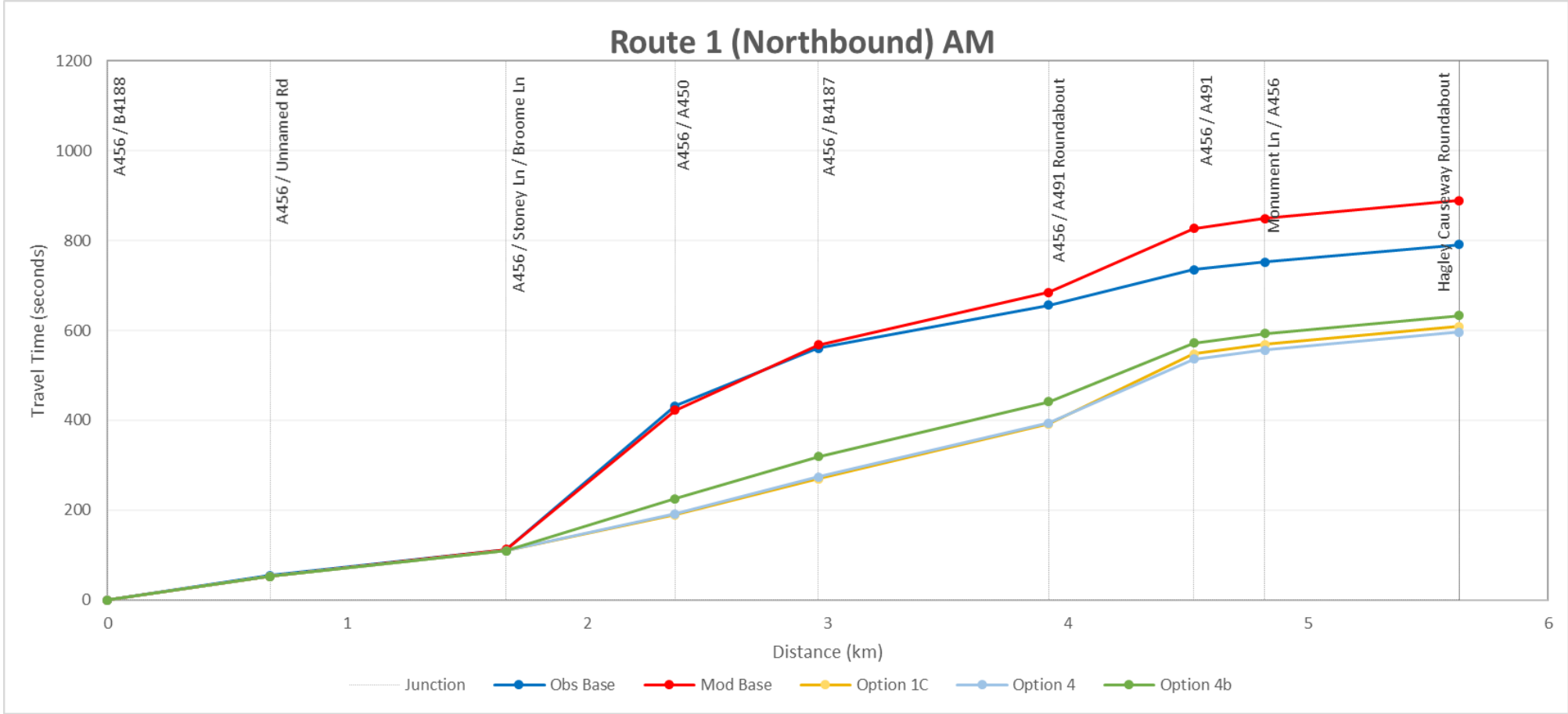


Figure 8-1: Route 1 NB – 2019 AM Journey Times – Option 4 and 4b

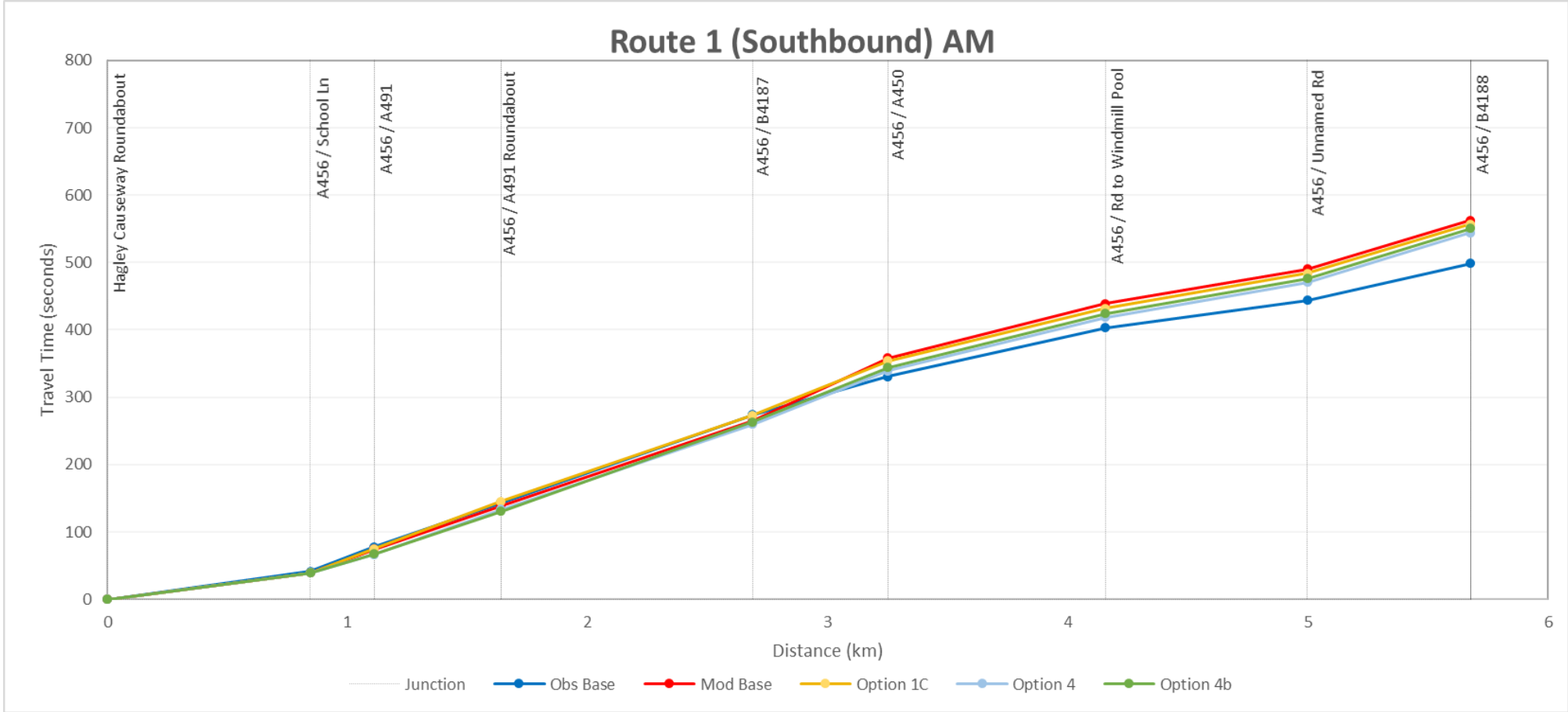


Figure 8-2: Route 1 SB – 2019 AM Journey Times – Option 4 and 4b

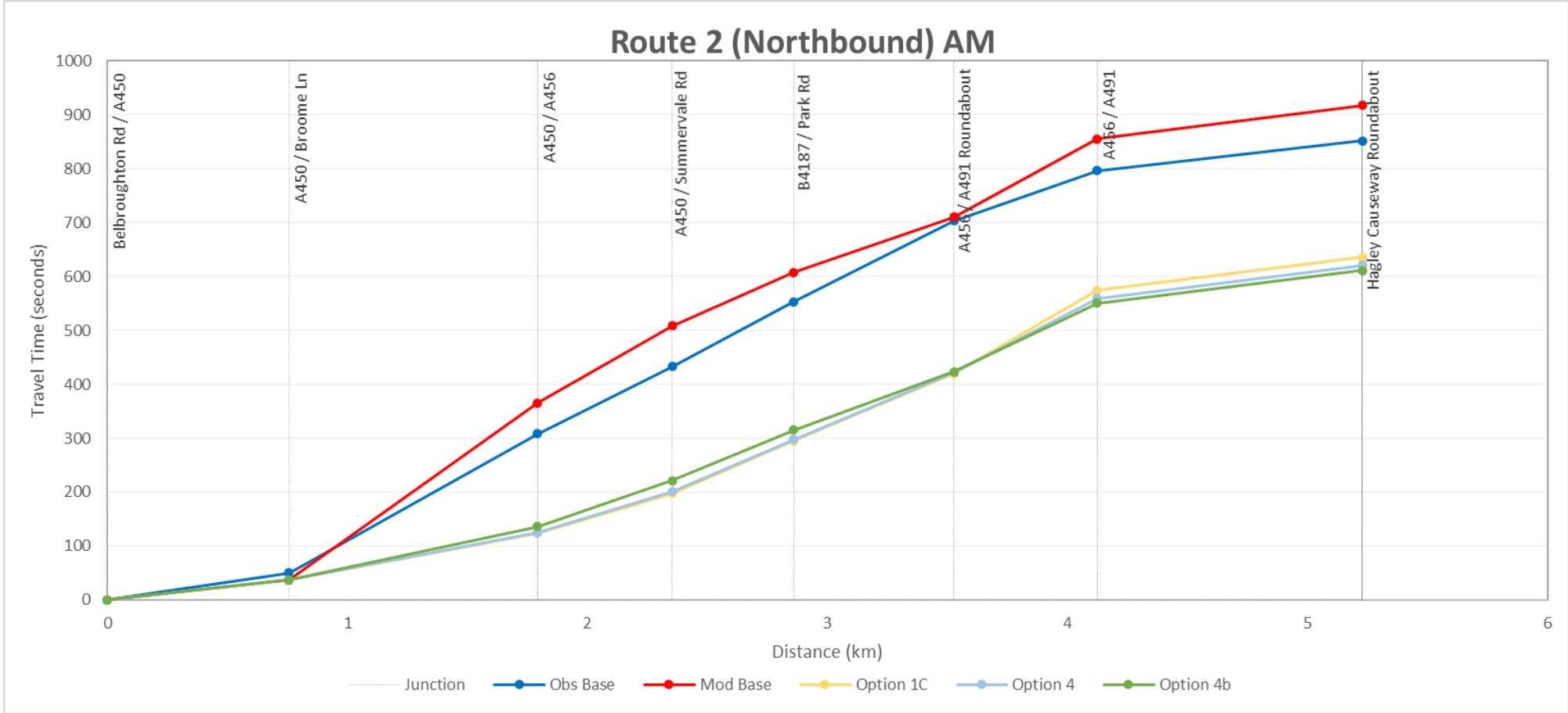


Figure 8-3: Route 2 NB – 2019 AM Journey Times – Option 4 and 4b

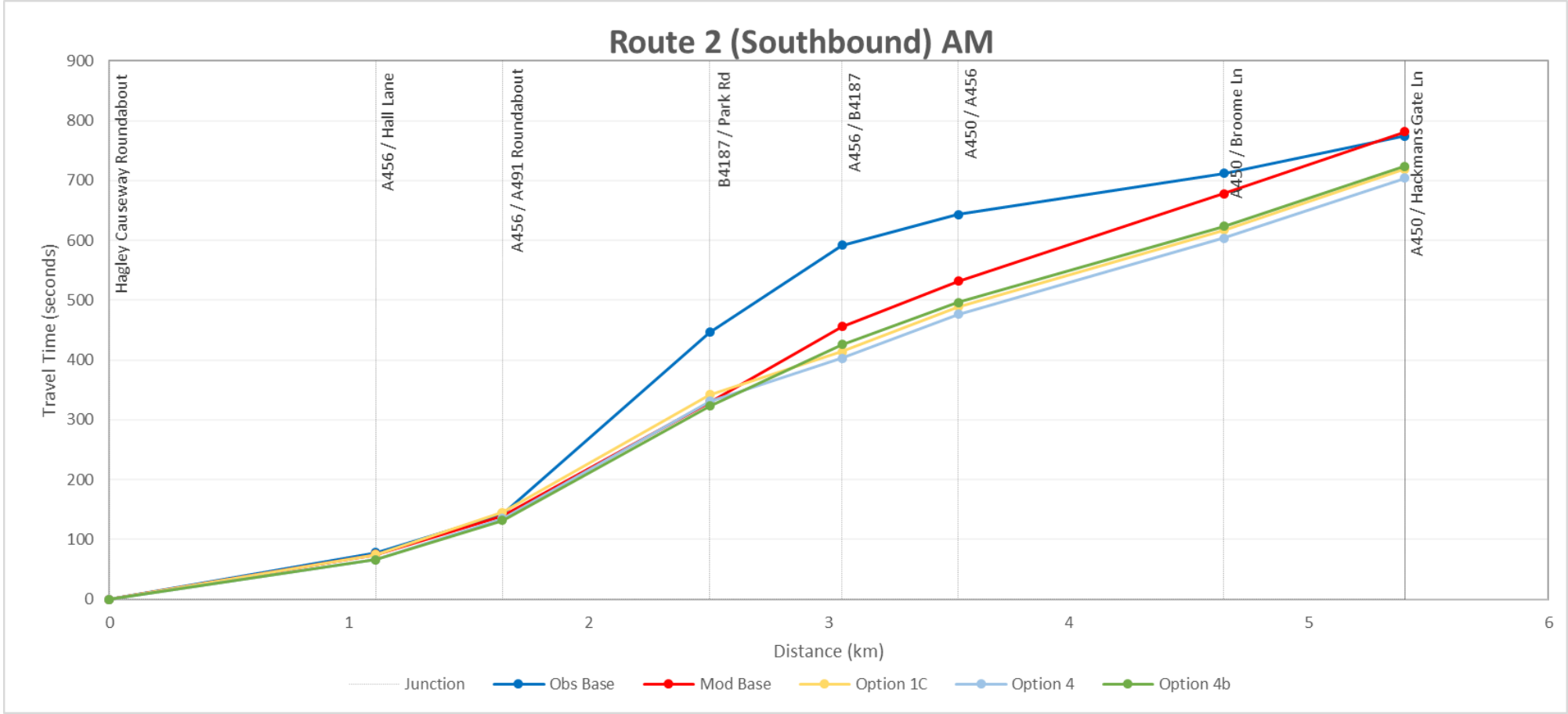


Figure 8-4: Route 2 SB – 2019 AM Journey Times – Option 4 and 4b

The journey times under each of the modelled scenarios, alongside observed journey times, are given in Table 8-7 for the 2019 PM peak.

Table 8-7: 2019 PM Peak Journey Times – Options 1c, 4 and 4b

	Direction	PM Peak (17:00-18:00)				
		Observed Base	Modelled Base	Option 1c	Option 4	Option 4b
Route 1	NB	00:11:00	00:10:13	00:08:28	00:08:31	00:08:41
	SB	00:10:01	00:09:03	00:08:37	00:08:36	00:08:47
Route 2	NB	00:12:23	00:10:46	00:08:54	00:08:56	00:09:04
	SB	00:10:58	00:11:27	00:10:37	00:10:35	00:11:00

The table shows that all of the routes experience a travel time saving compared with the modelled base under Options 4 and 4b.

Graphical representations for the two routes in both directions for the 2019 PM peak are given in Figure 8-5 to Figure 8-8.

Figure 8-5 to Figure 8-8 show that the travel times along these routes in the 2019 PM peak are almost identical between Option 1c and Option 4, differing by a maximum of 3 seconds overall. However, there are more significant differences in travel time under Option 4b compared with Option 1c.

For Route 1 northbound, Option 4b leads to a 13 second increase in travel time compared with Option 1c. This increase in travel time occurs on the approach to the A456 / B4187 Worcester Road junction. This is due to the left turn from the B4187 Worcester Road onto the A456 being allowed under Option 4b for reasons previously explained. Similarly, Route 2 northbound also experiences a 10 second increase in travel time under Option 4b compared with Option 1c.

For Route 1 southbound, Option 4b leads to a 10 second increase in journey time compared with Option 1c. This increase occurs on the approach to the A456 / B4187 Worcester Road signalised junction due to the same reasons as Route 1 northbound.

Finally, Option 4b leads to a 23 second increase in journey time compared with Option 1c for Route 2 southbound. This occurs on the approach to the A456 / B4187 Worcester Road signalised junction and is due to the revised signal staging at the junction with a separate pedestrian phase and also due to an increase in demand on this section due to allowing the left turn onto the A456.

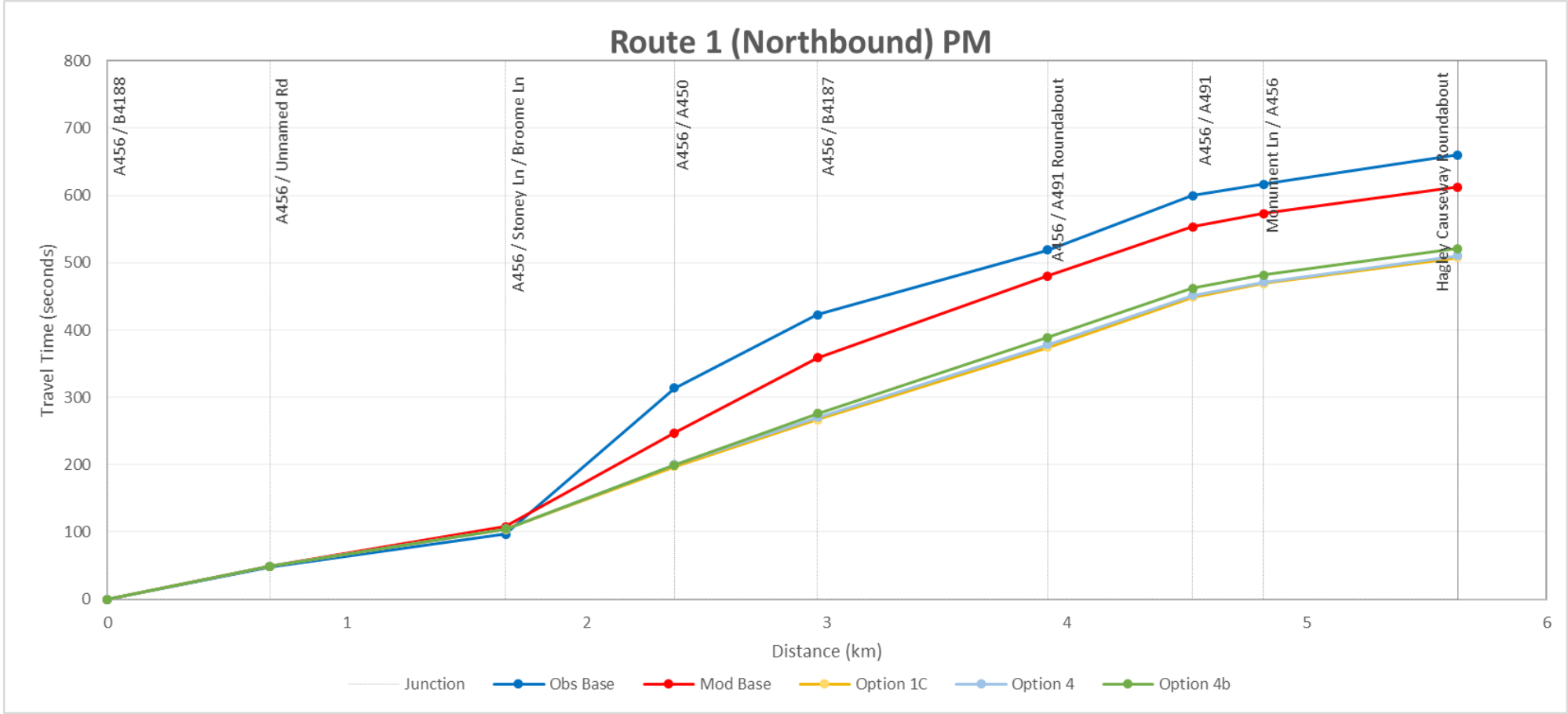


Figure 8-5: Route 1 NB – 2019 PM Journey Times – Option 4 and 4b

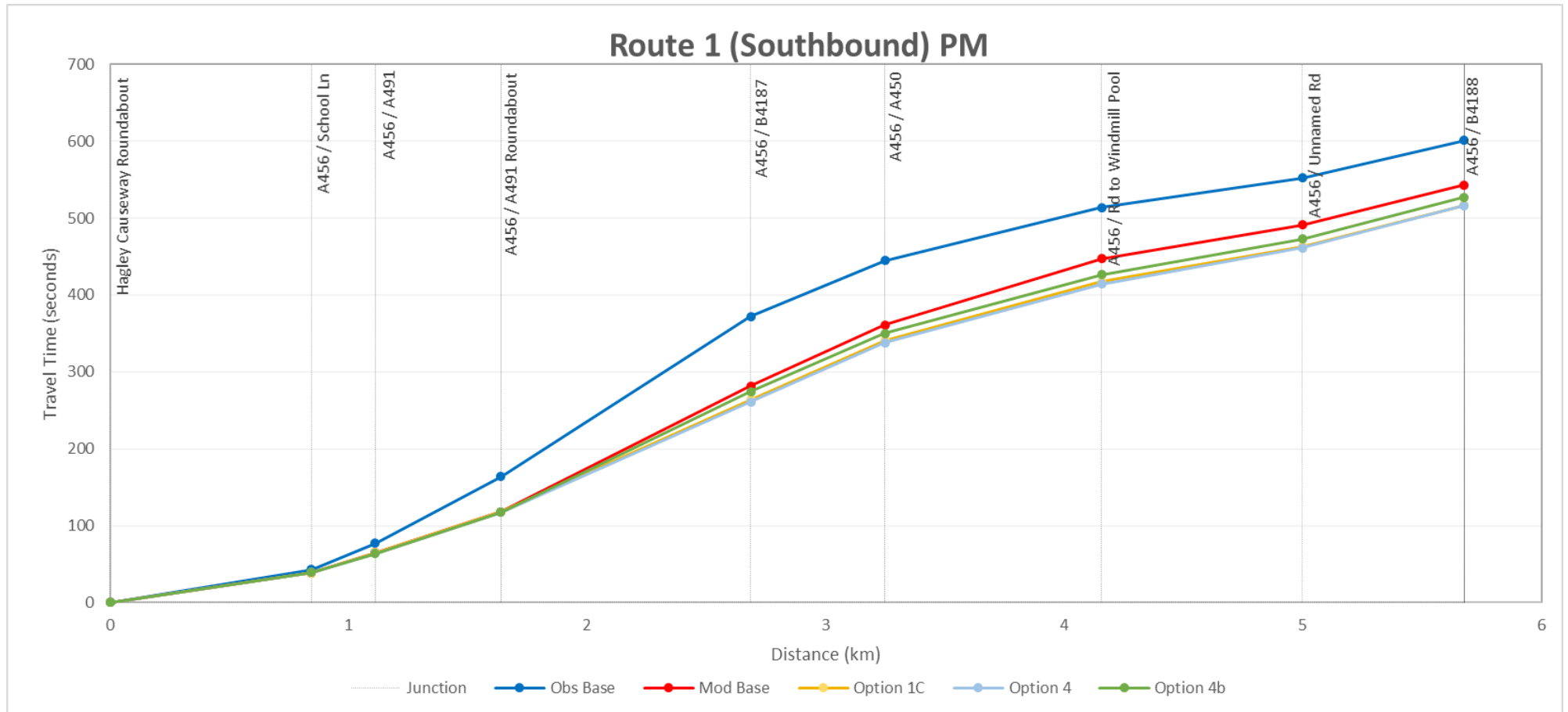


Figure 8-6: Route 1 SB – 2019 PM Journey Times – Option 4 and 4b

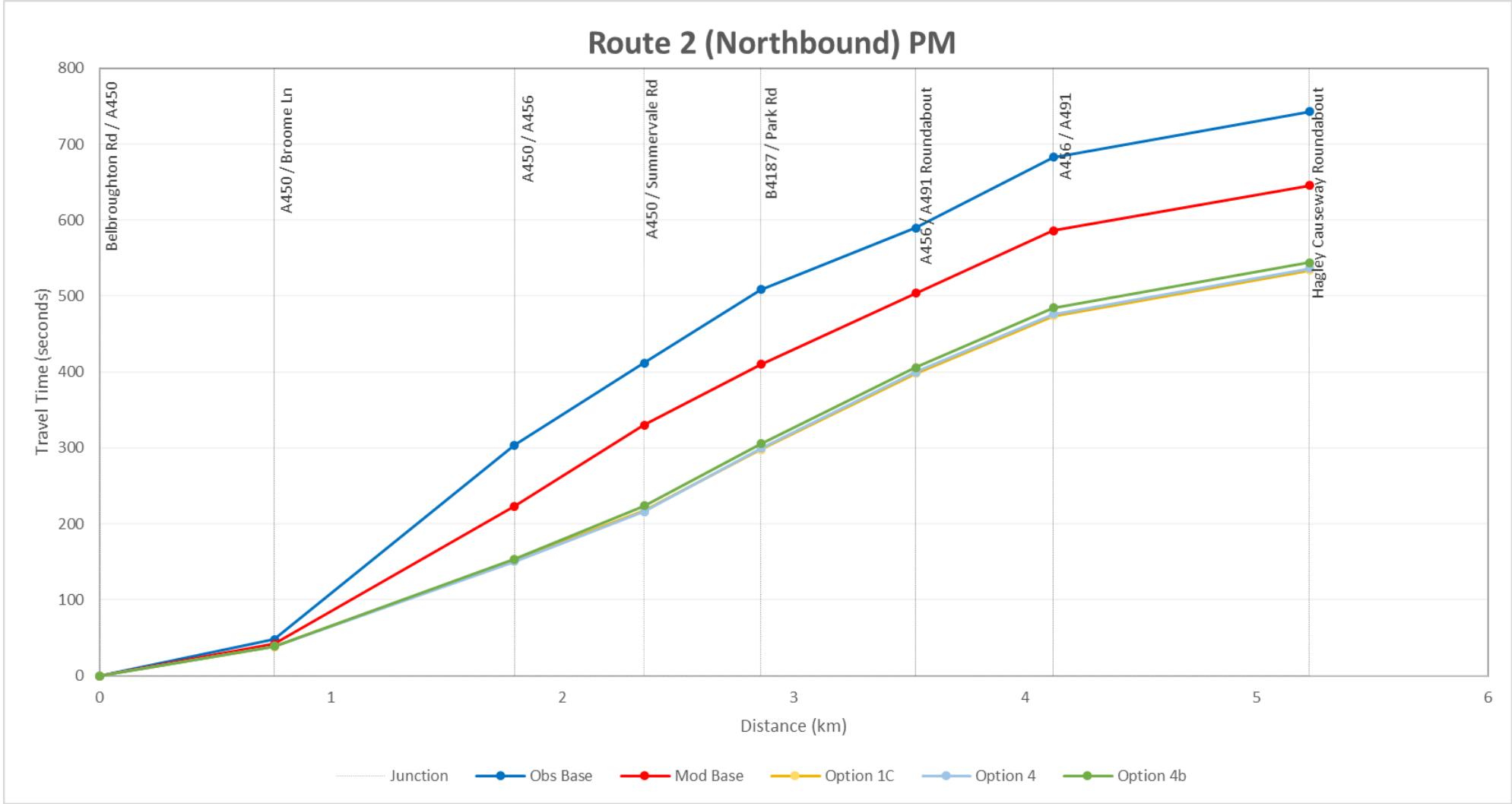


Figure 8-7: Route 2 NB – 2019 PM Journey Times – Option 4 and 4b

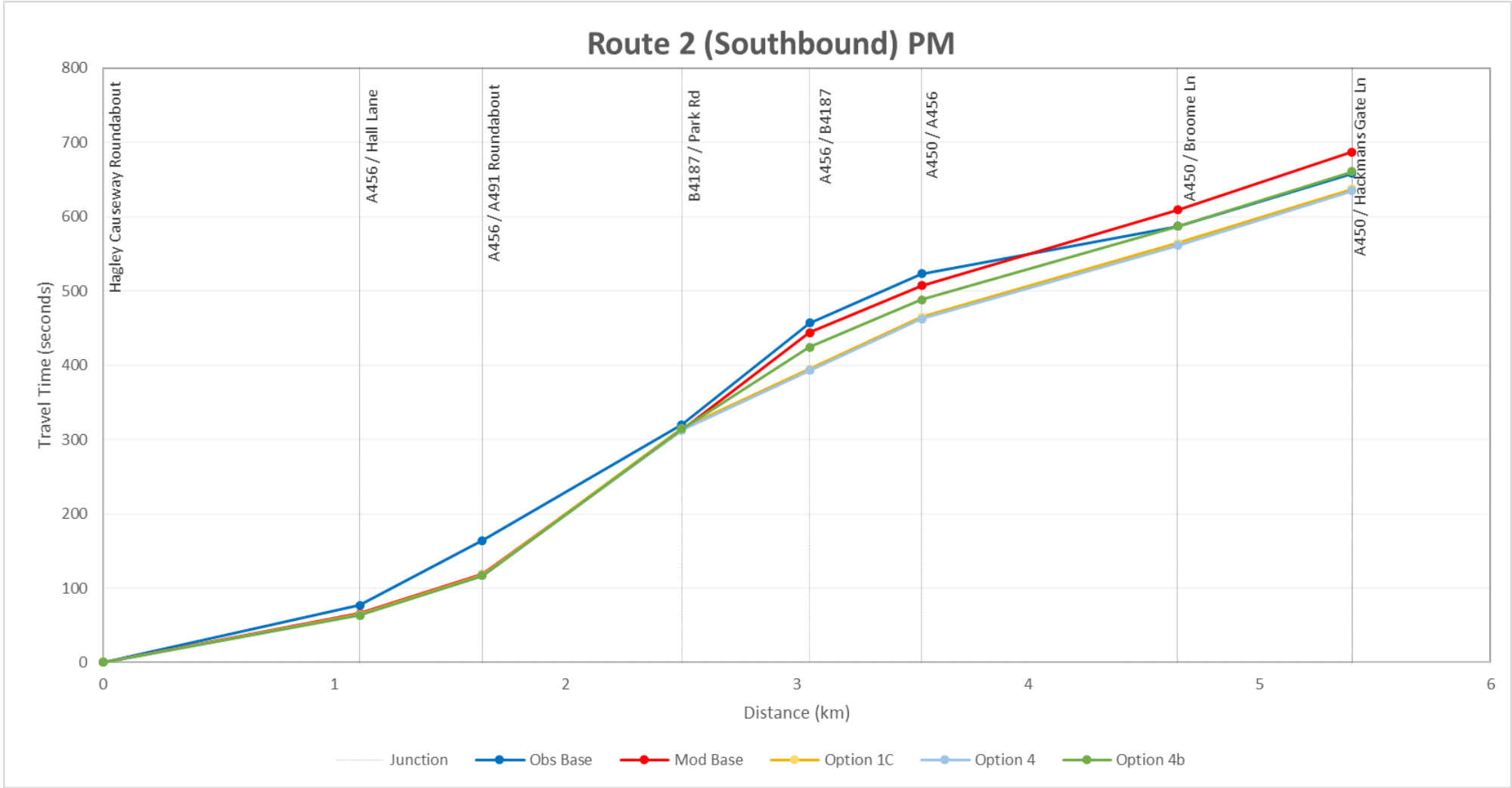


Figure 8-8: Route 2 SB – 2019 PM Journey Times – Option 4 and 4b

9. A456/A491 Hagley Roundabout Enhancements

9.1 Introduction

This chapter investigates scheme options to improve the performance of the A456/A491 Hagley signalised roundabout.

The outcome of this work is used to define infrastructure requirements at the junction alongside other improvement options at junctions that currently suffer congestion on the A456 corridor in Hagley.

9.2 Technical References:

In this section are presented references from the Design Manual for Roads and Bridges (DMRB), WCC Design Guide and Technical guidance notes.

The following standards have been used to assess the options in this note.

Design Manual for Roads and Bridges:

- Volume 6: Road Geometry: Section 1
Part 1 TD 9/93 Highway Link Design - Chapter 3 & 4
- Volume 6: Road Geometry: Section 3
Part 5 TA 90/05 The Geometric Design of Pedestrian, Cycle and Equestrian Routes – Chapter 7

CD 116 Geometric Design of Roundabouts:

- Chapter 8: Designing for Pedestrians, Cyclists and Equestrians at Roundabouts - Controlled Crossings NOTE 1 & NOTE 2

The layouts have been prepared to conceptual standard, once a preferred option is selected in the next stage of the study the layouts to be drawn to preliminary standard and feasibility analysis are to be undertaken.

9.3 Existing Conditions

The 2019 validated VISSIM (micro-simulation) was used to identify the problem areas and then to define potential improvements. The model indicated the main issues on the eastern circulatory lanes, with queues that extend beyond the available internal physical stacking area.

The problem occurs due to a heavy traffic flow from A456 Kidderminster Road north to south through the roundabout. A single lane exit from the roundabout onto the A456 Kidderminster Road south creates a bottleneck which results in large queues and delays being formed on the circulatory.

9.4 Options

A list of options has been identified as potential solutions:

Table 9-1: List of Options

Location	Option	Commentary
A456 Hagley Roundabout	Option i – Minor Widening works	<ul style="list-style-type: none"> Move stop-line forward on the A491 approach and circulatory lanes to reduce intergreen which should provide some additional capacity. Increase the length of the flare on the A491 approach lane, the optimum length to be determined from the modelling. Widen exit lane onto the A456 Kidderminster Road South to provide an 80 metres two lane exit followed by 100 metre merge.
	Option ii – same as Option 1 with Park Road entry closed	<ul style="list-style-type: none"> Same as Option i Close Park Road entry arm (observations show during gaps created by upstream traffic lights, the traffic from Park Road enters the roundabout and fills up the circulatory stacking area and impacts on the ability to clear traffic out of the circulatory before new traffic enters the back of the queue. The traffic numbers using the Park Road are low, the closure would result in re-assigned traffic which could use an existing left out junction to the north of the roundabout, this will increase length of journey's and increase number of 'u' turners at the roundabout.
	Option iii – same as Option 1 with Park Road fully closed	<ul style="list-style-type: none"> Same as Option i Fully close Park Road Re-assigned traffic wishing to travel north will require 'u' turning at the roundabout and would increase the length of the journey
	Option iv - same as Option 1 but increase the width of the A491 circulatory lane	<ul style="list-style-type: none"> Same as Option i Increase the width of the A491 circulatory to allow for 3 lanes instead of two.
	Option v – A456 Through-about	<ul style="list-style-type: none"> Construct a dual lane through the existing central island and provide a two lane exit onto the A456 Kidderminster south arm

Each of the layouts are illustrated as follows:

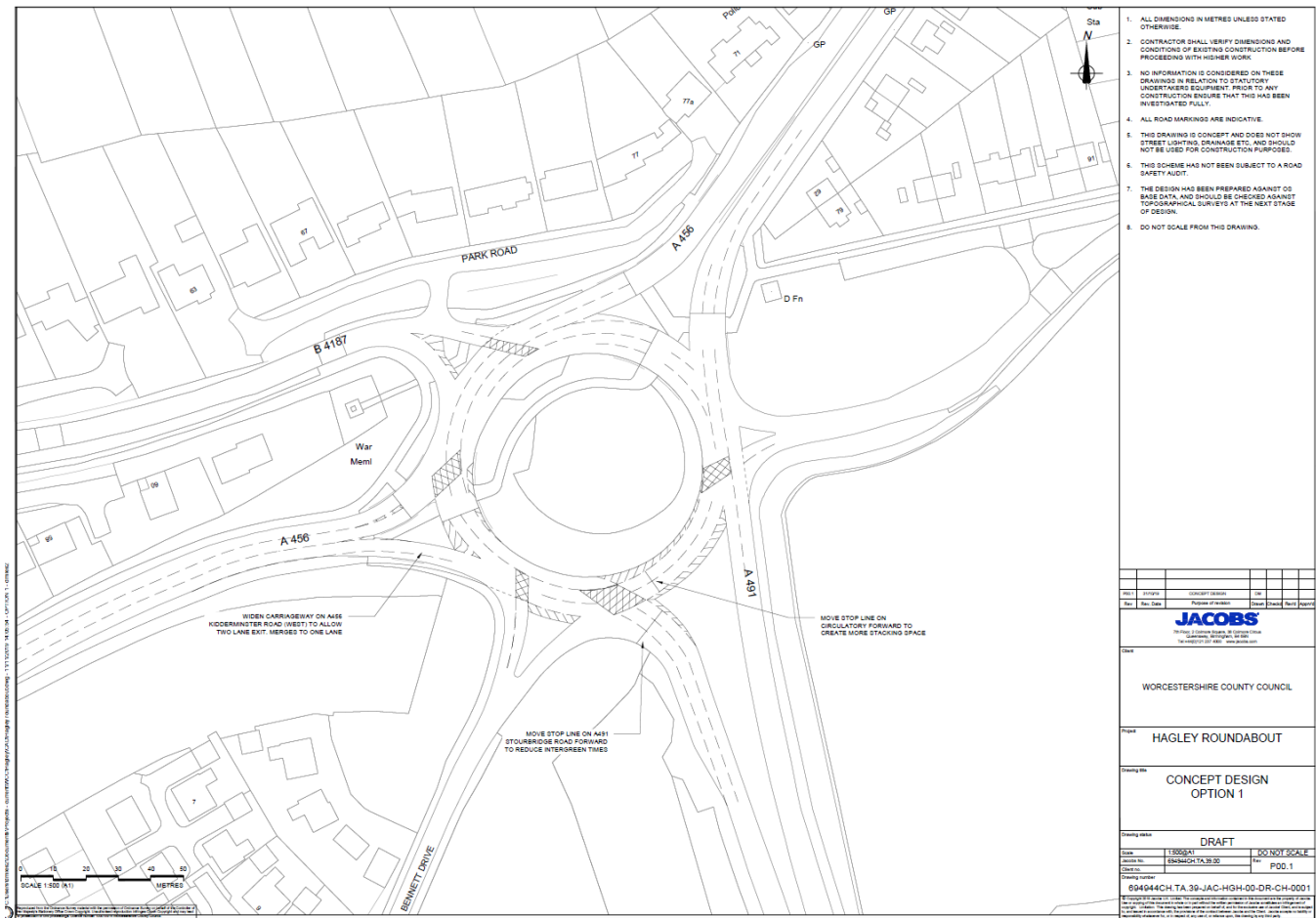


Figure 9-1: Option i - Minor Widening Works



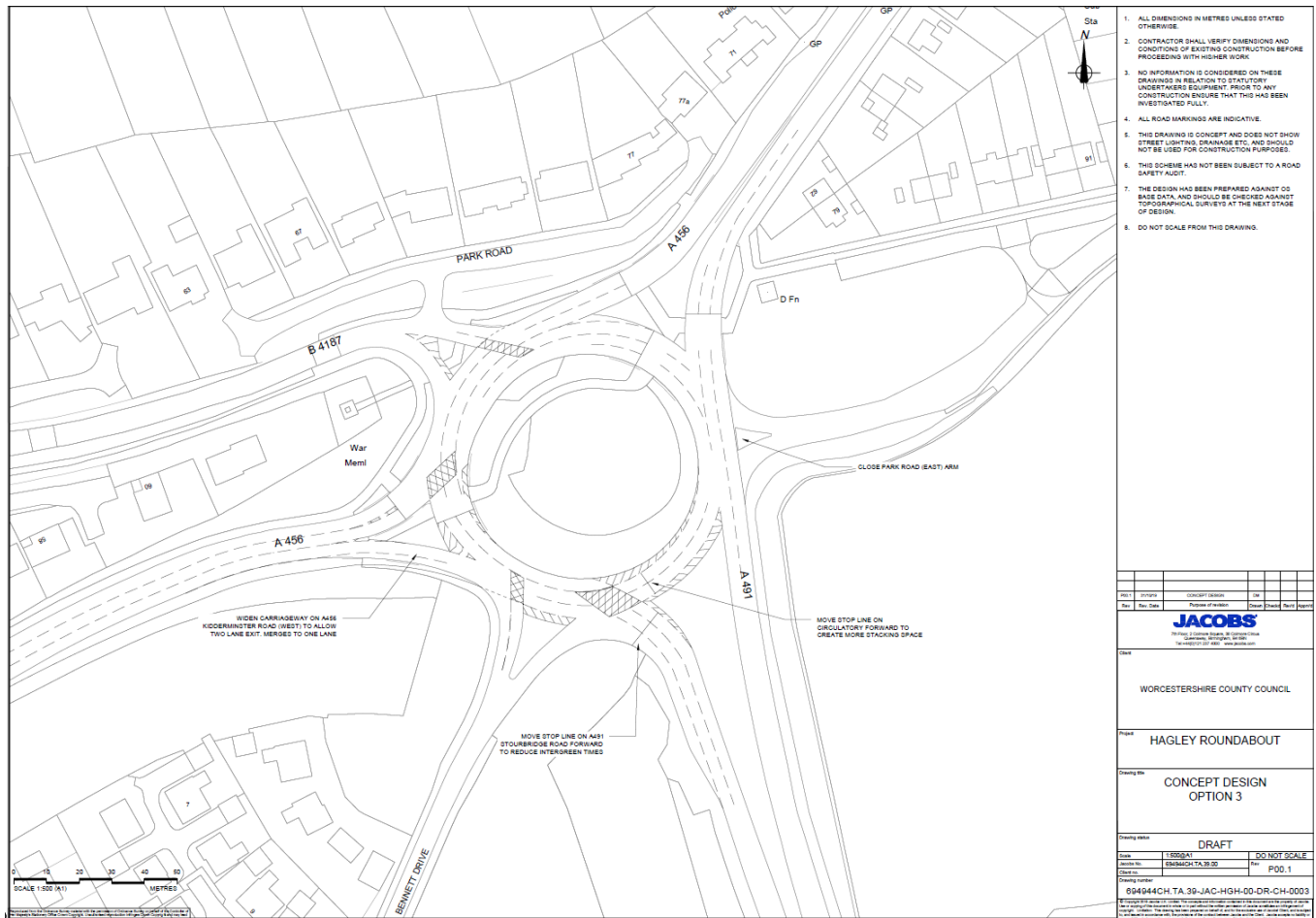


Figure 9-3: Option iii - Same improvements as Option i with Park Road East closed for all traffic



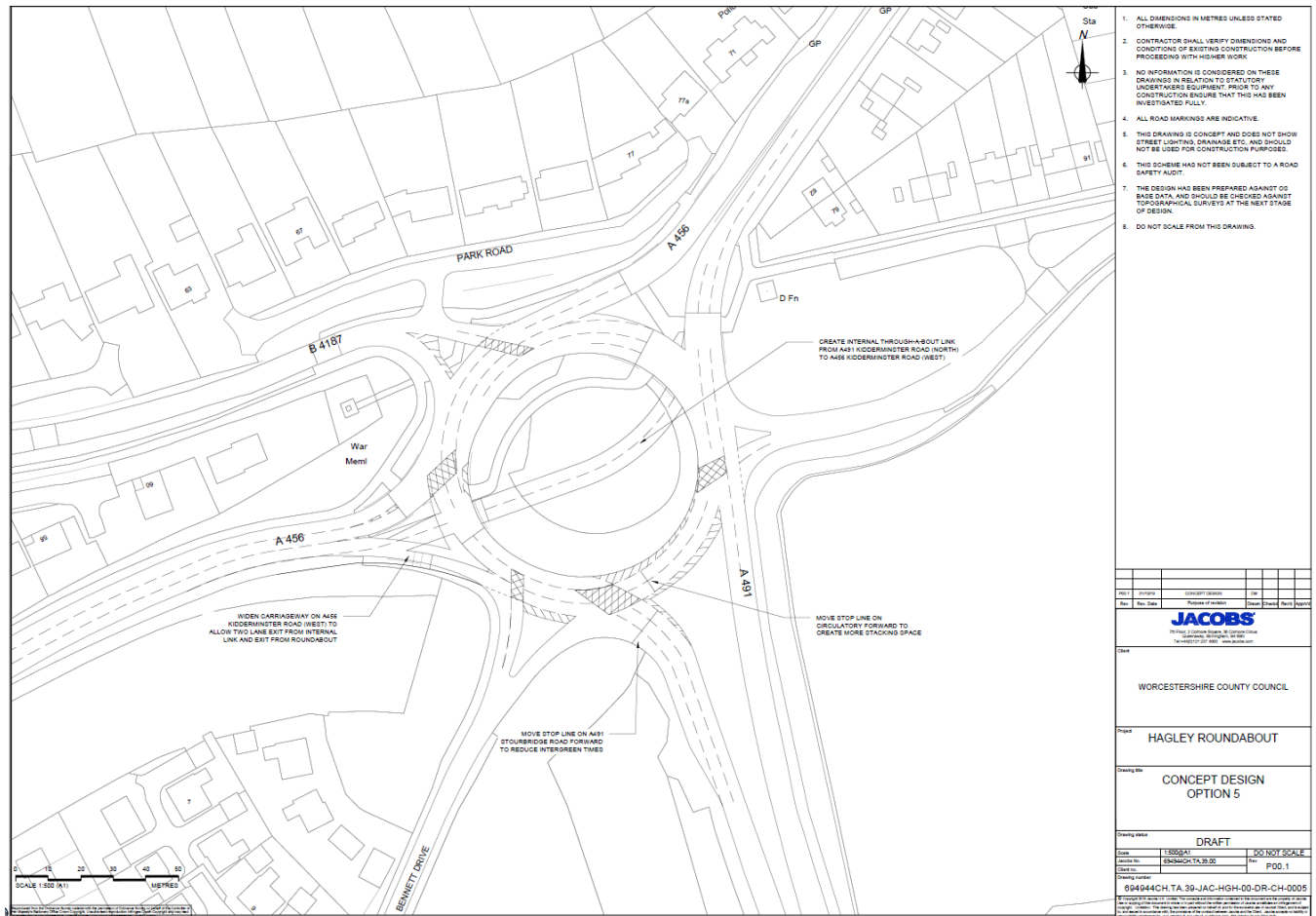


Figure 9-5: Option v - A456 Through-About

9.5 Summary

A list of options has been identified as potential solutions and considered that these should be taken forward for detailed modelling in the next stage of the study.

It has been decided to assess Options i, ii and v to begin with, as Option iv is likely to provide less benefits than Option v but will require less infrastructure and therefore cost.

Although Option ii is being tested, this option and Option iii are likely to result in longer journeys for some traffic and an increase in 'u' turners at the roundabout and may therefore result in more objections than the other options.

Options i, ii and v will be referred to as Options 5a, 5b and 5c in the following sections for consistency with previous options tested.

10. Model Outputs – Options 5a, 5b and 5c

10.1 Model Runs

The AM and PM peak models for Option 5a-c were each run 10 times with 2019 and 2036 demand, with each run having a different random seed to represent daily variations in traffic. The Option 5 runs incorporate improvements to other junctions as per Option 4. The AM models were run for the period 06:30 to 09:30 whilst the PM model was run for the period 15:30-18:30. Junction flows and delays, journey times and vehicle network performance indicators were collected, and the results obtained were averaged over the 10 runs and are reported in the following sections.

10.2 2019 Results

10.2.1 Junction Flows

The total number of vehicles passing through each of the key junctions in the network during the AM and PM pre-peak and peak hours were collected for each Option 5 scenario and are presented in Table 10-1 to Table 10-4.

Where flows have increased compared with the base flows, the values are indicated in green whilst red indicates the opposite. As Option 4 was the best performing scenario from previously tested options, it has been included in the table for comparison.

Table 10-1: Options 4, 5a, 5b and 5c - Junction Flows – 2019 AM Peak

Junction	Junction Throughput				
	2019 AM (08:00-09:00)				
	Base	Op 4	Op 5a	Op 5b	Op 5c
B4187 Worcester Rd / Station Rd / Park Rd	1488	1442	1439	1491	1471
A456 / B4187 Worcester Rd / Summervale Rd / Western Rd	2438	2272	2270	2326	2269
A456 Kidderminster Rd / A450 Worcester Rd	2110	2193	2188	2251	2193
A456 Kidderminster Rd / Stakenbridge Ln / Thicknall Ln	1258	1238	1238	1268	1239
A450 Worcester Rd / Thicknall Ln	863	853	854	874	858
A456 Kidderminster Rd / Park Rd / A491 Stourbridge Rd / Bennett Dr	3922	3865	3849	3881	3847
Middlefield Ln / A491 Kidderminster Rd	3303	3301	3293	3454	3326
B4187 Worcester Rd / Middlefield Ln	1037	1099	1099	1121	1129
A456 Kidderminster Rd / A456 Birmingham Rd / A491 Stourbridge Rd	4035	3992	3987	3980	3984

Table 10-2: Options 4, 5a, 5b and 5c - Junction Flows – 2019 AM 2-hour Peak

Junction	Junction Throughput				
	2019 AM (07:00-09:00)				
	Base	Op 4	Op 5a	Op 5b	Op 5c
B4187 Worcester Rd / Station Rd / Park Rd	2642	2567	2563	2663	2624
A456 / B4187 Worcester Rd / Summervale Rd / Western Rd	4618	4490	4492	4571	4492
A456 Kidderminster Rd / A450 Worcester Rd	4153	4366	4365	4445	4368
A456 Kidderminster Rd / Stakenbridge Ln / Thicknall Ln	2444	2446	2448	2486	2447
A450 Worcester Rd / Thicknall Ln	1771	1768	1767	1792	1772
A456 Kidderminster Rd / Park Rd / A491 Stourbridge Rd / Bennett Dr	7688	7637	7641	7680	7641
Middlefield Ln / A491 Kidderminster Rd	6474	6522	6524	6780	6588
B4187 Worcester Rd / Middlefield Ln	1842	1942	1940	1996	2002
A456 Kidderminster Rd / A456 Birmingham Rd / A491 Stourbridge Rd	7901	7905	7908	7900	7909

It can be seen in Table 10-1 that, under Option 5a, most junctions experience a reduction in throughput compared with the base scenario during the AM peak hour.

Table 10-2 shows the combined two-hour junction throughput. This shows that several junctions experience an increase in throughput and several experience a decrease during the modelled two-hour period. Compared with Option 4, throughput under Option 5a is very similar during the two-hour AM period, differing by a maximum of just 4 vehicles at any junction. It can be seen in Table 10-1 that, under Option 5b, most junctions experience an increase in throughput compared with the base scenario during the AM peak hour.

Table 10-2 shows that overall most junctions experience an increase in throughput during the modelled two-hour period compared with the base. Compared with Option 4, throughput under Option 5b is generally higher at most junctions. The implementation of the Option 5b scheme at the A456 / A491 roundabout leads to an increase in throughput at this junction of 43 vehicles over the two-hour period.

Option 5c follows a similar pattern to Option 5a.

Table 10-2 shows that overall several junctions experience an increase in throughput and several experience a decrease during the modelled two-hour period. Compared with Option 4, throughput under Option 5c is very similar during the two-hour AM period at several junctions. However, several junctions experience an increase in throughput compared with Option 4. These junctions are: the B4187 Worcester Road / Station Road / Park Road signalised junction, the A491 Kidderminster Road / Middlefield Road junction and the B4187 Worcester Road / Middlefield Lane junction. However, the improvements at the A456 / A491 roundabout under Option 5c do not lead to a significant increase in throughput at this junction, with it increasing by just 4 vehicles compared with Option 4 over two hours.

Table 10-3: Options 4, 5a, 5b and 5c - Junction Flows – 2019 PM Peak

Junction	Junction Throughput				
	2019 PM (17:00-18:00)				
	Base	Op 4	Op 5a	Op 5b	Op 5c
B4187 Worcester Rd / Station Rd / Park Rd	1279	1338	1339	1419	1366
A456 / B4187 Worcester Rd / Summervale Rd / Western Rd	2441	2446	2442	2456	2461
A456 Kidderminster Rd / A450 Worcester Rd	2336	2440	2432	2452	2451
A456 Kidderminster Rd / Stakenbridge Ln / Thicknall Ln	1542	1454	1453	1462	1461
A450 Worcester Rd / Thicknall Ln	881	932	926	939	942
A456 Kidderminster Rd / Park Rd / A491 Stourbridge Rd / Bennett Dr	3868	3780	3738	3837	3987
Middlefield Ln / A491 Kidderminster Rd	3212	3126	3126	3342	3360
B4187 Worcester Rd / Middlefield Ln	961	997	1000	1075	1038
A456 Kidderminster Rd / A456 Birmingham Rd / A491 Stourbridge Rd	3909	3785	3767	3829	3944

Table 10-4: Options 4, 5a, 5b and 5c - Junction Flows – 2019 PM 2-hour Peak

Junction	Junction Throughput				
	2019 PM (16:00-18:00)				
	Base	Op 4	Op 5a	Op 5b	Op 5c
B4187 Worcester Rd / Station Rd / Park Rd	2365	2539	2554	2661	2594
A456 / B4187 Worcester Rd / Summervale Rd / Western Rd	4878	4975	4965	4995	4995
A456 Kidderminster Rd / A450 Worcester Rd	4676	4871	4856	4892	4891
A456 Kidderminster Rd / Stakenbridge Ln / Thicknall Ln	3034	2885	2886	2899	2894
A450 Worcester Rd / Thicknall Ln	1824	1889	1880	1898	1901
A456 Kidderminster Rd / Park Rd / A491 Stourbridge Rd / Bennett Dr	7562	7511	7376	7576	7735
Middlefield Ln / A491 Kidderminster Rd	6377	6324	6258	6709	6609
B4187 Worcester Rd / Middlefield Ln	1750	1825	1837	1899	1906
A456 Kidderminster Rd / A456 Birmingham Rd / A491 Stourbridge Rd	7925	7792	7704	7840	7959

Table 10-4 shows that, compared with the base scenario, several junctions experience a decrease in throughput and several experience an increase under Option 5a during the 2019 two-hour PM period.

Compared with Option 4, flows at the A456 / A491 roundabout decrease by 186 vehicles over two hours under Option 5a.

Under Option 5b, most junctions experience an increase in throughput compared with the base scenario over the two-hour PM period, as shown in Table 10-4. Compared with the base scenario, the A456 / A491 roundabout experiences an increase in throughput of 14 vehicles over two hours. Compared with Option 4, this increase is 65 vehicles.

10.2.2 Junction Delays

Under Option 5c, all except one junction experience an increase in throughput compared with the base scenario. Table 10-4 shows that throughput at the roundabout increases by 173 compared with the base scenario and 224 vehicles compared with Option 4 over two hours.

The average delay time for each vehicle passing through each of the key junctions in the model was collected for the AM and PM peak hours for each scenario and are presented in Table 10-5 and Table 10-6. Where delays have increased compared with the base delays, the values are indicated in red whilst green indicates the opposite.

Table 10-5: Options 4, 5a, 5b and 5c - Junction Delays – 2019 AM Peak

Junction	Average Delay per Vehicle (s)				
	2019 AM (08:00-09:00)				
	Base	Op 4	Op 5a	Op 5b	Op 5c
B4187 Worcester Rd / Station Rd / Park Rd	44.9	45.4	46.0	52.4	47.7
A456 / B4187 Worcester Rd / Summervale Rd / Western Rd	25.5	13.8	13.8	14.2	14.3
A456 Kidderminster Rd / A450 Worcester Rd	28.8	16.1	15.6	15.8	15.7
A456 Kidderminster Rd / Stakenbridge Ln / Thicknall Ln	15.5	3.5	3.6	3.7	3.5
A450 Worcester Rd / Thicknall Ln	5.9	3.4	3.4	3.4	3.5
A456 Kidderminster Rd / Park Rd / A491 Stourbridge Rd / Bennett Dr	40.1	39.7	30.0	29.3	29.4
Middlefield Ln / A491 Kidderminster Rd	29.7	18.0	16.9	16.2	16.4
B4187 Worcester Rd / Middlefield Ln	3.3	3.2	3.1	2.9	3.3
A456 Kidderminster Rd / A456 Birmingham Rd / A491 Stourbridge Rd	45.6	37.0	36.4	37.0	36.0

Compared with the base scenario, most junctions experience a decrease in delays under Options 5a-5c in the 2019 AM peak.

The A456 Kidderminster Road / A491 Stourbridge Road roundabout experiences similar levels of delays under each variant of Option 5 of 29.3-30.0 seconds. Each of these are approximately 10 seconds less than the 39.7 second delay experienced under Option 4. Delays at other junctions are similar under Options 5a-c as under Option 4.

Table 10-6: Options 4, 5a, 5b and 5c - Junction Delays – 2019 PM Peak

Junction	Average Delay per Vehicle (s)				
	2019 PM (17:00-18:00)				
	Base	Op 4	Op 5a	Op 5b	Op 5c
B4187 Worcester Rd / Station Rd / Park Rd	60.8	47.6	43.8	56.4	47.2
A456 / B4187 Worcester Rd / Summervale Rd / Western Rd	30.1	13.6	13.7	13.6	14.2
A456 Kidderminster Rd / A450 Worcester Rd	30.4	19.5	19.8	19.9	19.7
A456 Kidderminster Rd / Stakenbridge Ln / Thicknall Ln	10.1	7.0	6.6	7.0	7.2
A450 Worcester Rd / Thicknall Ln	6.9	2.5	2.6	2.6	2.7
A456 Kidderminster Rd / Park Rd / A491 Stourbridge Rd / Bennett Dr	52.0	52.8	56.8	49.9	27.8
Middlefield Ln / A491 Kidderminster Rd	2.3	2.1	2.2	2.6	2.5
B4187 Worcester Rd / Middlefield Ln	24.0	3.4	3.1	8.7	4.0
A456 Kidderminster Rd / A456 Birmingham Rd / A491 Stourbridge Rd	26.0	20.5	20.5	20.6	20.5

Compared with the base scenario, most junctions experience a decrease in delays under Options 5a-5c in the 2019 AM peak.

Under Option 5a, delays at the A456 Kidderminster Road / A491 Stourbridge Road roundabout increase compared to the base scenario, from 52.0 seconds to 56.8 seconds. However, these delays decrease under both Option 5b and 5c. Delays are significantly lower under Option 5c at 27.8 seconds.

Delays at other junctions remain similar in Options 5a-c compared with Option 4.

10.2.3 Journey Times

The journey times in the network under Options 5a, 5b and 5c, alongside observed journey times under Option 4 are given in Table 10-7 for the 2019 AM peak.

Table 10-7: 2019 AM Peak Journey Times - Option 4, 5a, 5b and 5c

	Direction	2019 AM Peak (08:00-09:00)					
		Observed Base	Modelled Base	Option 4	Option 5a	Option 5b	Option 5c
Route 1	NB	00:13:11	00:14:49	00:09:56	00:09:52	00:09:51	00:10:08
	SB	00:08:19	00:09:22	00:09:04	00:08:52	00:09:07	00:09:03
Route 2	NB	00:14:12	00:15:18	00:10:20	00:09:59	00:10:04	00:10:06
	SB	00:12:54	00:13:01	00:11:44	00:11:26	00:12:04	00:11:36

It can be seen that all routes experience a decrease in travel time under the Option 5 scenarios compared with the base scenario. Graphical representations for the two routes in both directions for the 2019 AM peak are given in Figure 10-1 to Figure 10-4.

For Route 1 northbound, all three of the proposed variants of Option 5 have similar travel times to that of Option 4. Options 5a and 5b lead to a small reduction in travel time of just a few seconds compared with Option 4 whilst Option 5c leads to a 12 second increase. This increase occurs on the approach to the A456

Kidderminster Road / A491 Stourbridge Road roundabout due to the improvements made in the southbound direction.

Similarly, for Route 1 southbound, all three of the proposed variants of Option 5 have similar travel times to that of Option 4. Options 5a and 5c lead to a small reduction in travel time of 1-12 seconds compared with Option 4. These journey time savings occur on the approach to the A456 Kidderminster Road / A491 Stourbridge Road roundabout due to the improvements made. Option 5b leads to a 3 second increase in travel time.

For Route 2 northbound, all of the Option 5 schemes lead to a reduction in travel time compared to Option 4. The Option 5 variant with the lowest travel time for this route is Option 5a with a travel time of 9 minutes 59 seconds, compared with 10 minutes 20 seconds under Option 4. The majority of this travel time saving occurs on the Park Road west approach to the A456 / A491 roundabout due to the improvements made.

For Route 2 southbound, Options 5a and 5c lead to a reduction in travel time compared with Option 4 of 18 seconds and 8 seconds respectively. The majority of this saving occurs on the approach to the roundabout, as for Route 1 southbound. Option 5b leads to a 20 second increase in travel time for this route.

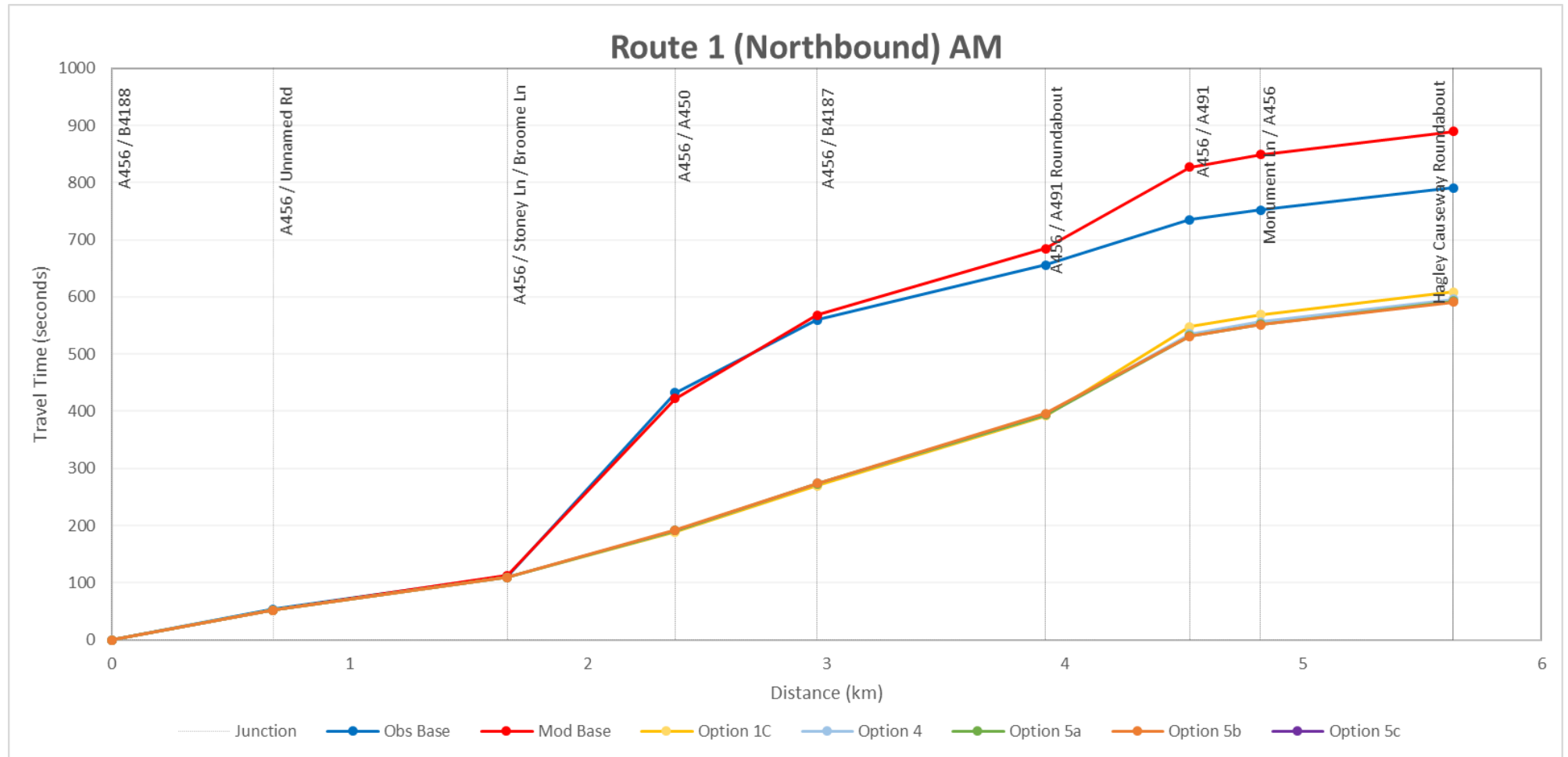


Figure 10-1: Route 1 NB – 2019 AM Journey Times – Options 4, 5a, 5b and 5c

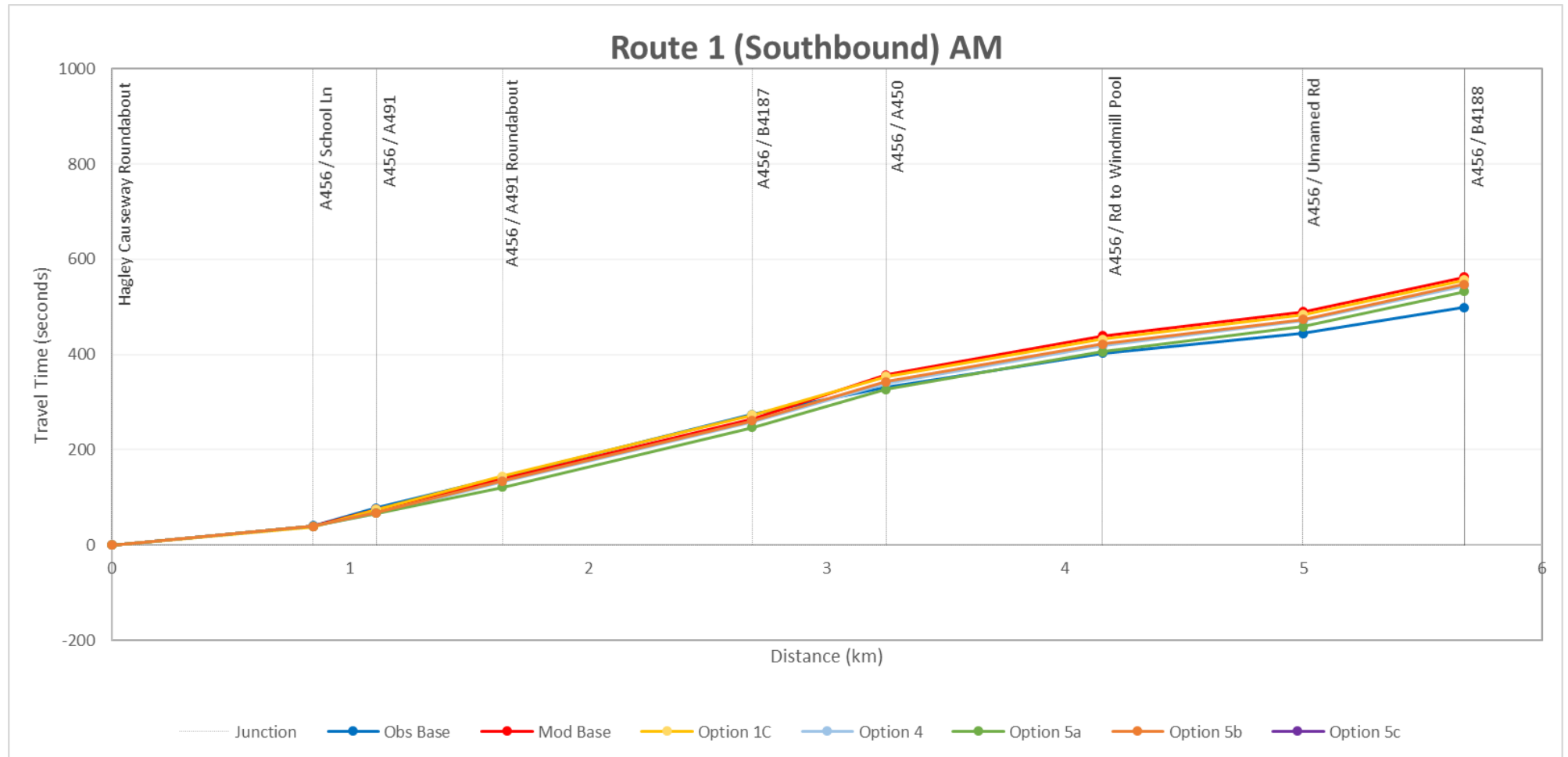


Figure 10-2: Route 1 SB – 2019 AM Journey Times – Options 4, 5a, 5b and 5c

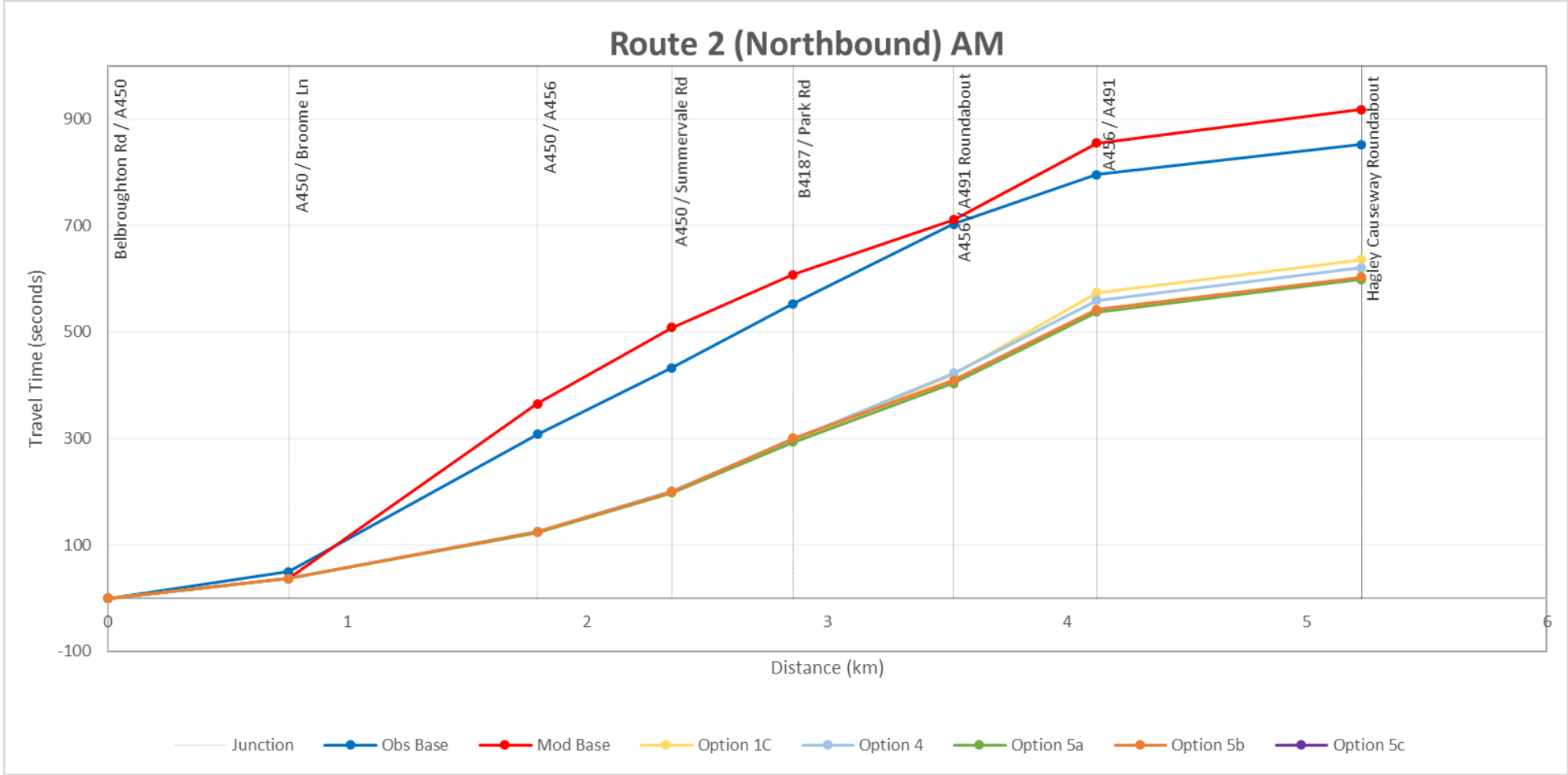


Figure 10-3: Route 2 NB – 2019 AM Journey Times – Options 4, 5a, 5b and 5c

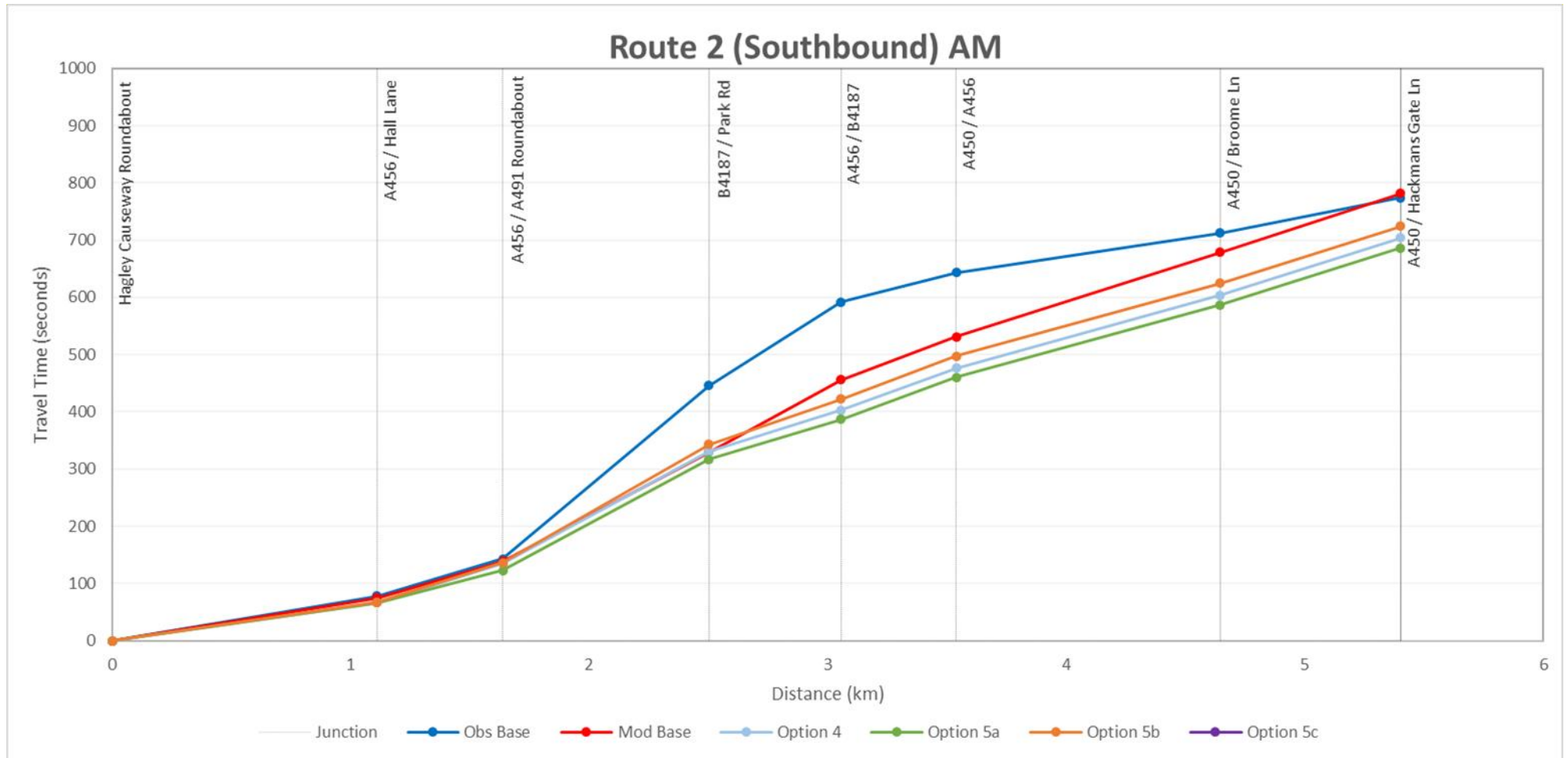


Figure 10-4: Route 2 SB – 2019 AM Journey Times – Options 4, 5a, 5b and 5c

The journey times under each of the modelled scenarios, alongside observed journey times, are given in Table 10-8 for the 2019 PM peak.

Table 10-8: 2019 PM Peak Journey Times – Options 4, 5a, 5b and 5c

	Direction	PM Peak (17:00-18:00)					
		Observed Base	Modelled Base	Option 4	Option 5a	Option 5b	Option 5c
Route 1	NB	00:11:00	00:10:13	00:08:31	00:08:26	00:08:26	00:08:36
	SB	00:10:01	00:09:03	00:08:36	00:08:34	00:08:33	00:08:31
Route 2	NB	00:12:23	00:10:46	00:08:56	00:08:55	00:09:03	00:08:58
	SB	00:10:58	00:11:27	00:10:35	00:10:41	00:10:53	00:10:37

It can be seen that all routes experience a decrease in travel time under the Option 5 scenarios compared with the base scenario. Graphical representations for the two routes in both directions for the 2019 PM peak are given in Figure 10-5 to Figure 10-8.

For Route 1 northbound, Options 5a and 5b lead to a 5 second improvement in journey time compared with Option 4. This saving occurs on the approach to the A456 Kidderminster Road / A491 Stourbridge Road roundabout. Option 5c leads to a 5 second increase in travel time on this route compared with Option 4.

For Route 1 southbound, all of the Option 5 schemes lead to a reduction in travel time compared with Option 4. The scheme which leads to the greatest reduction in travel time is Option 5c with a travel time of 8 minutes 31 seconds compared with 8 minutes 36 seconds under Option 4.

For Route 2 northbound, the travel time for Option 5a is 1 second less than that for Option 4. However, Options 5b and 5c lead to a higher but still small increases in travel time.

For Route 2 southbound, all of the Options 5a-c lead to an increase in travel time compared with Option 4. The highest travel time occurs under Option 5b at 10 minutes 53 seconds compared with 10 minutes 35 seconds under Option 4. This increase occurs along Park Road on the approach to the B4187 / Park Road signalised junction.

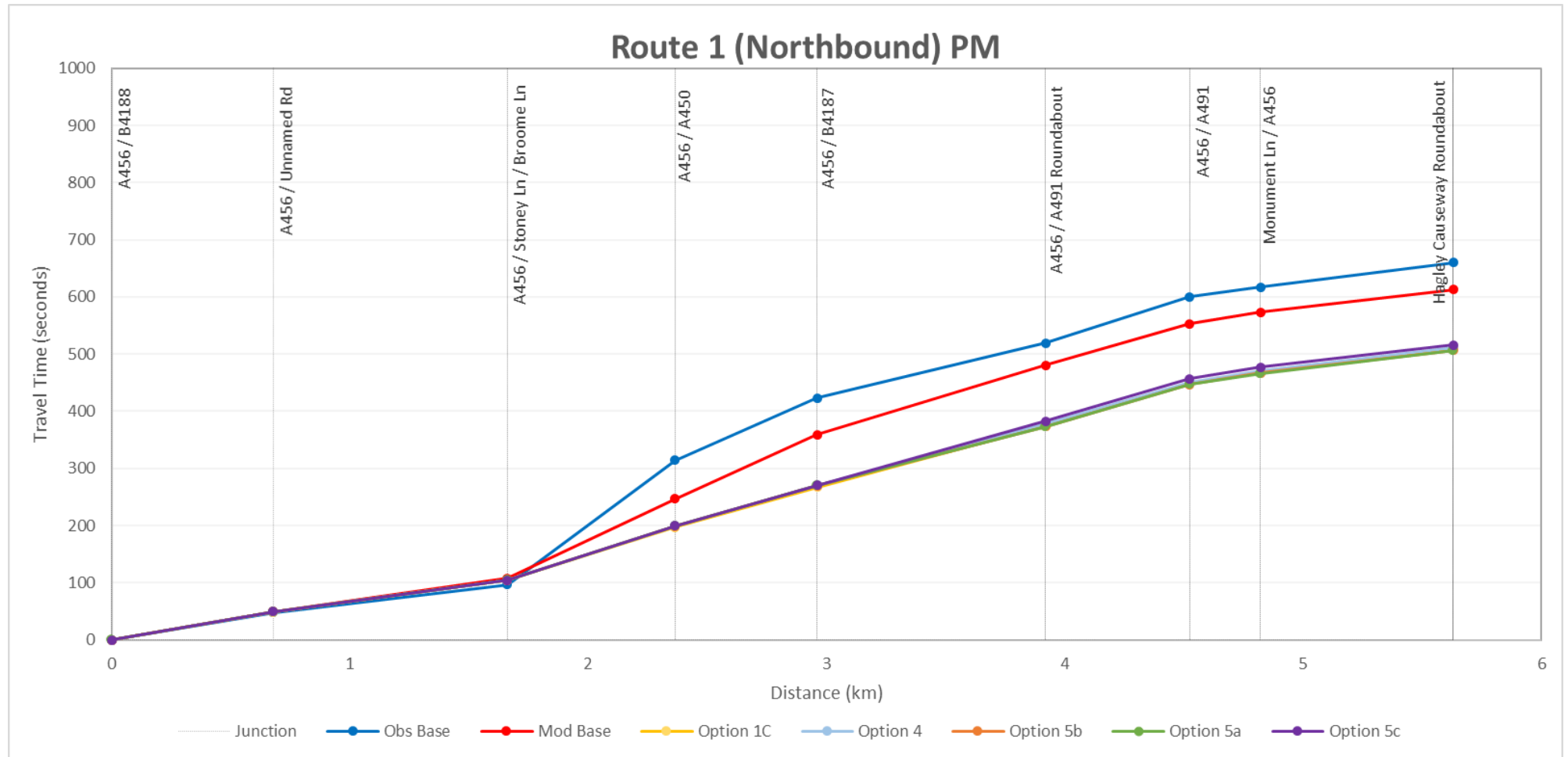


Figure 10-5: Route 1 NB – 2019 PM Journey Times – Options 4, 5a, 5b and 5c

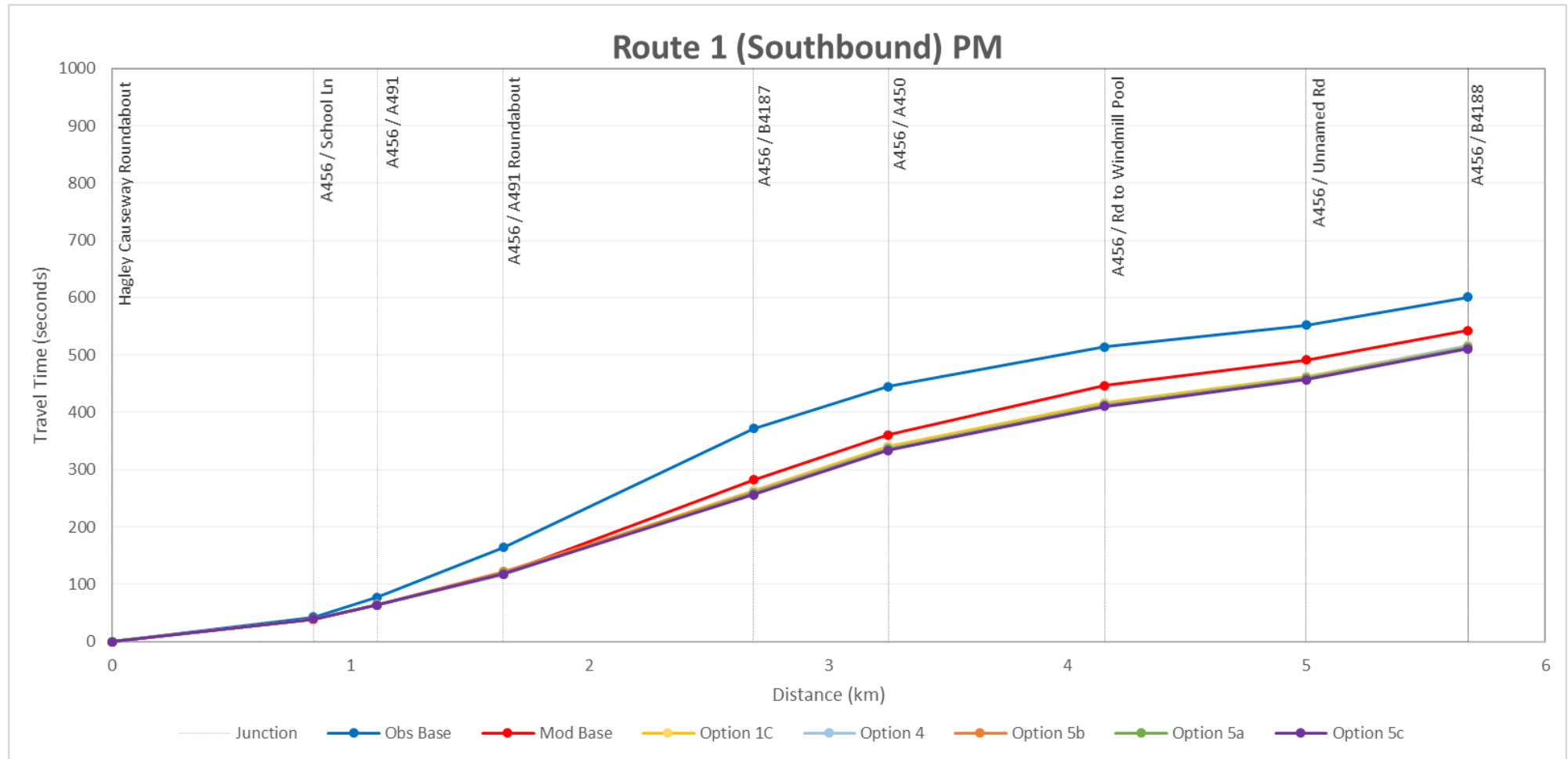


Figure 10-6: Route 1 SB – 2019 PM Journey Times – Options 4, 5a, 5b and 5c

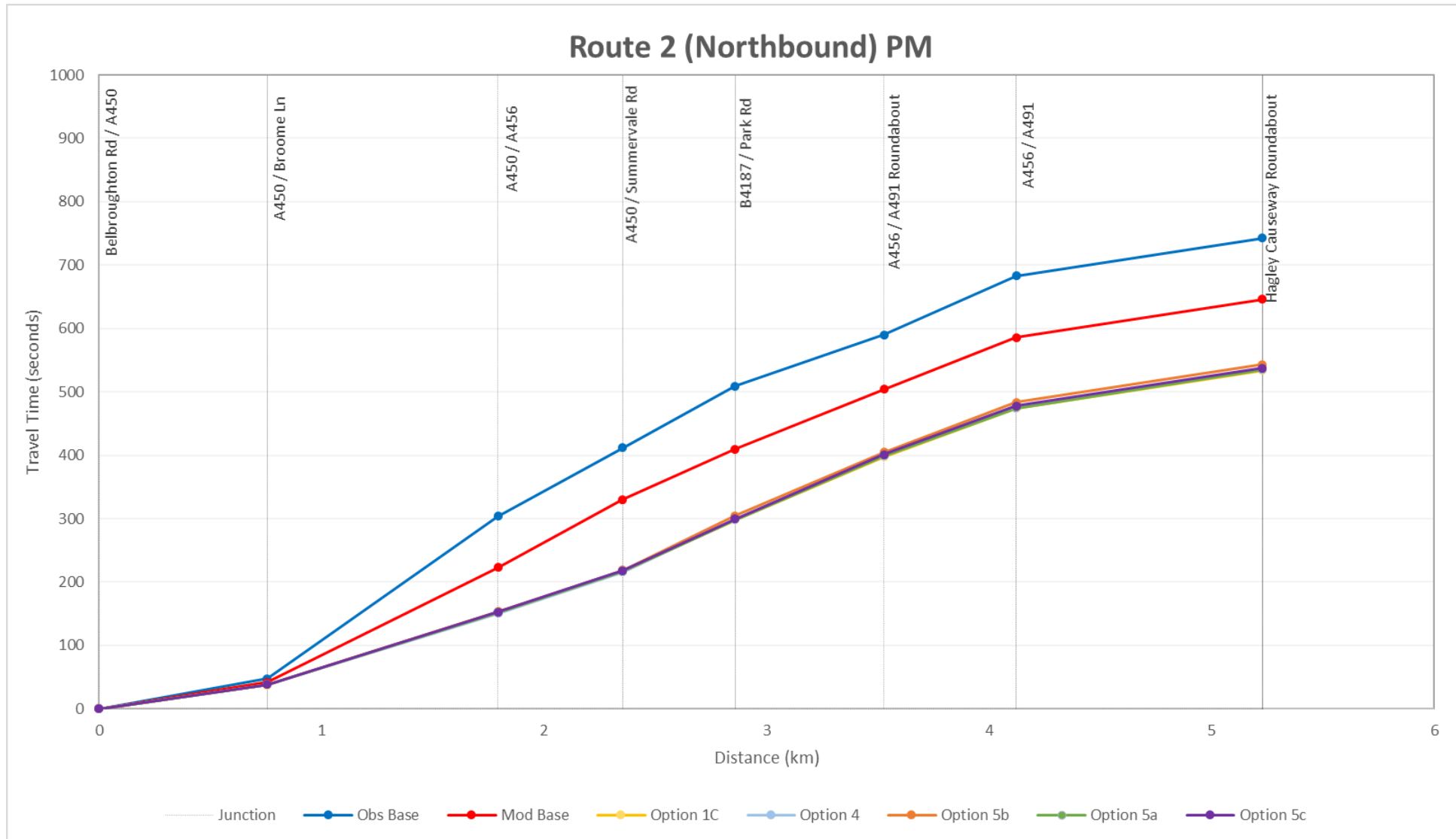


Figure 10-7: Route 2 NB – 2019 PM Journey Times – Options 4, 5a, 5b and 5c

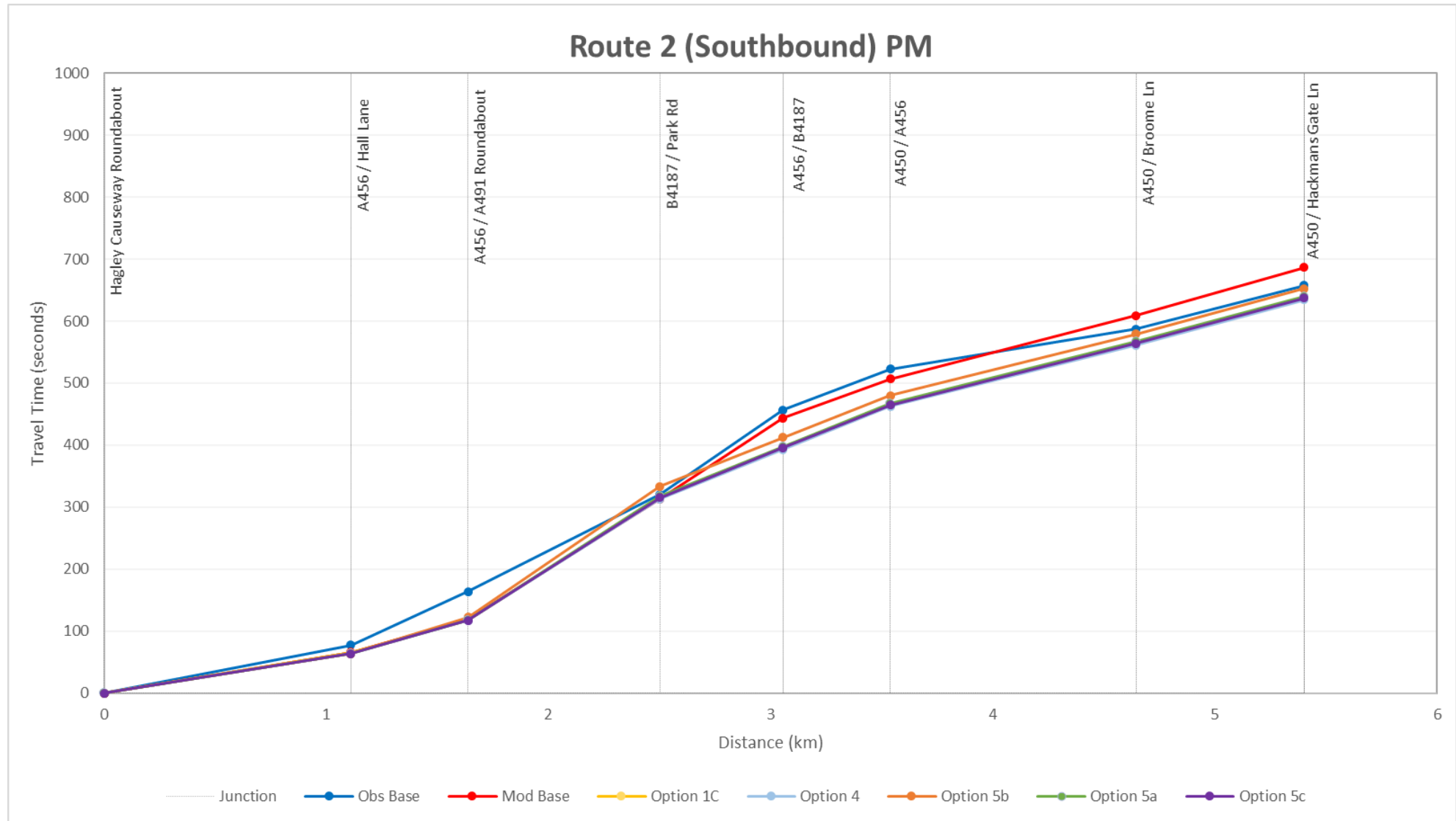


Figure 10-8: Route 2 SB – 2019 PM Journey Times – Options 4, 5a, 5b and 5c

10.3 2036 Results

10.3.1 Junction Flows

The total number of vehicles passing through each of the key junctions in the network during the AM and PM pre-peak and peak hours were collected for each scenario and are presented in Table 10-9 to Table 10-12. Where flows have increased compared with the base flows, the values are indicated in green whilst red indicates the opposite.

Table 10-9: Options 5a, 5b and 5c - Junction Flows – 2036 AM Peak

Junction	Junction Throughput - AM (08:00-09:00)			
	2019	2036		
	Base	Op 5a	Op 5b	Op 5c
B4187 Worcester Rd / Station Rd / Park Rd	1488	1233	1160	666
A456/B4187 Worcester Rd/Summervale Rd/Western Rd	2438	2547	2529	2300
A456 Kidderminster Rd / A450 Worcester Rd	2110	2463	2456	2268
A456 Kidderminster Rd / Stakenbridge Ln / Thicknall Ln	1258	982	962	914
A450 Worcester Rd / Thicknall Ln	863	1369	1398	1280
A456 Kidderminster Rd / Park Rd / A491 Stourbridge Rd / Bennett Dr	3922	3383	3593	3654
Middlefield Ln / A491 Kidderminster Rd	3303	2960	3090	3187
B4187 Worcester Rd / Middlefield Ln	1037	833	939	414
A456 Kidderminster Rd / A456 Birmingham Rd / A491 Stourbridge Rd	4035	3484	3424	3744

Table 10-10: Options 5a, 5b and 5c - Junction Flows – 2036 AM 2-hour Peak

Junction	Junction Throughput - AM (07:00-09:00)			
	2019	2036		
	Base	Op 5a	Op 5b	Op 5c
B4187 Worcester Rd / Station Rd / Park Rd	2642	2447	2379	1736
A456/B4187 Worcester Rd/Summervale Rd/Western Rd	4618	5388	5329	5096
A456 Kidderminster Rd / A450 Worcester Rd	4153	5208	5169	4978
A456 Kidderminster Rd / Stakenbridge Ln / Thicknall Ln	2444	2102	2019	1971
A450 Worcester Rd / Thicknall Ln	1771	2974	3039	2921
A456 Kidderminster Rd / Park Rd / A491 Stourbridge Rd / Bennett Dr	7688	7194	7287	7401
Middlefield Ln / A491 Kidderminster Rd	6474	6321	6261	6442
B4187 Worcester Rd / Middlefield Ln	1842	1643	1901	1265
A456 Kidderminster Rd / A456 Birmingham Rd / A491 Stourbridge Rd	7901	7438	7072	7507

It can be seen in Table 10-9 that, under Option 5a, most junctions experience a reduction in throughput compared with the base scenario during the 2036 AM peak hour. Table 10-10 shows the combined two-hour junction throughput. This shows that most junctions experience a decrease in throughput during the modelled two-hour period. This is because congestion in the network leads to blocking back between junctions, reducing the number of vehicles able to pass through.

Table 10-10 shows that, under Option 5b, several junctions experience a reduction in throughput compared with the base scenario whilst several experience an increase during the modelled two-hour period. The junctions which experience an increase in throughput are due to higher demand in 2036 than in 2019. The decreases in throughput are due to congestion in the network leading to blocking back between junctions, reducing the number of vehicles able to pass through.

Table 10-10 shows that, under Option 5c, most junctions experience a reduction in throughput compared with the base scenario during the modelled two-hour period. This is due to congestion in the network leading to blocking back between junctions, reducing the number of vehicles able to pass through.

For the A456 Kidderminster Road / A491 Stourbridge Road roundabout, the Option 5 variant with the highest throughput in the 2036 two-hour AM peak is Option 5c with 7401 vehicles. This is 287 vehicles less than in the 2019 base scenario.

Table 10-11: Options 5a, 5b and 5c - Junction Flows – 2036 PM Peak

Junction	Junction Throughput - PM (17:00-18:00)			
	2019	2036		
	Base	Op 5a	Op 5b	Op 5c
B4187 Worcester Rd / Station Rd / Park Rd	1279	1363	1392	1065
A456 / B4187 Worcester Rd / Summervale Rd / Western Rd	2441	2627	2616	2144
A456 Kidderminster Rd / A450 Worcester Rd	2336	2639	2636	2218
A456 Kidderminster Rd / Stakenbridge Ln / Thicknall Ln	1542	1541	1541	1376
A450 Worcester Rd / Thicknall Ln	881	1062	1047	825
A456 Kidderminster Rd / Park Rd / A491 Stourbridge Rd / Bennett Dr	3868	3975	3955	2837
Middlefield Ln / A491 Kidderminster Rd	3212	3375	3455	2553
B4187 Worcester Rd / Middlefield Ln	961	1012	1026	769
A456 Kidderminster Rd / A456 Birmingham Rd / A491 Stourbridge Rd	3909	4155	4040	3509

Table 10-12: Options 5a, 5b and 5c - Junction Flows – 2036 PM 2-hour Peak

Junction	Junction Throughput - PM (16:00-18:00)			
	2019	2036		
	Base	Op 5a	Op 5b	Op 5c
B4187 Worcester Rd / Station Rd / Park Rd	2365	2577	2667	2287
A456 / B4187 Worcester Rd / Summervale Rd / Western Rd	4878	5334	5334	4838
A456 Kidderminster Rd / A450 Worcester Rd	4676	5342	5352	4904
A456 Kidderminster Rd / Stakenbridge Ln / Thicknall Ln	3034	3086	3106	2941
A450 Worcester Rd / Thicknall Ln	1824	2204	2183	1927
A456 Kidderminster Rd / Park Rd / A491 Stourbridge Rd / Bennett Dr	7562	7891	7881	7023
Middlefield Ln / A491 Kidderminster Rd	6377	6834	7000	6264
B4187 Worcester Rd / Middlefield Ln	1750	2002	2009	1739
A456 Kidderminster Rd / A456 Birmingham Rd / A491 Stourbridge Rd	7925	8600	8423	8122

It can be seen in Table 10-12 that, under Option 5a and 5b, all junctions experience an increase in throughput compared with the base scenario during the 2036 AM two-hour period. This is due to demand in the network being higher in 2036 than in 2019. However, under Option 5c, most junctions experience a decrease in throughput compared with the 2019 base, despite demand being higher. This is due to congestion in the network leading to blocking back between junctions, reducing the number of vehicles able to pass through. Under Option 5c, traffic entering the A456 / A491 roundabout via the Park Road east approach experiences significant congestion due to having less opportunities to enter the roundabout under this scheme. This in turn leads to blocking back on the B4187 Worcester Road, Middlefield Lane and the A456 Kidderminster Road.

Throughput at the roundabout is highest under Option 5a at 7891 vehicles over two hours. However, it can be seen that throughput under Option 5b is similarly high at 7881 vehicles.

10.3.2 Junction Delays

The average delay time for each vehicle passing through each of the key junctions in the model was collected for the AM and PM peak hours for each scenario and are presented in Table 10-13 and Table 10-14.

Table 10-13: Options 5a, 5b and 5c - Junction Delays – 2036 AM Peak

Junction	Average Delay per Vehicle (s) - AM (08:00-09:00)			
	2019	2036		
	Base	Op 5a	Op 5b	Op 5c
B4187 Worcester Rd / Station Rd / Park Rd	44.9	116.5	128.6	288.6
A456 / B4187 Worcester Rd / Summervale Rd / Western Rd	25.5	47.0	39.1	53.1
A456 Kidderminster Rd / A450 Worcester Rd	28.8	47.7	50.4	54.5
A456 Kidderminster Rd / Stakenbridge Ln / Thicknall Ln	15.5	86.1	85.4	91.2
A450 Worcester Rd / Thicknall Ln	5.9	45.9	47.5	49.7
A456 Kidderminster Rd / Park Rd / A491 Stourbridge Rd / Bennett Dr	40.1	173.4	154.8	108.0
Middlefield Ln / A491 Kidderminster Rd	29.7	78.5	79.3	60.6
B4187 Worcester Rd / Middlefield Ln	3.3	117.6	59.4	203.1
A456 Kidderminster Rd / A456 Birmingham Rd / A491 Stourbridge Rd	45.6	112.1	121.1	104.5

Under each of the 2036 Options 5a-c, all junctions experience an increase in delays compared with the 2019 base scenario due to demand in the network being higher in 2036.

For the A456 Kidderminster Road / A491 Stourbridge Road roundabout, the Option 5 variant with the lowest average delay per vehicle in the 2036 AM peak is Option 5c at 108 seconds. Option 5a is highest at 173 seconds.

Table 10-14: Options 5a, 5b and 5c - Junction Delays – 2036 PM Peak

Junction	Average Delay per Vehicle (s) - PM (17:00-18:00)			
	2019	2036		
	Base	Op 5a	Op 5b	Op 5c
B4187 Worcester Rd / Station Rd / Park Rd	60.8	70.7	85.5	82.5
A456 / B4187 Worcester Rd / Summervale Rd / Western Rd	30.1	41.8	42.1	64.8
A456 Kidderminster Rd / A450 Worcester Rd	30.4	35.6	35.8	48.2
A456 Kidderminster Rd / Stakenbridge Ln / Thicknall Ln	10.1	44.4	45.8	57.0
A450 Worcester Rd / Thicknall Ln	6.9	53.3	58.4	74.9
A456 Kidderminster Rd / Park Rd / A491 Stourbridge Rd / Bennett Dr	52.0	105.4	85.1	175.0
Middlefield Ln / A491 Kidderminster Rd	2.3	26.0	21.0	37.5
B4187 Worcester Rd / Middlefield Ln	24.0	71.4	76.2	114.0
A456 Kidderminster Rd / A456 Birmingham Rd / A491 Stourbridge Rd	26.0	80.8	82.3	68.3

Under each of the 2036 Options 5a-c, all junctions experience an increase in delays compared with the 2019 base scenario due to demand in the network being higher in 2036.

For the A456 Kidderminster Road / A491 Stourbridge Road roundabout, the Option 5 variant with the lowest average delay per vehicle in the 2036 AM peak is Option 5b at 85 seconds. Option 5c is highest at 175 seconds.

10.3.3 Journey Times

The journey times in the network under Options 5a, 5b and 5c, alongside observed journey times under Option 4 are given in Table 10-15 for the 2019 AM peak. Where journey times have increased compared with the modelled base journey times, the values are indicated in red whilst green indicates the opposite.

Table 10-15: 2036 AM Peak Journey Times – Options 5a, 5b and 5c

	Direction	AM Peak (08:00-09:00)				
		2019		2036		
		Observed Base	Modelled Base	Option 5a	Option 5b	Option 5c
Route 1	NB	00:13:11	00:14:49	00:52:44	00:34:33	00:38:59
	SB	00:08:19	00:09:22	00:30:10	00:35:43	00:27:40
Route 2	NB	00:14:12	00:15:18	00:46:46	00:47:25	01:18:57
	SB	00:12:54	00:13:01	00:39:01	00:38:35	00:29:16

The table shows that, for the 2036 AM peak, each of the Option 5 scenarios lead to significant increase in journey time compared with the 2019 base. This is due to higher demand in the network in 2036, as previously discussed in Section 3.1 and Table 3-2, causing delays to increase at various junctions.

Graphical representations for the two routes in both directions for the 2036 AM peak are given in Figure 10-9 to Figure 10-12.

For Route 1 northbound, the highest travel time occurs in Option 5a, at 52 minutes 44 seconds. Option 5b experiences the lowest travel time at 34 minutes 33 seconds. It can be seen that all three options experience significant delays on the approach to the A456 / A450 signalised junction compared with the 2019 base.

For Route 1 southbound, the highest travel time occurs under Option 5b. Figure 10-10 shows that this travel time increase compared with Options 5a and 5c occurs primarily to the north of the roundabout. The travel time on this section is higher under Option 5b as the closure of the Park Road east approach to the roundabout under this option means that traffic instead has to re-route to use the A456 southbound approach which leads to an increase in demand and delays on this section compared with Option 5a. Option 5c has the lowest travel time for this route at 27 minutes 40 seconds. This is due to the cut-through at the roundabout reducing delays. In all three options, traffic blocks back from the A456 / A450 signalised junction and the A456 / B4187 Worcester Road signalised junction to the roundabout, leading to a significantly higher journey time across the route.

For Route 2 northbound, the travel times for Options 5a and 5b are similar at 46 minutes 46 seconds and 47 minutes 25 seconds respectively. However, the travel time under Option 5c is significantly higher at almost 1 hour 19 minutes. This significant increase occurs on the Park Road approach to the roundabout. The implementation of the cut-through in Option 5c means that there are less opportunities for traffic on this approach to enter the roundabout. As for Route 1 northbound, it can be seen that all three options experience significant delays on the approach to the A456 / A450 signalised junction compared with the 2019 base.

For Route 2 southbound, the travel times follow a similar pattern to Route 1 southbound. Option 5c experiences the lowest travel time of 29 minutes 16 seconds. This is almost 10 minutes less than Options 5a and 5b due to the implementation of the cut-through. As for Route 1 southbound, in all three options traffic blocks back from the A456 / A450 signalised junction and the A456 / B4187 Worcester Road signalised junction to the roundabout, leading to a significantly higher journey time across the route.

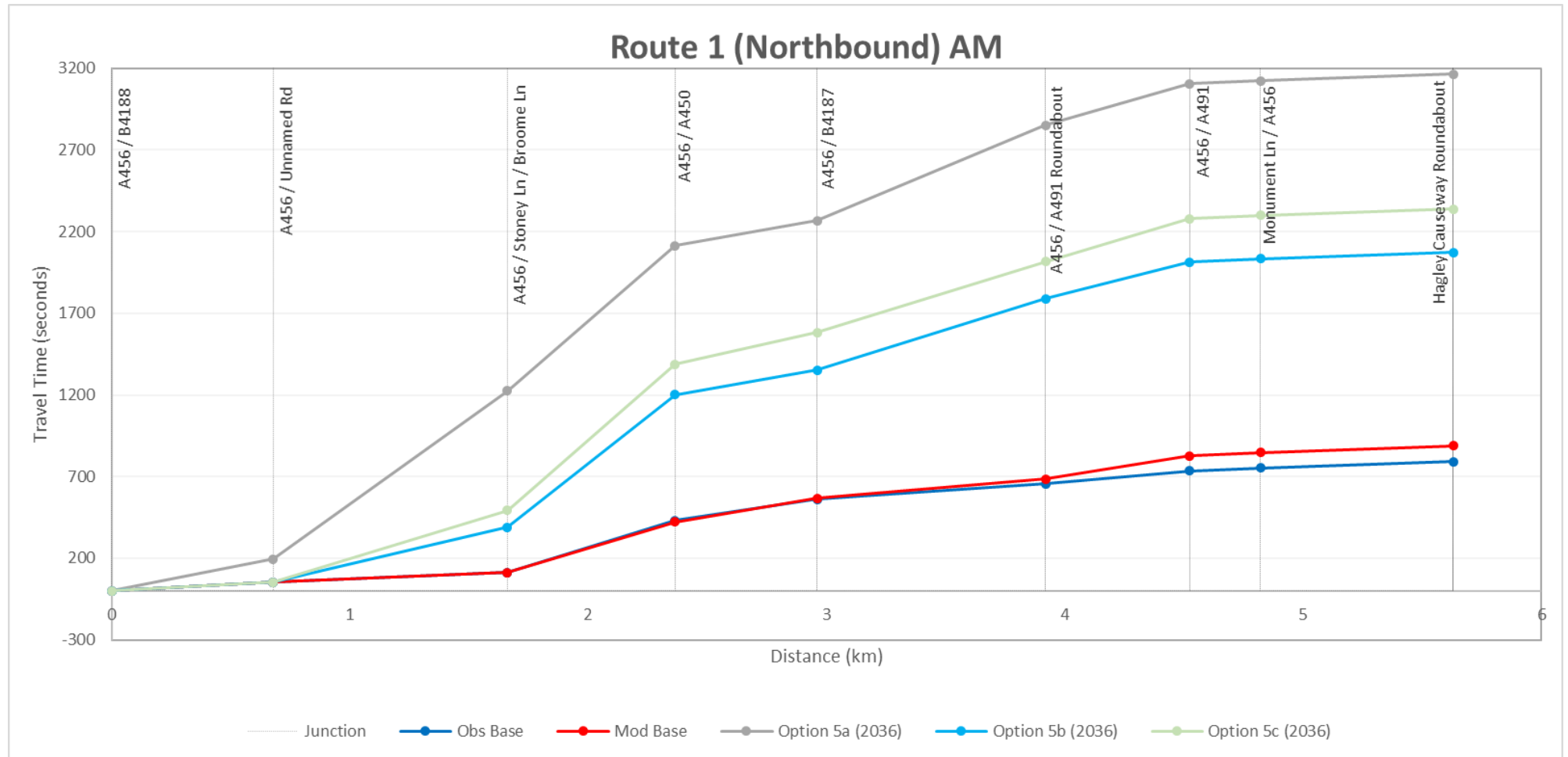


Figure 10-9: Route 1 NB – 2036 AM Journey Times – Options 5a, 5b and 5c

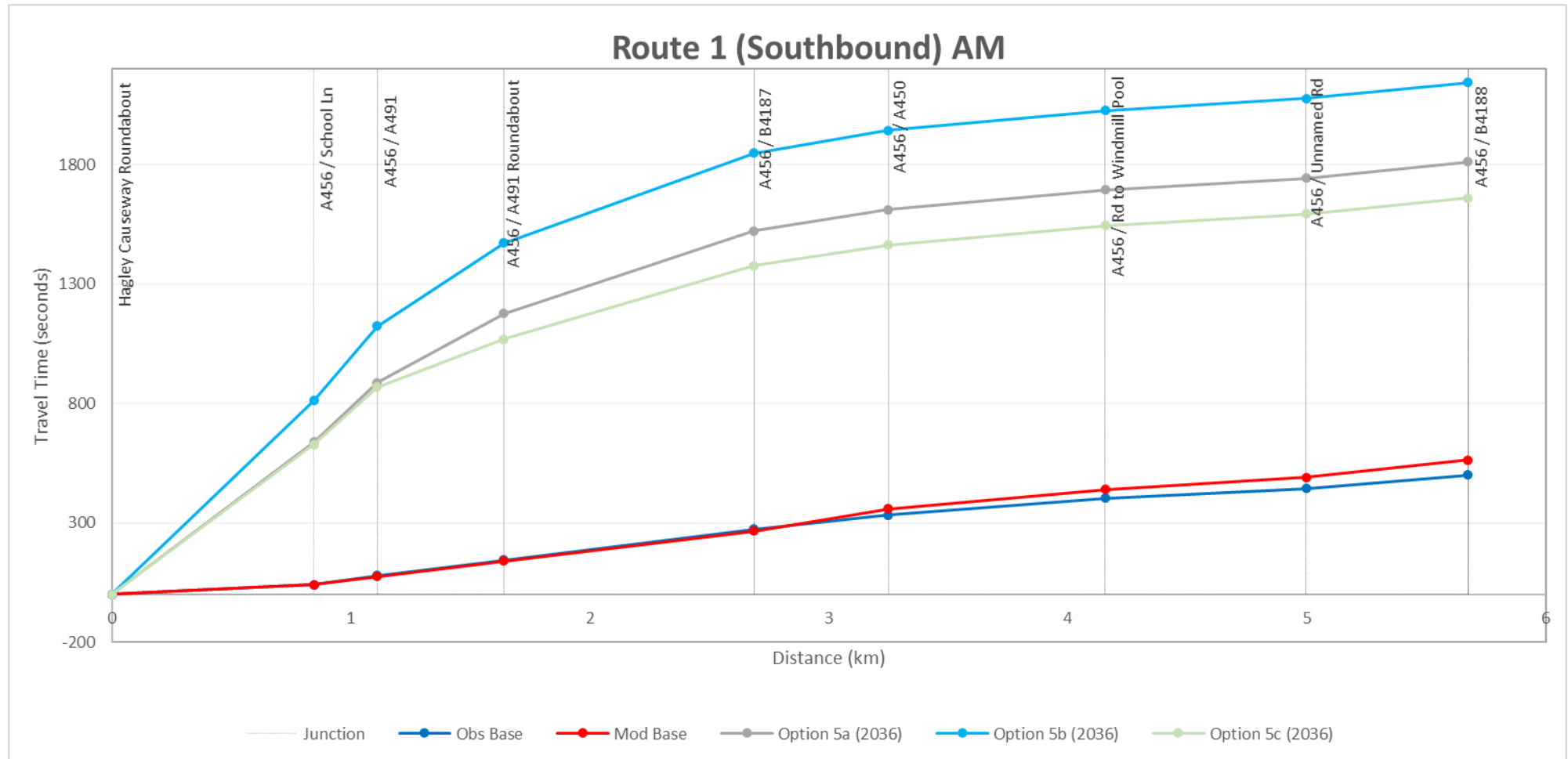


Figure 10-10: Route 1 SB – 2036 AM Journey Times – Options 5a, 5b and 5c

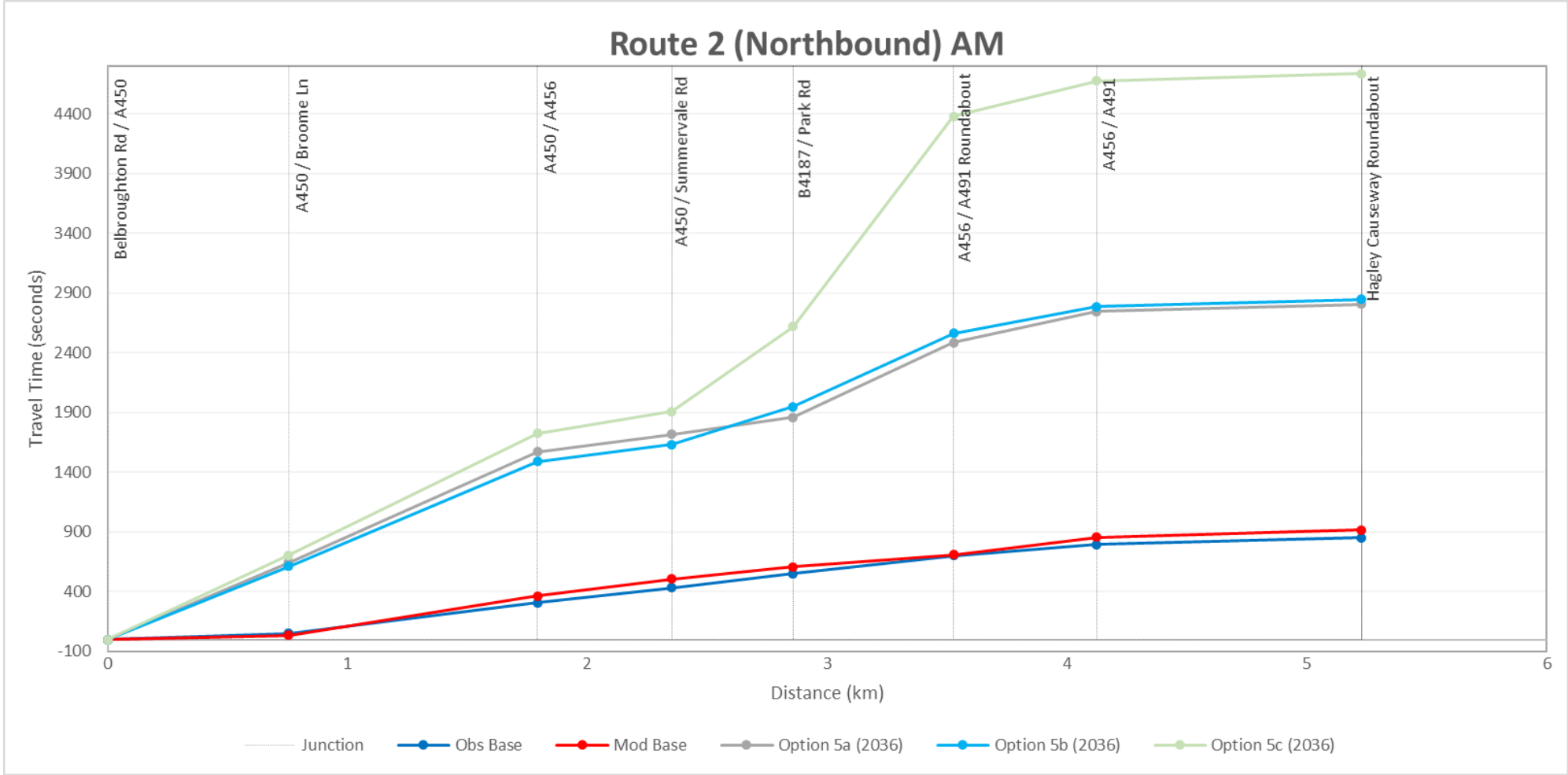


Figure 10-11: Route 2 NB – 2036 AM Journey Times – Options 5a, 5b and 5c

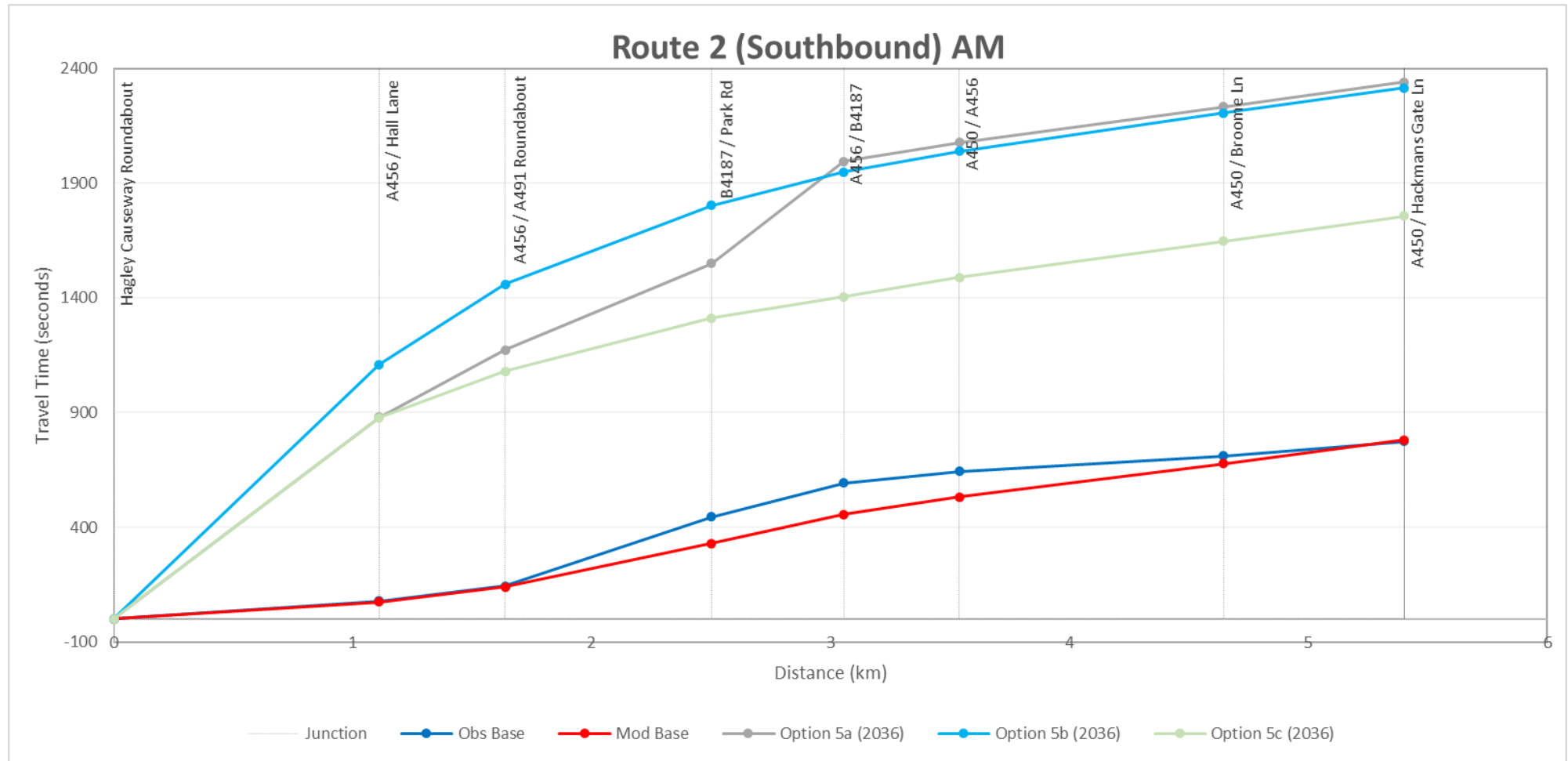


Figure 10-12: Route 2 SB – 2036 AM Journey Times – Options 5a, 5b and 5c

The journey times under each of the modelled scenarios, alongside observed journey times, are given in Table 10-16 for the 2019 PM peak. Where journey times have increased compared with the modelled base journey times, the values are indicated in red whilst green indicates the opposite.

Table 10-16: 2036 PM Peak Journey Times – Options 5a, 5b and 5c

		PM Peak (17:00-18:00)				
	Direction	2019		2036		
		Observed Base	Modelled Base	Option 5a	Option 5b	Option 5c
Route 1	NB	00:11:00	00:10:13	00:32:29	00:32:12	00:46:06
	SB	00:10:01	00:09:03	00:19:46	00:20:32	00:18:22
Route 2	NB	00:12:23	00:10:46	00:24:06	00:24:07	00:28:43
	SB	00:10:58	00:11:27	00:25:41	00:26:59	00:32:33

The table shows that, for the 2036 PM peak, each of the Option 5 scenarios lead to an increase in journey time compared with the 2019 base. This is due to higher demand in the network in 2036 under Option 5 as previously discussed.

Graphical representations for the two routes in both directions for the 2036 PM peak are given in Figure 10-13 to Figure 10-16.

For Route 1 northbound, the highest travel time occurs in Option 5c, at 46 minutes 6 seconds. It can be seen that the travel time for this option is higher than Option 5a and 5b on the approach to the A456 Kidderminster Road / A456 Worcester Road signalised junction. This is because traffic on the Park Road west approach to the roundabout blocks all the way back to the B4187 Worcester Road which in turn blocks along Middlefield Road and onto the A456 northbound to the north of the roundabout. Option 5b experiences the lowest travel time at 32 minutes 12 seconds. As in the AM peak, under each of the three options there are significant delays on the approach to the A456 / A450 signalised junction compared with the 2019 base network.

For Route 1 southbound, the highest travel time occurs under Option 5b. Figure 10-10 shows that this travel time increase compared with Options 5a and 5c occurs primarily at the beginning of the route. The travel time on this section is higher under Option 5b as the closure of the Park Road east approach to the roundabout under this option means that traffic instead has to re-route to use the A456 southbound approach which leads to an increase in demand and delays on this section compared with Option 5a. Option 5c has the lowest travel time for this route at 18 minutes 22 seconds. This is due to the cut-through at the roundabout reducing delays. As in the AM peak, in all three options traffic blocks back from the A456 / A450 signalised junction and the A456 / B4187 Worcester Road signalised junction to the roundabout, leading to a significantly higher journey time across the route.

For Route 2 northbound, the travel times for Options 5a and 5b are similar at 24 minutes 6 seconds and 24 minutes 7 seconds respectively. However, the travel time under Option 5c is higher at 28 minutes 43 seconds. This significant increase occurs at the beginning of the route, on the approach to A456 / A450 signalised junction. As for Route 1 northbound, under each of the three options there are significant delays on the approach to the A456 / A450 signalised junction compared with the 2019 base network.

For Route 2 southbound, the travel times follow a similar pattern to Route 1 southbound. Option 5c experiences the highest travel time of 32 minutes 33 seconds. This is almost 6 minutes higher than Options 5a and 5b. Figure 10-16 shows that this occurs on the approach to the B4187 Worcester Road / Park Road signalised junction due to congestion in this area due to blocking back from the roundabout. As for Route 1 northbound, in all three options traffic blocks back from the A456 / A450 signalised junction and the A456 / B4187 Worcester Road signalised junction to the roundabout, leading to a significantly higher journey time across the route.

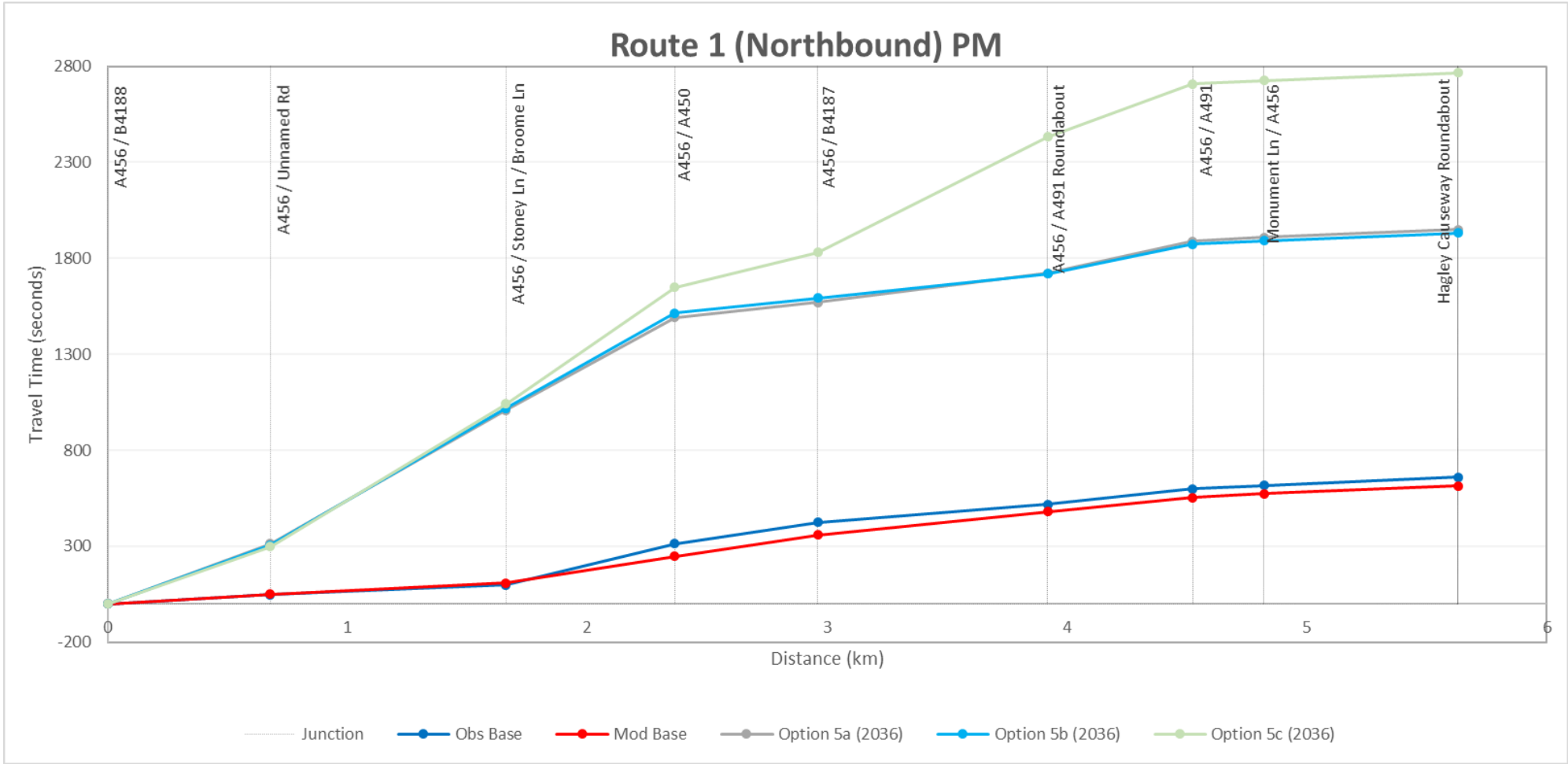


Figure 10-13: Route 1 NB – 2036 PM Journey Times – Options 5a, 5b and 5c

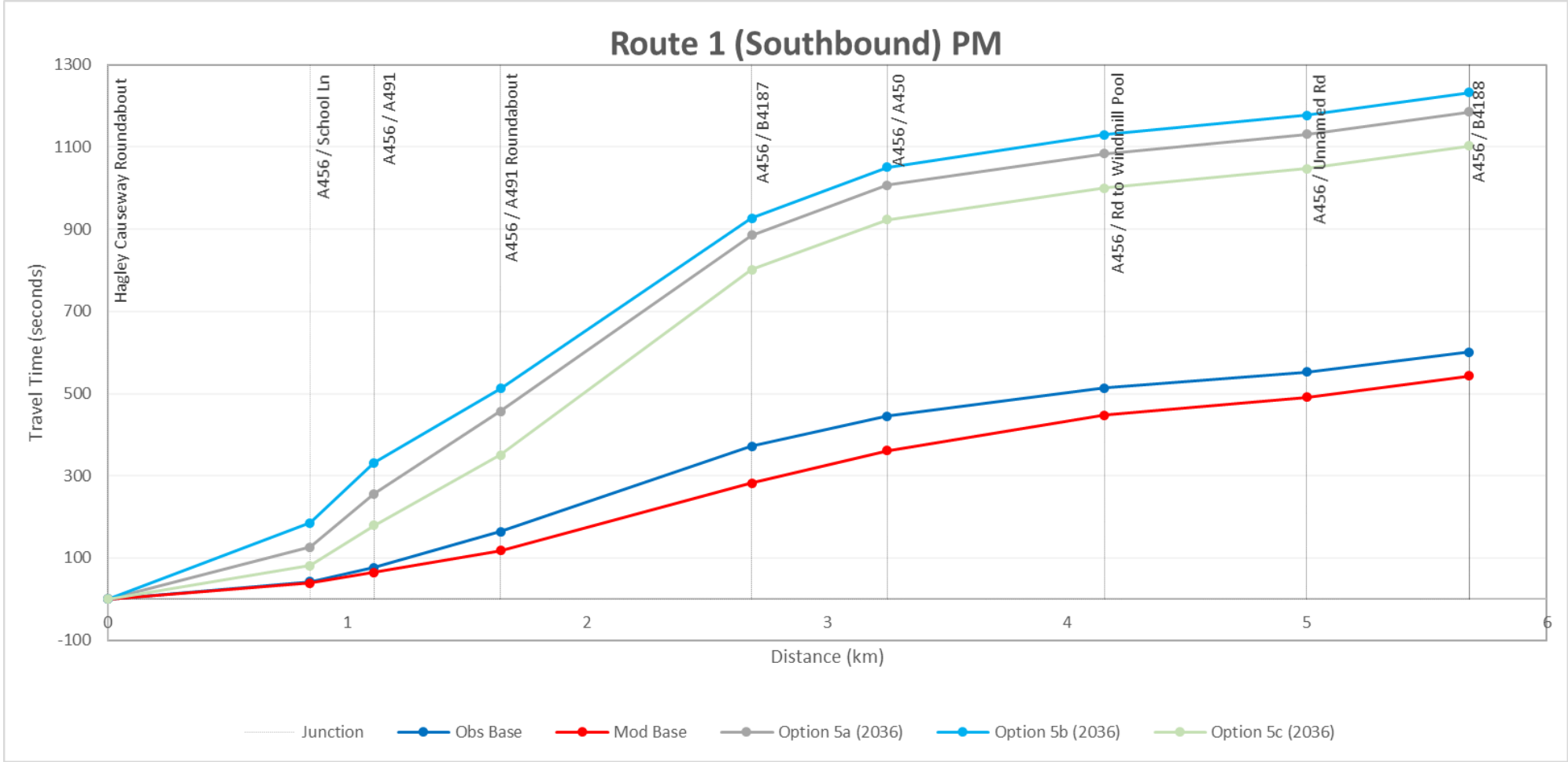


Figure 10-14: Route 1 SB – 2036 PM Journey Times – Options 5a, 5b and 5c

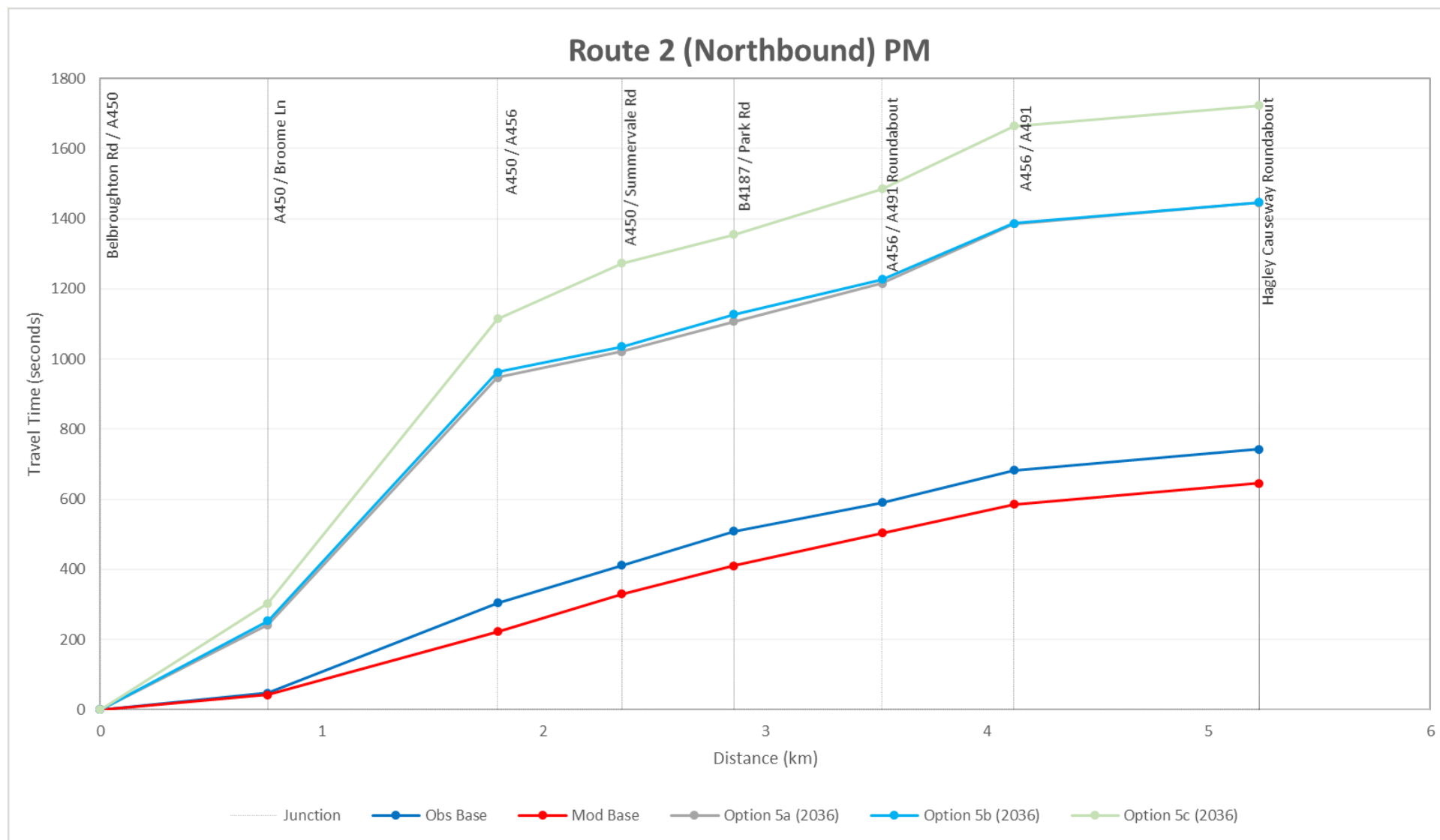


Figure 10-15: Route 2 NB – 2036 PM Journey Times – Options 5a, 5b and 5c

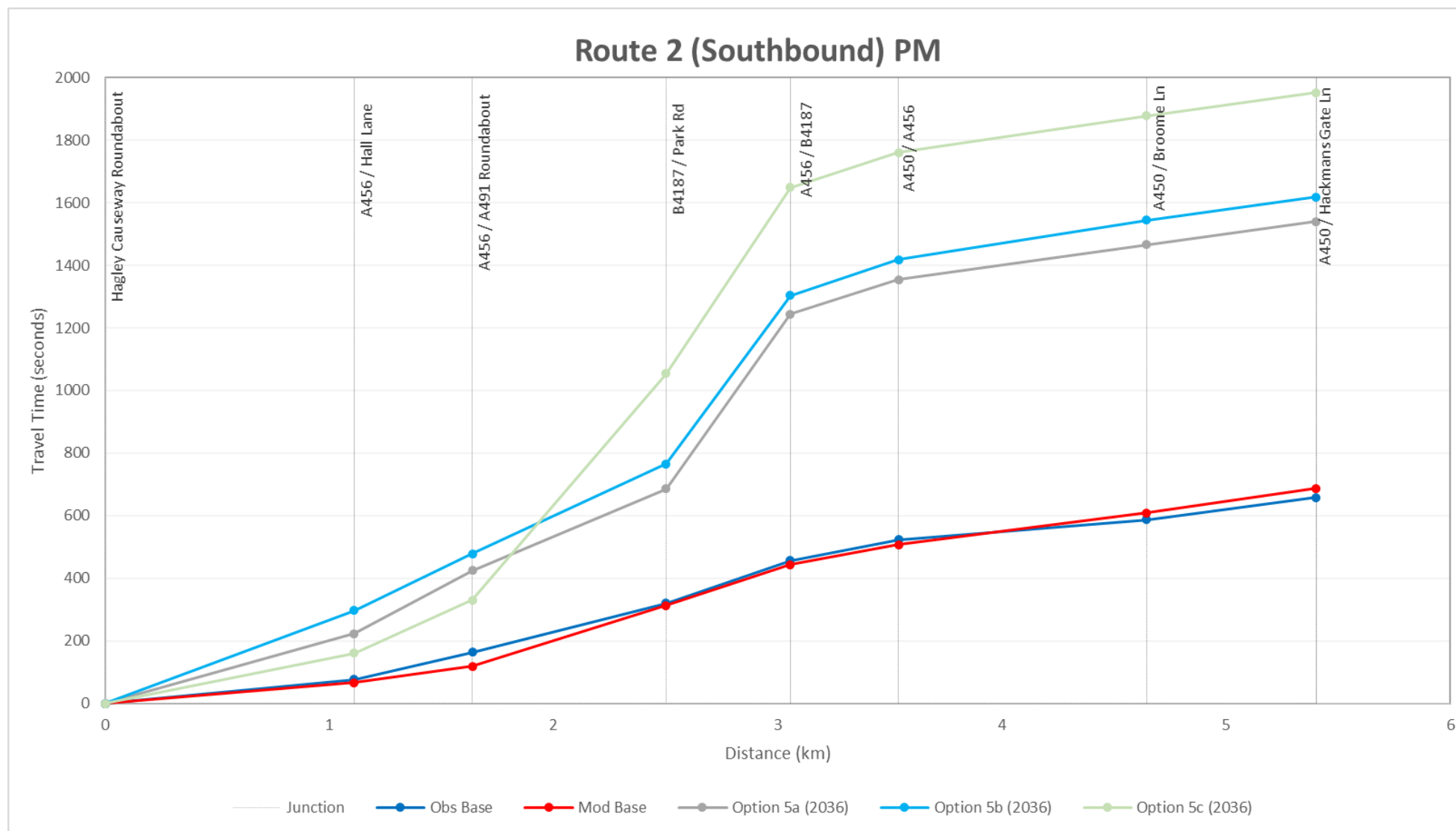


Figure 10-16: Route 2 SB – 2036 PM Journey Times – Options 5a, 5b and 5c

10.3.4 Vehicles Unable to Enter the Network

It was noted that in all of the models under Option 5 that were run for 2036, some vehicles were unable to enter the modelled network during the modelled interval. Therefore, the number of vehicles unable to enter the network is used as a measure of performance of congestion. The numbers of these vehicles and the locations of where they were unable to enter was recorded and are shown in Table 10-17. The locations of the zones given in the table are shown in Figure 10-17.

Table 10-17: Vehicles Unable to Enter the Network

	AM Peak				PM Peak			
	2019	2036			2019	2036		
	Base	Op5a	Op5b	Op5c	Base	Op5a	Op5b	Op5c
1	0	74	0	0	0	119	115	446
4	0	34	0	21	0	0	0	50
7	0	20	0	54	0	0	0	0
8	0	1	0	0	0	0	0	0
9	0	38	0	32	0	0	0	13
11	0	86	0	100	0	132	145	192
12	0	84	2	113	0	0	0	2
13	0	116	27	215	0	0	0	73
14	0	45	62	19	0	1	0	33
15	0	123	12	17	0	322	8	158
16	0	177	0	66	0	141	428	1110
17	0	1073	1115	866	0	0	0	0
18	0	1263	1422	746	0	361	376	24
Total	0	3133	2641	2249	0	1076	1073	2100

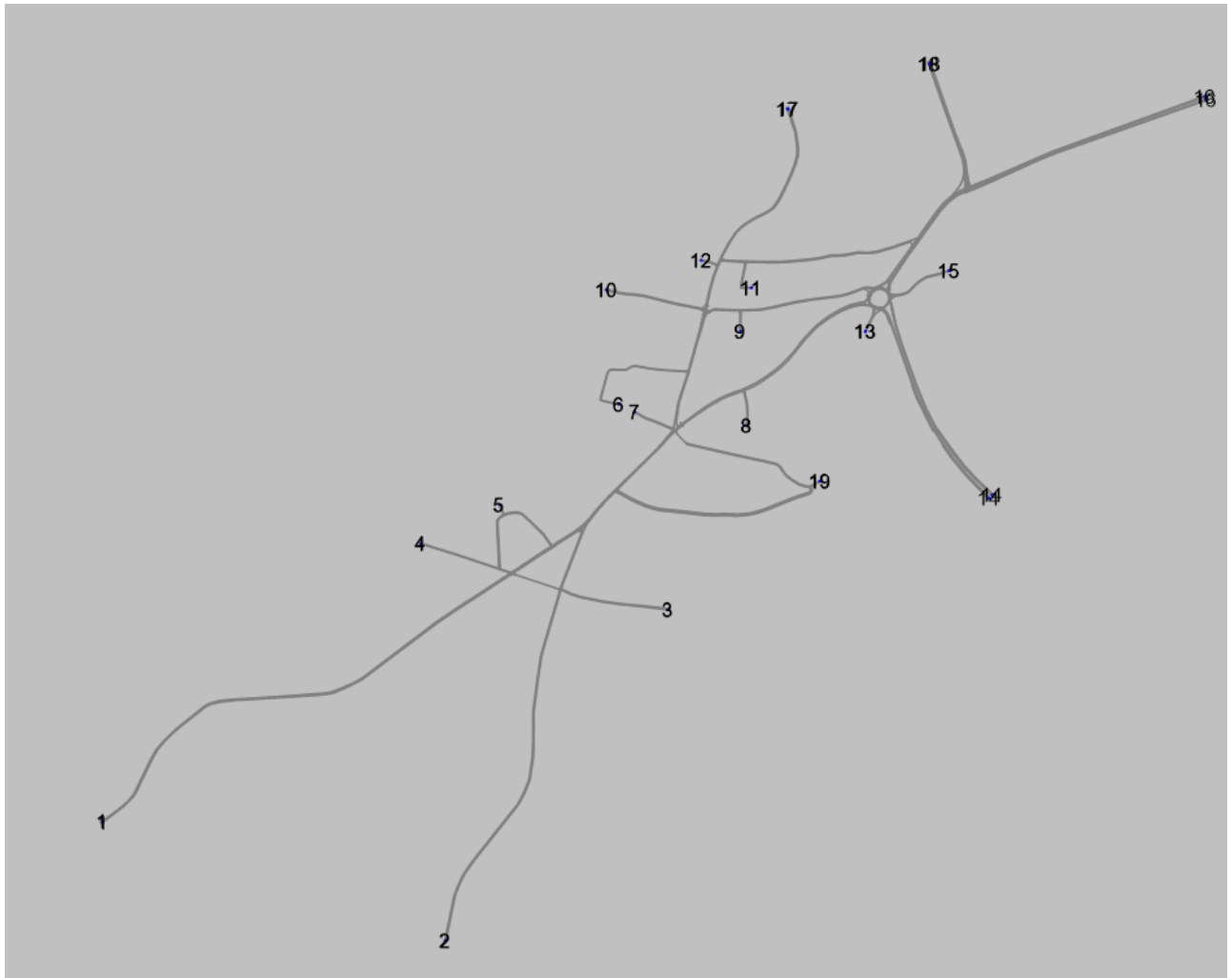


Figure 10-17: VISSIM Zone Locations

Table 10-17 shows that, in the AM peak, the scenario with the greatest number of vehicles unable to enter the network is Option 5a with 3133 vehicles unable to enter. The zone with the greatest number unable to enter under Option 5a is zone 18, which is located on the A491 Stourbrige Road to the north of the A456 which has 1263 vehicles unable to enter. However, this value is even higher at 1422 vehicles under Option 5b due to increased congestion on the A456 in this scenario. Another zone with a high number of vehicles unable to enter the network is zone 17, located on the northern approach to the network via the B4187 Worcester Road. Option 5b has the highest number of vehicles unable to enter the network via this zone at 1115 vehicles. In the 2036 AM peak, Option 5c has the fewest number of vehicles unable to enter the network at 2249 vehicles.

In the PM peak, the numbers of vehicles unable to enter the network are generally lower than in the AM peak. The scenario with the greatest number of vehicles unable to enter the network is Option 5c with 2100 vehicles unable to enter. The zone with the greatest number unable to enter under Option 5c is zone 16, which is located on the A456 Birmingham Road approach to the network from the west. Options 5a and 5b have similar number of vehicles unable to enter the network in the 2036 PM peak at 1076 and 1073 vehicles respectively.

11. Summary and Conclusions

11.1 Summary

Jacobs was commissioned by WCC to use the micro-simulation model of Hagley, developed in VISSIM, in order to evaluate potential highway improvement schemes at several junctions in the network.

11.2 Conclusion

Based on the results presented within this report it can be concluded that each of Options 1a, 1b and 1c lead to the road network in Hagley to perform better in both the AM and PM peaks with 2019 levels of traffic compared with the current network layout.

For the 2019 AM peak, Options 1a and 1b lead to a reduction in journey time for three of the four journey time routes in the model. The fourth route, Route 1 southbound, experiences a small increase in journey time of 9 seconds under Option 1a and hardly no change under Option 1b. Option 1c leads to a travel time saving for all routes compared with the base scenario. The most significant travel time savings occur in the northbound direction on the approach to the A456 Kidderminster Road / B4187 Worcester Road signalised junction due to the improvements made to this junction under each of the proposed options. However, there are also improvements in journey time on other approaches to this junction under Option 1c due to the banning of two movements under this option. This enables the pedestrian phase at this junction to run with traffic, giving the traffic phases more green time.

For the 2019 PM peak, all three options lead to a reduction in journey time for all routes compared with the base scenario. As in the AM peak, the most significant travel time savings occur in the northbound direction on the approach to the A456 Kidderminster Road / B4187 Worcester Road signalised junction due to the improvements made to this junction under each of the proposed options.

Options 2 and 3 were then assessed and the results compared with those of Option 1c. It was found that Options 2 and 3 did not lead to significant improvements to the network compared with Option 1c and actually lead to worsening of travel times in most cases.

For the 2019 AM peak, the Options 2 and 3 scenarios experienced a higher travel time than the Option 1c for three of the four journey time routes. This is primarily due to traffic having to re-route along longer distances in the Option 2 and 3 scenarios due to converting of some sections to one-way. Additionally, signals are implemented at the A456 / Stakenbridge Lane / Thicknall Lane junction in both options and at the A450 / Thicknall Lane junction under Option 3. These signals add delays to movements which were previously unimpeded under the base network. The fourth route, Route 2 southbound, experiences an improvement in travel time due to the conversion of the A450 southbound to two lanes between the A456 / A450 signalised junction and the A450 / Thicknall Lane junction.

For the 2019 PM peak, the Options 2 and 3 scenarios experienced a higher travel time than the Option 1c scenario for all routes. This is for the same reasons mentioned above for the AM peak.



Figure 11-1 Summary graph for 2019 Option 1c

It can be seen in Figure 11-1 that Option 1c leads to improvements at the A456 / Stakenbridge Lane / Thicknall Lane junction, the A456 / A450 signalised junction and the A456 / B4187 Worcester Road signalised junction in the 2019 AM and PM peaks. This is because the improvements at the A456 / B4187 Worcester Road junction reduce blocking back from this junction to the junctions to the south.

However, the Option 1c improvements lead to an increase in delays at the A456 Kidderminster Road / A491 Stourbridge Road roundabout in the 2019 AM peak. This is because the improvements at the A456 / B4187 Worcester Road junction lead to more traffic being released to the roundabout in the northbound direction. Additionally, more traffic is released to the A456 Kidderminster Road / A491 Stourbridge Road signalised junction which leads to some blocking back from this junction to the roundabout. Option 4 was therefore tested in the network to reduce this blocking back in the 2019 AM peak.



Figure 11-2 Summary graph for 2019 Option 4 and 4b

Figure 11-2 shows that the Option 4 improvements at the A456 Kidderminster Road / A491 Stourbridge Road signalised junction lead to reduced delays at this junction in the 2019 AM peak. Additionally, this reduces blocking back from this junction to the roundabout which brings delays at the roundabout back to a similar level to the base conditions. Delays at the A456 Kidderminster Road / A491 Stourbridge Road signalised junction are not significant in the 2019 PM peak, so the Option 4 improvements do not lead to significant changes in delay for this period.

Option 4b test results show similar improvements to Option 4 when compared to base conditions, however, delays at the A456/B4187 Worcester Road junction increase due to the revised signal staging at the junction with a separate pedestrian phase to permit the left turn onto the A456 from the B4187.

It can be seen that the improvements under Option 4 are sufficient at reducing congestion in the network for 2019 traffic levels. Most junctions experience a reduction in delays compared with the base network. The A456 Kidderminster Road / A491 Stourbridge Road roundabout is the only junction which does not experience benefits from the proposed schemes, but delays remain at the same level as in the base network.



Figure 11-3 Summary graph for 2036 with No Improvements at A456 / A491 Roundabout

Figure 11-3 shows the performance of junctions in the network with 2036 levels of traffic where no improvements are made to the A456 Kidderminster Road / A491 Stourbridge Road roundabout. When no improvements are made to this junction, it becomes a bottleneck in the network with 2036 traffic in both the AM and PM peaks in the southbound direction. This means that delays at the roundabout are very high, as well as at the A456 Kidderminster Road / A491 Stourbridge Road signalised junction due to traffic blocking back from the roundabout. Junctions to the south of the roundabout do not experience significant increases in delay due to traffic being stuck at the roundabout and unable to get to these junctions. Therefore, three options were tested at the roundabout for both 2019 and 2036 levels of traffic.



Figure 11-4 Summary graph for Option 5a

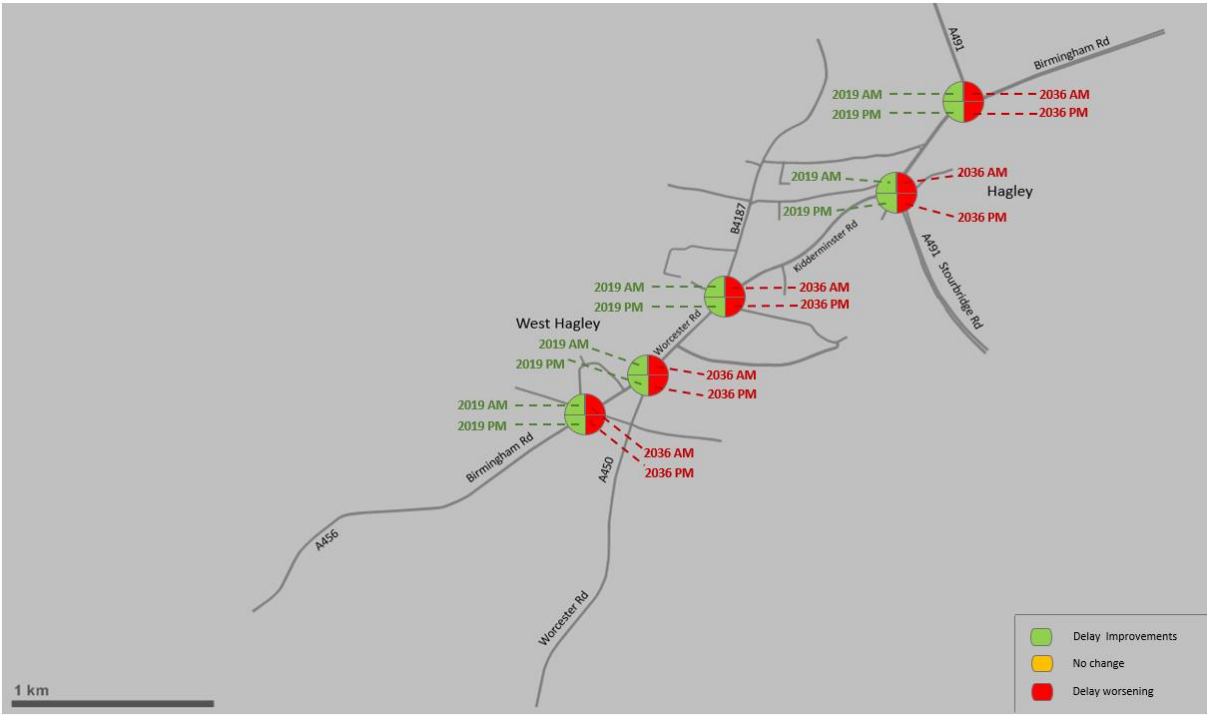


Figure 11-5 Summary graph for Option 5b



Figure 11-6 Summary graph for Option 5c

For each of the Options 5a-5c, all junctions in the network experience significant delays in both the 2036 AM and PM peaks. This is because the improvements at the A456 Kidderminster Road / A491 Stourbridge Road roundabout remove the bottleneck from this location, enabling more traffic to travel southbound to downstream junctions. This causes significant delays at the A456 / Stakenbridge Lane / Thicknall Lane junction, the A456 / A450 signalised junction and the A456 / B4187 Worcester Road signalised junction. This suggests that these junctions will require improvements to enable them to operate efficiently with 2036 levels of traffic.

It can also be seen that, despite the roundabout improvements under each of Options 5a-5c, this roundabout also experiences high levels of delay in the 2036 AM and PM peaks. This is partially due to traffic blocking back from downstream junctions in the southbound direction. This makes it difficult to assess the performance of Options 5a-5c as it is unclear how well these schemes would operate if no blocking back was present.

11.3 Recommendations

Based on the analysis discussed in this report, the following are our recommendations:

In the short-term, it is recommended that Option 4 is carried forward as the best option to address congestion issues in Hagley for 2019 traffic levels. Detailed design based on a true topographical survey will however be required for the A456/B4187 junction and the Cattle market junction.

To address the potential network gridlocking scenario in the future, it is recommended that **in the medium-term**, options are explored to:

- Downgrade B4187 Worcester Road to reduce traffic from/to Stourbridge and convert the junction into a priority junction; and
- Restrict/close access to the A456/A491 roundabout from Park Road (East and West)

For the **long-term** forecast conditions, it is suggested that WCC take a strategic view on the performance of the A456 corridor in Hagley exploring further options at the A456/B4187 junction in conjunction with Options 2/3, Option 5.

Appendix A - A456/B4187 junction scheme drawings (Existing and Proposed layout)