3 Transport Modelling

3.1 Introduction

This section provides information on:

- Section 3.2 – Transport modelling methodology overview; and
- Section 3.3 – Summary of modelled scheme impacts.

3.2 Overview of the transport modelling work undertaken since the Outline Business Case

The OBC report was submitted in January 2017 and was based on modelling forecasts that used TEMPro v7.0. Following revisions to the TEMPro datasets for Worcestershire and other counties and subsequent release of TEMPRo version 7.2 in February 2017, an addendum report of the traffic modelling and forecasts was submitted to the DfT in March 2017. DfT sought clarifications on the modelling and economics and a response was submitted in July 2017. In November, 2017 the DfT announced funding of £54.5m for the scheme and development of the Full Business Case (FBC).

As part of the FBC submission, DfT recommended further tests are reported:

- To demonstrate the impacts of changes to webTAG databook (May 2018 at the time of analysis undertaken) since the OBC ('Forthcoming changes to webTAG values November 2016 released in July 2016);
- To see the iImpact of long term extrapolation of benefits; and
- To see changes to the Road Traffic Forecasts (2018) on freight growth.

These tests are reported in Section 3.6.8. Since the submission of the OBC in January 2017, the assumptions for the Central Case (Section 3.5 of OBC) has been superseded. The FBC reports on the Core scenario forecasts constrained to TEMPro v7.2 and the high and low growth sensitivity tests as reported in the addendum to the OBC submitted in March 2017; and further sensitivity tests outlined above.

3.3 Transport modelling methodology overview

The transport modelling work undertaken to support this Business Case has primarily been undertaken using the 2014 Worcester Transport Model (WTM). WTM is a detailed travel demand model using EMME4 software, linked to a highway assignment model developed in SATURN and public transport assignment model also in EMME4. The demand model is an incremental multinomial logit model that uses the base year trip costs and forecasts reference trip patterns assuming no change in travel costs. It then pivots travel costs off the base year to generate forecast demand based on future network changes to:

- Values of Time (VoT) due to income changes;
- forecast fuel costs;
- car fuel efficiency; and
- increasing network congestion.

The model is based primarily on data collected in October 2014 and where data comes from another year or month it has been normalised using seasonal factors from long term traffic count data to create a base year model representing October 2014 conditions. Three time periods were developed:

- AM peak hour (8.00-9.00am);
- Inter-peak hour (average hour between 10.00am - 4.00pm); and
- PM peak hour (5.00-6.00pm).

The hours represent the peak hours for highway traffic on an average weekday in a neutral month.

It is recognised that the nature of this scheme is such that a multi-modal model approach is not strictly necessary. However, the model structure is such that the demand forecasting process is integrated into the WTM complete assignment process meaning that to run the model as a standalone highway model is not possible without changes to the model structure.

3.3.1 WTM model scenarios

The transport modelling work to assess the scheme has been undertaken using the Worcester Transport Model. The scheme has been considered as a With Scheme (WS) scenario and results compared against a Without Scheme (WoS) scenario.

The forecast growth in travel demand is based on a combination of the housing and employment allocations as determined by the adopted South Worcestershire Development Plan (SWDP), which also contained information on completions and existing commitments, and also by comparison to NTEM (TEMPRo v7.2) growth. Only the developments identified as 'near certain' or 'more than likely' have been included in the 'core' development scenario. In addition, many developments identified in the SWDP have had planning applications submitted and approved, under construction or built-out since the model base year (2014). These developments too are included in forecasting the reference case demand.

In addition, in line with webTAG guidance unit M4- Forecasting and Uncertainty, sensitivity tests undertaken for **Low growth** and **High growth** scenarios around the Core Scenario as detailed in Appendix I – Traffic Forecasting Report. The high/low growth scenarios are created by applying % changes to core scenario converged matrices as per Section 4.2 of webTAG unit M4- Forecasting and Uncertainty. The change is calculated as follows:

- +/-2.5% x the square root of the number of years from the base year, for highway matrices;
- the required matrix adjustment is determined by applying the calculated % change to the base observed matrices and adding to / subtracting from the forecast matrices and the model re-run to convergence.

Growth rates from the forecasts DfT provided in October 2016 were used to constrain the 'Core' scenario to NTEM (TEMPro v7.2) growth rates at district level within South Worcestershire as well as Local authority levels. All other model areas adopted TEMPRo v7.2 growth factors.

In addition to the 2014 base year model, the following model scenarios were developed for the Core Scenario and low and high growth sensitivity tests:

- 2021 WoS Scenario (AM, IP and PM peaks);
- 2021 WS Scenario (AM, IP and PM peaks);
- 2031 WoS Scenario (AM, IP and PM peaks);
- 2031 WS Scenario (AM, IP and PM peaks).

The above tests were reported in the addendum to the OBC submitted in March 2017. The additional sensitivity tests requested by DfT to understand the impact of changes in guidance on the modelled results comprise of:

- 2031 WS scenario (AM, IP and PM peak) to test impact of May 2018 webTAG tables;
- 2038 WoS and WS scenarios (AM, IP and PM peaks) forecasts to assess long term extrapolation of benefits; and
- 2031 WoS and WS scenario (AM, IP and PM) to assess impact of 2018 Road Traffic Forecasts.

3.3.2 WTM reporting

The WTM development is reported in the following supplementary documents:

- WTM 2014 – Report of Surveys;

- WTM 2014 – Highway Local Model Validation Report;
- WTM 2014 – Public Transport Local Model Validation Report; and
- WTM 2014 – Demand Model Report.

Appendix I contains A4440 Worcester Southern Link Road Improvements Phase 4 Forecasting Report.

3.4 Network Changes

The WoS scenario elements are detailed below for both the highway and public transport networks. The WoS scenario schemes have been identified based on various schemes identified in line with webTAG Uncertainty guidelines with only 'Near Certain' or 'More than Likely' schemes included in the WoS scenario. The Highway and PT network improvement schemes identified below are included in both 2021 and 2031 forecast years.

3.4.1 WoS Highway Network

3.4.1.1 Multi-Modal Corridor Improvements

- Route 1 - B4204 Martley Road/A443 Henwick Road/Hylton Road - from Lower Broadheath to Tybridge Street gyratory;
- Route 3 - A449 Malvern Road/Bromwich Road – from South of Old Malvern Road, Powick to New Road Island;
- Route 4 - A38 Worcester Road/Bath Road/Commandery Road – from Broomhall Lane to Sidbury;
- Route 4b - Norton Road, including the Norton Road pedestrian/cycle link – from St Peter's Drive to Bath Road;
- Route 8 - Woodgreen Drive/Middle Hollow Drive/Tolladine Road/Lowesmoor;
- Route 9 - A449 Ombersley Road - Claines Roundabout to A38 Droitwich Road junction;
- Route 7a - B4550 Astwood Road/Rainbow Hill/Lowesmoor – B4482 Bilford Road to Pheasant Street.

3.4.1.2 Highway Improvements

- New signalised junction on A44 London Road (Waitrose);
- Highway alterations on A44 Worcester (Cathedral Square);
- Cornmarket scheme;
- Tolladine Road/Middle Hollow Drive;
- Tolladine Road/Woodgreen Drive;
- New roundabout on Blackpole Road;
- Dualling of Southern Link Road between Whittington and Ketch;
- Ketch Roundabout improvements;
- Norton Roundabout improvements;
- New Roundabout on A4538 (Worcester 6);
- A4538/B4636 Plough Road Roundabout improvements;
- M5 J6-J4a Smart motorway scheme improvements;
- M5 Junction 5 improvements;
- M5 Junction 6 improvements;
- M5 Junction 7 signalisation;
- A44 London Road junction with Spetchley Road;
- New roundabout on B4636 Newtown Road to serve potential development;
- Alterations to existing roundabout on B4636 by the hospital site;
- Alterations to Newton Road/Grange Way Roundabout on A4440;
- New roundabout on A44 to facilitate the West of Worcester Development; and
- Traffic signal priority for buses at
    - Newtown Road / Midland Road / Sherriff Street;

- Newtown Road / Canterbury Road (W);
- Newtown Road / Canterbury Road (E).

3.4.1.3 Rail Station Improvements

- Inclusion of Worcestershire Parkway station and associated access junction.

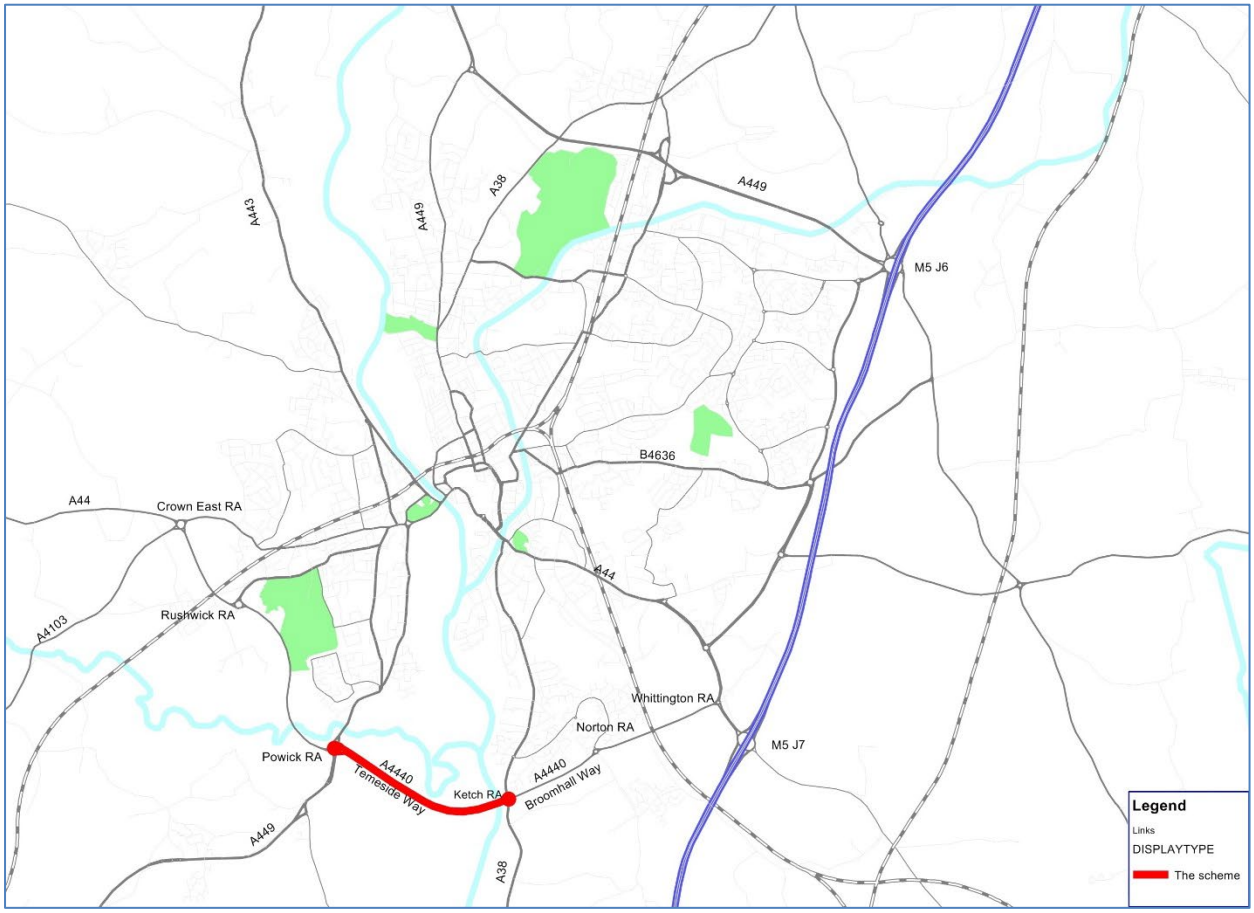
3.4.2 WS Transport Network

Worcester city is bifurcated by the River Severn flowing from north to south. There are only two River crossings, one in the city centre and another on the SLR. As a result, the SLR has been identified as a key route for improvement due to the high level of congestion and poor journey time reliability it currently experiences and the links it provides to employment centres. The following improvements are proposed as part of Phase 4 of the SLR dualling:

- Improvements to Powick and Ketch Roundabouts including widening approach lanes and circulatory lanes to provide additional capacity; and
- Dualling of the SLR between Powick and Ketch roundabout.

The scheme location (highlighted in 'red' in ***Figure 3-1***) is expected to alleviate congestion and increase journey time reliability thereby increasing the attractiveness of Worcester, west of Worcester and the wider region for businesses.

Figure 3-1: WS Schemes



3.5 Summary of modelled scheme impacts

This section provides information about the transport modelled impacts of the scheme on the A4440 Worcester SLR and other parts of the network. Information is provided on:

- Network wide statistics;

- Link flow analysis;
- A4440 Worcester SLR Select Link Analysis; and
- Analysis of A4440 Worcester SLR future year journey times.

The analysis of the modelling work undertaken provides a summary of the main impacts of the A4440 Worcester SLR Improvements Phase 4 scheme in Worcester and the surrounding area. Information is provided to set out how the distribution of trips across the highway network changes as a result of the proposed scheme. The distribution of trips is analysed further in the form of select link analysis plots to understand the function of some of the key routes through and around Worcester City centre.

The transport modelling analysis is focussed on the 2031 forecast year for the Core scenarios. This provides a commentary on how the scheme operates with the demand arising from the full growth as well as constraining to TEMPro v7.2 up to 2031.

3.6 Core Scenario - scheme impacts

Network wide statistics are provided to understand the overall journey time and distance travelled on the highway network. Further details regarding the journey times for A4440 Worcester SLR users are also provided.

3.6.1 Network Wide Statistics

Network wide statistics from Highway Assignment model scenarios for the AM and PM peaks are presented in **Table 3.1** whilst details about the IP are presented in Appendix I.

Table 3.1 : Network wide statistics from Highway Assignment model scenarios

Description	Units	2014 Base AM	2014 Base PM	2031 Wos AM	2031 Wos PM	2031 WS AM	2031 WS PM
Transient Queues	pcu. hrs./hr.	2407	2367	2931	3137	3007	3050
Over Capacity Queues	pcu. hrs./hr.	1509	1406	3651	3849	3538	3809
Total Travel Time	pcu. hrs./hr.	15308	15207	19097	19914	19098	19872
Travel Distance	pcu. kms./hr.	805363	813203	878241	894134	886609	905672
Overall Average Speed	Kph	53	54	46	45	46	46
Total Trips Loaded	pcu/hr	81987	80911	90244	88919	90264	88945
Average Travel Time	Mins	11	11	13	13	13	13

Description	Units	2031 Wos vs Base AM	2031 Wos vs Base PM	2031 WS vs 2031 WoS AM	2031 WS vs 2031 WoS PM
Transient Queues	pcu. hrs./hr.	21.8%	32.6%	2.6%	-2.8%
Over Capacity Queues	pcu. hrs./hr.	1142.0%	173.8%	-3.1%	1.0%
Total Travel Time	pcu. hrs./hr.	24.8%	31.0%	0.0%	-0.2%
Travel Distance	pcu. kms./hr.	9.0%	10.0%	1.0%	1.3%

Description	Units	2031 Wos vs Base AM	2031 Wos vs Base PM	2031 WS vs 2031 WoS AM	2031 WS vs 2031 WoS PM
Overall Average Speed	kph	-12.5%	-16.1%	0.9%	1.6%
Total Trips Loaded	pcu/hr	10.1%	9.9%	0.0%	0.0%
Average Travel Time	mins	13.3%	19.2%	0.0%	-0.2%

Note: Over Capacity Queues occur where vehicle arrival rate is greater than the departure rate (capacity as a result of the cycle time or gap availability) resulting in one or more vehicles always being in queue. Transient queues. – are as per over capacity queues, but queue dissipates every simulation cycle – transitionary queuing

2014 Base Year Models vs 2031 WoS Models

Analysis of the Network Wide statistics extracted from the Highway Assignment model shows an increase in the number of trips of between 9.9% and 10.1% over the period between the 2014 base year and the 2031 forecast year.

The increase in the number of trips on the highway network leads to an increase in the amount of time spent queuing in transient and over-capacity queues. This in turn leads to an increase in the overall travel time in the model which increases by between 24.8% and approximately 31.0% between 2014 and 2031 in the AM and PM peaks respectively. Due to the additional delay in the 2031 forecast year models the overall average speed of vehicles in the highway model is reduced (by up to 16.7%) compared to the base year model.

The increased number of trips on the highway network compared to the 2014 base year also leads to an increase in the total distance travelled across the modelled highway network. The increase in the total distance travelled is just over 9% across the modelled peak hours.

2031 WoS Models vs 2031 WS Models

Analysis of the Network Wide statistics from the WoS and the WS scenarios shows a slight increase in the number of trips on the highway network under the WS scenario compared to the WoS scenario.

There is a marginal change in the overall number of vehicles in transient queues and over capacity queues under the WS scenario compared to the WoS scenario. The transient queues increase by 2.6% in the AM peak whilst they decrease by 2.8% in the PM peak. The over-capacity queues however decrease in both peak periods. These changes lead to a slight decrease in the overall travel time on the modelled highway network in PM peak periods with AM peak remaining almost same. Compared to the WoS scenario there is a slight increase in the overall average vehicle speed in the WS scenario during the PM peak. In line with the travel time, speed in AM remains at the same level. A review of the models show that the increase in capacity, both at Ketch and Powick along with the dualling of the link between them attracts significant volumes of traffic towards the scheme and re-routing across the network. These changes result in transient queues and over-capacity queues increasing in various parts of the model network as a result. Some of the areas they increase include Norton roundabout, Whittington roundabout, Rushwick roundabout as well as other junctions such as M5 J6, Holt Heath (A443/A4133) and Ombersley.

In the WS scenario, there is a slight increase in the total distance travelled on the modelled highway network. This can be attributed to vehicles routing via longer (but faster) distance routes to avoid congested locations in the modelled network – i.e. vehicles routing via the bypass routes (such as the A4440 Worcester SLR) to avoid congested city centre locations.

3.6.2 Forecast link flow analysis

The Highway Assignment program (SATURN) has been used to produce images of the changes in traffic flow between model scenarios. By comparing WoS and WS scenarios, this analysis usefully indicates the areas of the road network most affected by the scheme.

Figure 3-2 shows the AM peak 2031 traffic flow difference between the WoS and WS scenarios, with traffic volumes shown as band widths. Blue indicates a decrease in flow and green an increase.

Figure 3-2: 2031 - AM WS minus WoS link volumes

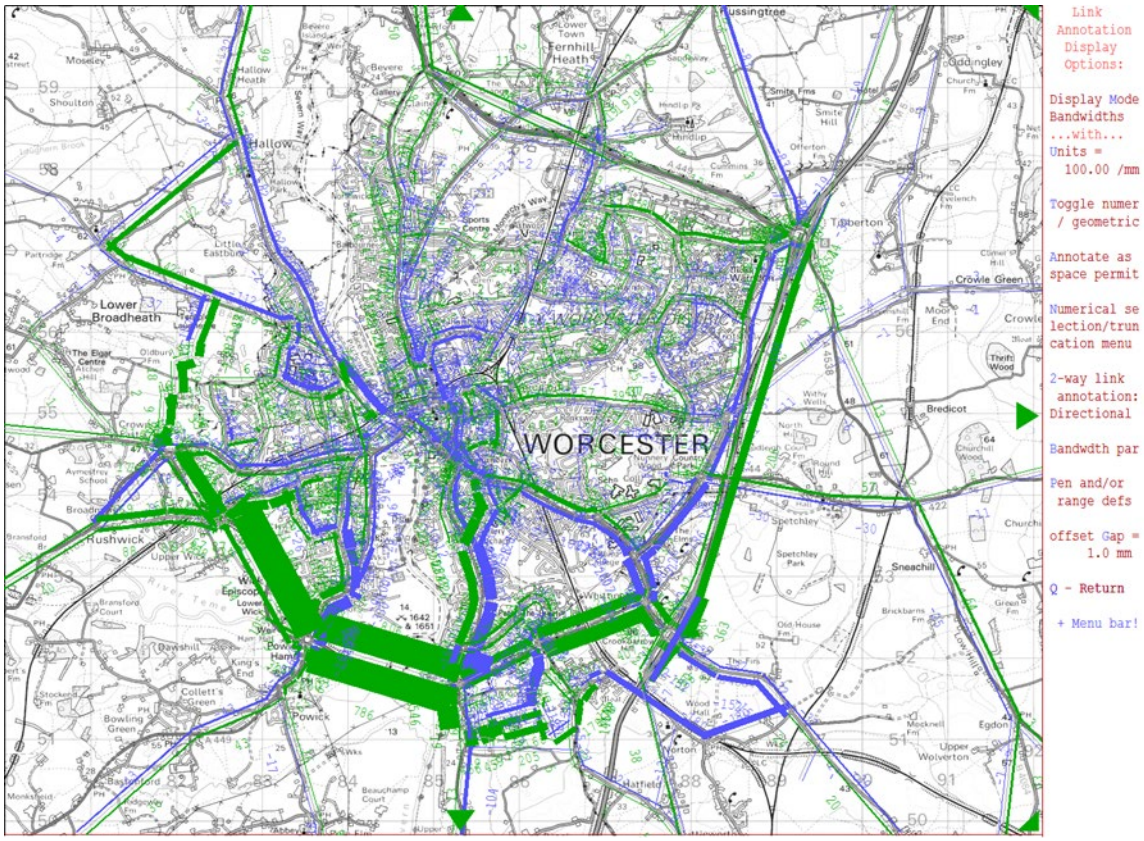


Figure 3-2 shows that, as expected, eastbound and westbound vehicle flows significantly increase on the Phase 4 section of A4440 Worcester SLR in the AM peak hour. Overall, the scheme is shown to have the desired impact in terms of maximising the use of strategic roads for strategic traffic, thereby reducing rat-running on inappropriate roads that were impacted upon as a result of the traffic growth in the area. There is generally a reduction in traffic in the city centre, thereby giving more opportunity for schemes to be implemented to encourage the use of more suitable modes as set out in the WTS.

To the east of the scheme, there is an increase in forecast traffic flows on the M5 between Junction 6 and 7, whilst traffic on the eastern bypass is forecast to reduce. To the west of the A4440 Worcester SLR Phase 4 scheme, between Powick and the A4103/A44 junction, the scheme results in an increase in flow as a result of the composition of traffic on the Powick to Ketch section changing. That is, the increase in eastbound traffic as a result of the scheme results in a reassignment of traffic from the A449 to the A4103 for traffic travelling from the south.

Within Worcester (defined as within the bypass network) the redistribution of traffic to the A4440 Worcester SLR is evident as shown by the reduction in traffic flows on the A449 between Powick Roundabout and the city centre. The model also shows that there is a general reduction of traffic in the city centre; a result of more trips being able to travel via the A4440 Worcester SLR.

Figure 3-3 shows the PM peak 2031 WoS and WS scenarios, with traffic volumes shown as band widths.

Figure 3-3: 2031 - PM WS minus WoS link volumes

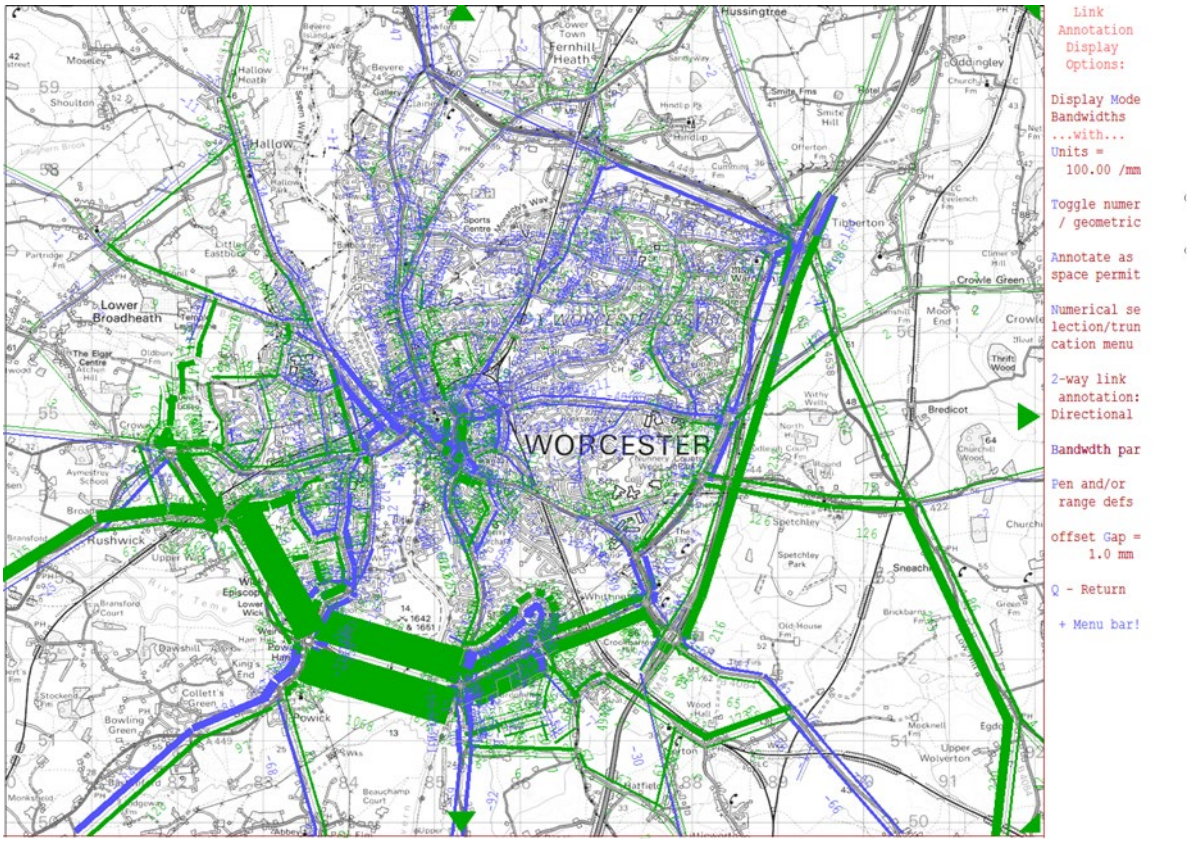


Figure 3-3 shows that, as with the AM peak hour, eastbound and westbound vehicle flows increase significantly on the section of A4440 Worcester SLR that is the scheme in the PM peak hour. To the west of Worcester there is an increase in traffic volumes on links from A44/A4103 junction as was similar in the AM peak hour.

Within Worcester (defined as within the bypass network) the scheme does have an impact in terms of traffic distribution. Modelled traffic flows show a reduction in the number of vehicles northbound on the A449 (Malvern Road) as they switch to the alternative route on the west to avoid congestion at Powick. North of Worcester city centre there is a general reduction in traffic flows on all the main corridor routes including Barbourne Road (A449), Droitwich Road (A38), Rainbow Hill (B4550) and northbound Tolladine Road (B4205). This traffic re-routes to the M5 between junction 6 and 7, and then continues on the improved A4440 Worcester SLR section. There are slight increases and decreases in traffic flows along a few local routes around the city centre.

The model also shows that there is a general reduction of traffic in the city centre; a result of more trips being able to travel via the SLR.

Due to the increased attractiveness of the scheme, the resulting changes in traffic patterns increase the traffic demand in the vicinity of the scheme. These changes could result in the need to identify additional mitigation measures on the surrounding network to ensure the strategic nature of the SLR route is maintained.

3.6.3 A4440 Worcester SLR Phase 4 'select link analysis'

The traffic movement trends as a result of the scheme improvements described in the previous section considered all traffic movements. The analysis provided below specifically identifies where the additional trips are coming from and where they are going to and any changes in these patterns between the modelled scenarios, using Select Link analysis.

In the following plots (**Figure 3-4** to **Figure 3-7**) the band widths shown have been kept to a consistent scale, thus changes in width are a result of changes in volume.

Figure 3-4: 2031 - AM WoS Southern Link Road (EB) – Select Link Analysis

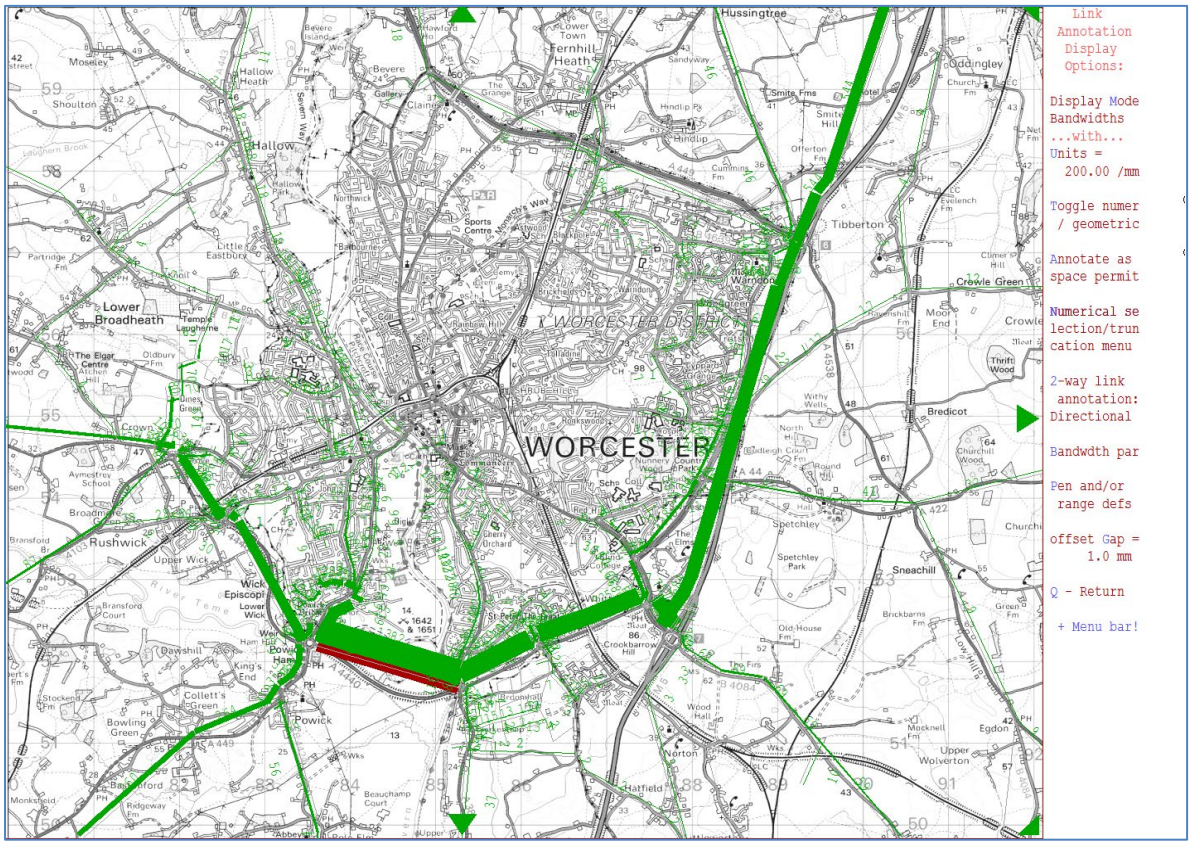
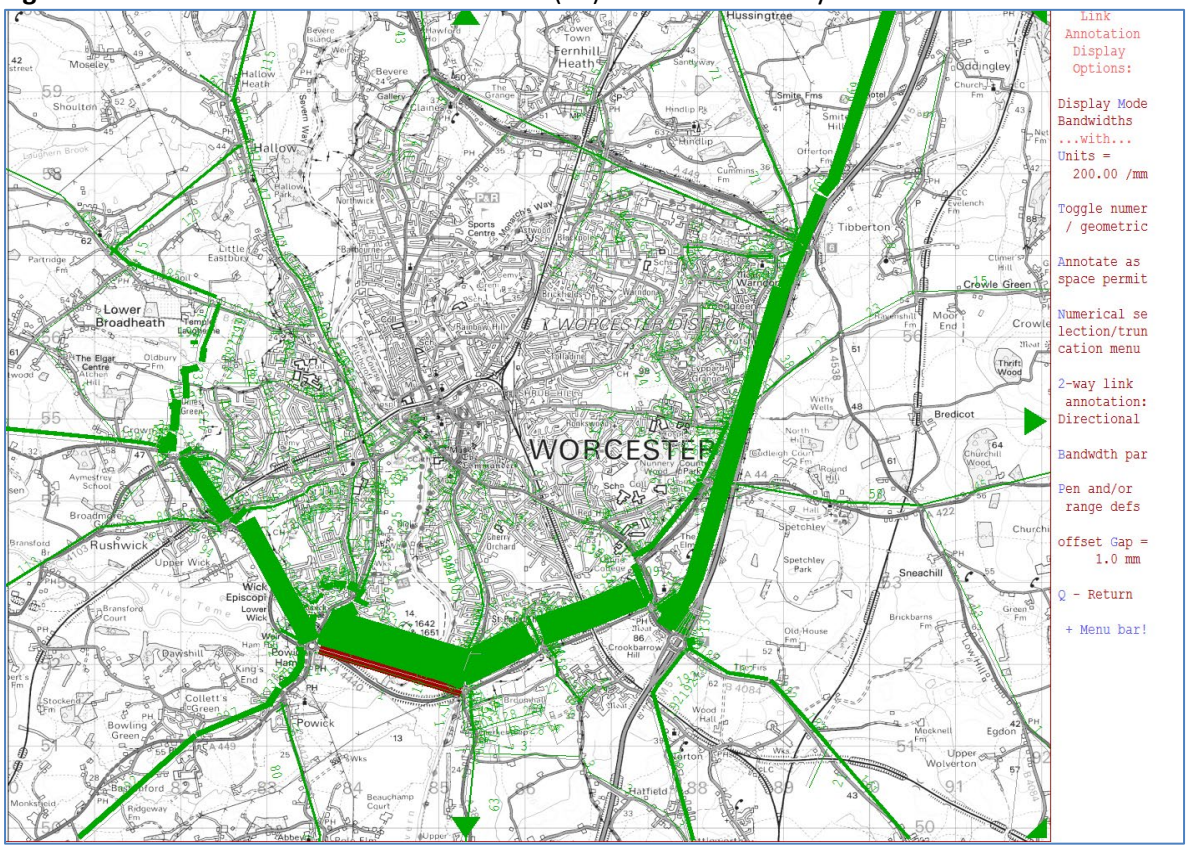


Figure 3-5: 2031 - AM WS Southern Link Road (EB) – Select Link Analysis



The routeing pattern of trips using the Worcester Southern Link Road under the WS scenario shows trips route to the section via similar routes. There is an increase in the number of trips routeing from the A449 (south west of Worcester), the A38 (and (Worcester Road, south of Worcester) and the A449 (Malvern Road) west of Worcester city centre, A44 Bromyard Road and Bransford Road. Also, the A4440 Worcester

SLR is accommodating a large proportion of more local trips that are currently rat-running on local roads to avoid the congested A4440 Worcester SLR.

The destination of trips using the eastbound Worcester Southern Link Road in the AM peak period is predominantly similar in the WoS and WS scenarios. The main trips destinations under both scenarios are:

- Worcester Eastern bypass (A4440);
- M5;
- A4538 / A38 towards Droitwich;
- B4636;
- A44; and
- Whittington Road towards Pershore.

Figure 3-6: AM WoS Southern Link Road (WB) – Select Link Analysis

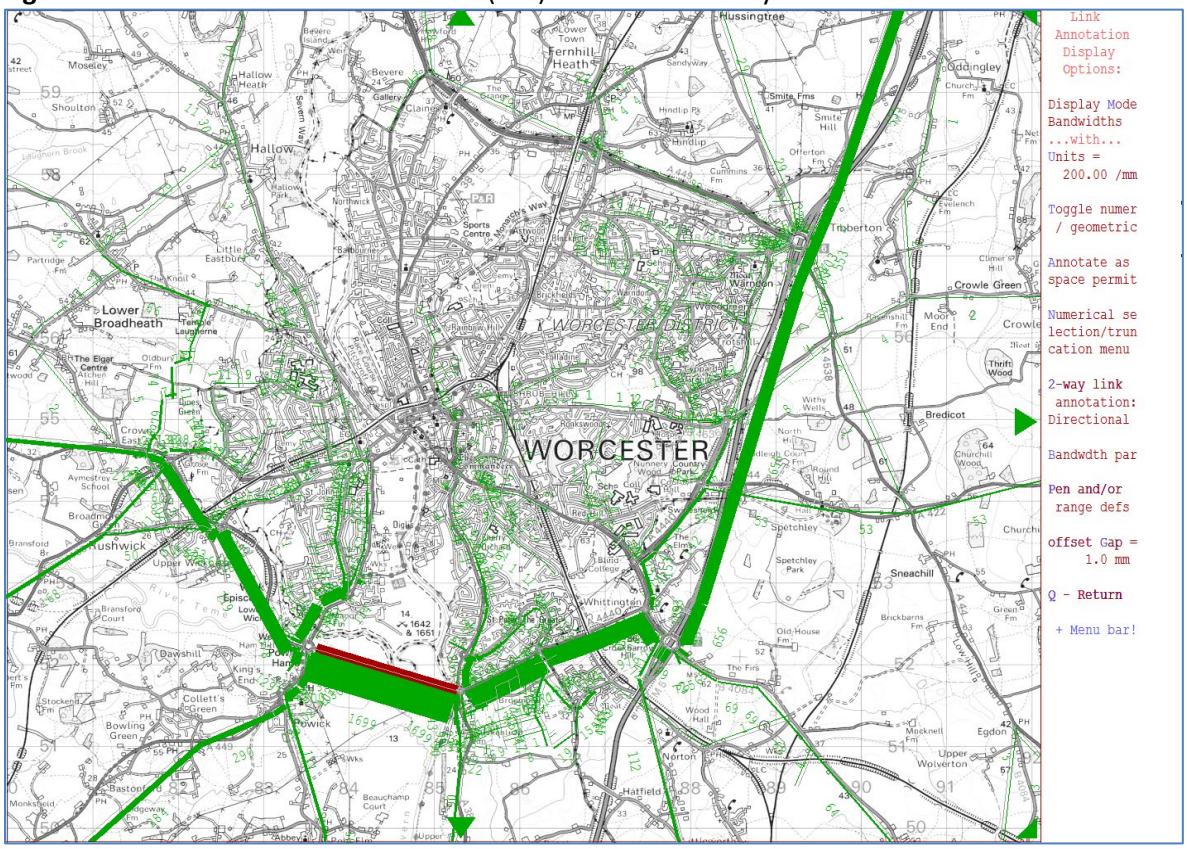
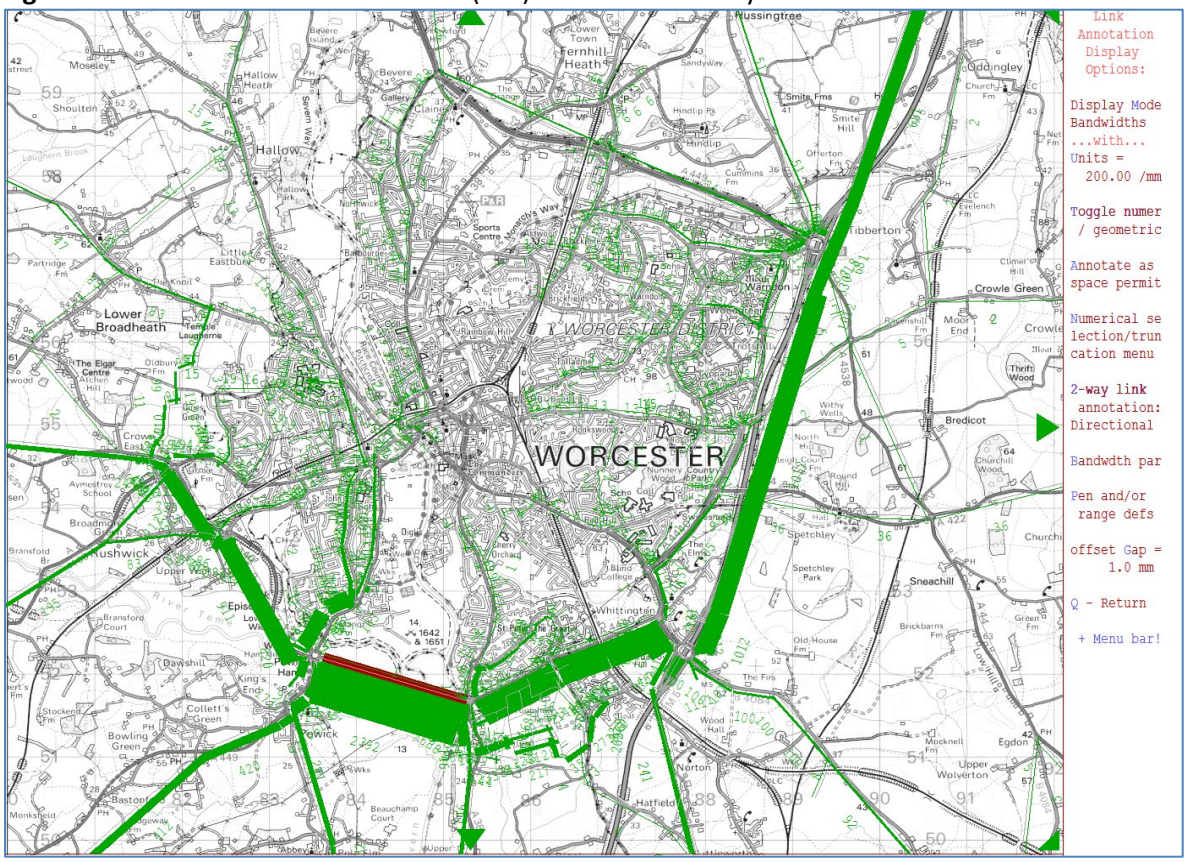


Figure 3-7: AM WS Southern Link Road (WB) – Select Link Analysis



The predominant trip origins of vehicles using the route are as follows:

- Worcester Eastern bypass (A4440);
- M5;
- A4538 / A38 from Droitwich;
- A38 (Worcester Road, south of Worcester);
- A44; and
- Whittington Road towards Pershore.

The destination of trips using the selected link is also modelled to be relatively similar between scenarios. Destinations under both scenarios are as follows:

- Worcester City Centre (via A449 – Malvern Road);
- A449 Malvern Road (south west of Worcester);
- A4103; and
- A44.

The destination of trips using the selected link is also shown to be relatively similar between scenarios.

3.6.4 Traffic flow and link capacity assessments

Traffic flows on the scheme link extracted from the model for the base year and 2031 are shown in **Table 3.2**.

Table 3.2: AM and PM Traffic Flows 2014 and 2031

	2014 AM	**2014 PM**	**2031 WoS AM**	**2031 WoS PM**	**2031 WS AM**	**2031 WS PM**
Powick to Ketch	896	1207	1383	1398	2189	2326
Ketch to Powick	1580	1600	1754	1800	2540	2868

Abs Difference

	WoS vs Base		**WS vs Base**		**WS vs WoS**	
Powick to Ketch	487	191	1293	1119	806	928
Ketch to Powick	174	200	960	1268	786	1068

% Difference

	WoS vs Base		**WS vs Base**		**WS vs WoS**	
Powick to Ketch	54%	16%	144%	93%	58%	66%
Ketch to Powick	11%	13%	61%	79%	45%	59%

Table 3.2 indicates that without the improvement scheme traffic flows increase by 13%-54% from the 2014 base year to the 2031 forecast year. This increase is primarily as a result of the SLR Phase-3 improvements that provide additional capacity between Ketch and Whittington junctions. With the scheme in place, however, the additional capacity allows for significant traffic growth of between 61% and 144% from the base year to 2031 forecast year. Compared to the WoS scenario, traffic growth in 2031 under the WS scenario ranges between 45% and 66% percent with the eastbound flows showing higher growth than the westbound flows. This additional capacity will help accommodate the growth in predicted traffic.

In addition, the SATURN highway model has been used to assess the performance of the scheme in terms of comparing the volume of traffic to the capacity of the road link between Powick and Ketch roundabouts. As the volume/capacity ratio shown by SATURN approaches 100% the performance of the section of network where the ratio approaches 100% can deteriorate when the highest peak flow is encountered, though the occurrence of performance issues can only be established through more detailed assessment of junction operation as SATURN averages network performance over an hour time period. **Table 3.3** shows the volume-capacity ratios for the base and 2031 model performance.

Table 3.3 : Volume/capacity Ratios (%) for the Powick to Ketch SLR section.

	2014 AM	2014 PM	2031 WoS AM	2031 WoS PM	2031 WS AM	2031 WS PM
Powick to Ketch	120	112	116	118	104	65
Ketch to Powick	88	89	97	100	71	80

Abs Difference

	WoS vs Base		WS vs WoS	
Powick to Ketch	-4	6	-12	-53
Ketch to Powick	9	11	-26	-20

% Difference

	WoS vs Base		WS vs WoS	
Powick to Ketch	**-3%**	**5%**	**-10%**	**-45%**
Ketch to Powick	**10%**	**12%**	**-27%**	**-20%**

In line with results earlier in the assessment the results indicate that the Powick to Ketch section of the SLR is shown to be under pressure currently which worsens up to the forecast year of 2031 such that the v/c ratio under WoS scenario is in the range 97%-118%.

With the implementation of the scheme, the V/C ratio under the WS scenario falls significantly to levels between 65% and 80% in all time periods except 2031 AM. In the 2031 AM peak hour the section between Powick and Ketch is forecast to experience a volume/capacity ratio over 100% in the eastbound direction, as a result of the Ketch roundabout junction operating at capacity.

3.6.5 Analysis of Worcester Southern Link Road Journey Times

In order to understand the impact of the scheme to the vehicles using the A4440 Worcester SLR, modelled journey times have been extracted. **Table 3.4** shows the difference in the time taken to travel along the A4440 Worcester SLR corridor between A44/A4103 junction in the west and Whittington junction in the east during the modelled peak periods.

Table 3.4 : Highway Assignment Model SLR Forecast Journey Times (minutes)

	2014 AM	2014 PM	2031 WoS AM	2031 WoS PM	2031 WS AM	2031 WS PM
SLR Eastbound	16.3	21.0	16.3	15.9	10.8	7.5
SLR Westbound	9.5	14.0	11.2	14.5	7.2	8.9

Abs Difference

	WoS vs Base		WS vs WoS	
SLR Eastbound	0.0	-5.1	-5.6	-8.4
SLR Westbound	1.7	0.5	-3.9	-5.7

% Difference

	WoS vs Base		WS vs WoS	
SLR Eastbound	0%	-24%	-34%	-53%
SLR Westbound	17%	4%	-35%	-39%

The modelled journey times on the A4440 Worcester SLR show the journey time benefits on the route as a result of the scheme when compared to the WoS.

The most significant impact in terms of journey time improvements is shown west to east in the PM peak period. This is as a result of the SLR-Phase 3 improvements. However, in the westbound direction, travel times in the Without Scheme scenario increase by 1.6 minutes. This is due to the increase in capacity from Phase 3 improvements meaning more traffic is able to pass from Whittington Roundabout to Ketch roundabout, and is thus then constrained by the single carriageway section to the west of the Ketch Roundabout, before traffic volumes split onto the routes to Malvern and West Worcester at Powick Roundabout.

The modelled time taken to travel from A44/A4103 Roundabout in the west to Whittington Roundabout in the east during the AM peak 2031 Without Scheme forecast year scenario is 16.3 minutes. Under the 2031 With Scheme scenario the modelled time taken to travel the same route is 10.8 minutes, thereby showing a journey time saving of 5.6 minutes (a 34% decrease) compared to the 2031 Without Scheme scenario.

The modelled time taken to travel westbound from Whittington to A44/A4103 Roundabout during the AM peak 2031 Without Scheme forecast year scenario is 11.2 minutes. Under the 2031 With Scheme scenario the modelled time taken to travel the same route is 7.2 minutes, thereby showing a journey time saving of 3.9 minutes (a 35% decrease) compared to the 2031 Without Scheme scenario.

Travel times between A44/A4103 and Whittington junction in the PM peak under the With Scheme scenario provide similar savings in both directions. Travel times in the eastbound direction drop from 15.9 minutes in the Without Scheme to 7.5 minutes (a 53% decrease) in the With Scheme scenario. Similarly, in the westbound direction, they drop from 14.5 minutes in the Without Scheme to 8.9 minutes (a 39% decrease) in the With Scheme scenario.

In all cases, it is significant that the forecast journey times in 2031 are all lower than the respective base year observed journey times in 2014. This represents a major improvement in overall journey time, a reduction in variability and a significant increase in reliability despite the growth in traffic demand of over 10% across the model network, and an increase range of 61% to 144% in the section between Powick and Ketch roundabouts.

3.6.6 Public transport impacts

The public transport network performance has also been reviewed from a network wide perspective under the WS scenario. **Table 3.5** contains the summary network statistics.
The table indicates that in the WoS scenario there is a significant decrease in the total number of bus boarding passengers in 2031 compared to the base year in line with the TEMPro v7.0 forecast reduction in PT growth. Under the WoS scenario, highway improvement measures and other public transport measures such as signal priority help average journey times to reduce in 2031.

The scheme is seen to decrease the total number of bus passengers by up to 0.3% in 2031 compared to the WoS scenario. The average journey time per passenger remains similar to WoS conditions.

Table 3.5 : Public Transport- Summary Statistics – 2031

Metric	2014		2031 WoS		2031 WS	
	AM	PM	AM	PM	AM	PM
Bus						
Total Number of Boarding Passengers	1548	1692	1272	1352	1271	1351
Average Journey Time per Passenger (hours)	0.27	0.25	0.24	0.23	0.24	0.23
Total Passenger kilometres	11115	10950	7880	8277	7874	8270
Rail						
Total Number of Boarding Passengers	1082	530	901	436	901	435
Average Journey Time per Passenger (hours)	0.66	0.83	0.65	0.82	0.65	0.82
Total Passenger kilometres	42766	26447	35230	21397	35183	21356

Metric	2031 WoS vs 2014		2031 WS vs 2031 WoS	
	AM	PM	AM	PM
Bus				
Total Number of Boarding Passengers	-17.8%	-20.1%	-0.1%	-0.1%
Average Journey Time per Passenger	-12.8%	-6.9%	0.0%	0.0%
Total Passenger kilometres	-29.1%	-24.4%	-0.1%	-0.1%
Rail				
Total Number of Boarding Passengers	-16.7%	-17.7%	0.0%	-0.2%
Average Journey Time per Passenger	-0.9%	-1.1%	-0.1%	0.0%
Total Passenger kilometres	-17.6%	-19.1%	-0.1%	-0.2%

3.6.7 Sensitivity tests – High and Low Growth

In addition to the Core Scenario, further sensitivity tests were undertaken on the highway network to determine the robustness of the core scenario. The additional tests undertaken were low growth and high growth demand in line webTAG guidance to account for uncertainty in NTEM forecasts.

The high/low growth scenarios are created by applying % changes to core scenario converged matrices as per Section 4.2 of webTAG unit M4- Forecasting and Uncertainty. The change is calculated as follows:

- +/-2.5% x the square root of the number of years from the base year, for highway matrices;
- the required matrix adjustment is determined by applying the calculated % change to the base observed matrices and adding to / subtracting from the forecast matrices and the model re-run to convergence.

As would be expected, the low growth scenario tends to decrease the level of trip making and the high growth increases the levels of trip making. The results show a general symmetry when comparing the High and Low outturn trip levels due to the symmetric growth assumptions employed. In 2021, the change in trip levels vary between -6.2% under low growth and 6.5% under high growth compared to the core scenario. The corresponding range in 2031 is between -8.9% under low growth and 9.5% under high growth.

The resulting patterns whilst more similar for the vehicle-kilometre growth, varies for the total travel time and overall network speeds due to increased congestion under high growth scenario. Under the high growth scenario, the change in total travel time (increase) and average network speeds (decrease) are generally greater than the corresponding change under the low growth scenario. In 2031, for a 9% reduction in demand, the total travel time reduces between 13.3% and 18.4% under low growth, but for a similar increase in demand under high growth, the total travel times increase between 15.1% and 19.5%. Comparison tables of Highway network performance statistics of the low and high growth scenarios against the core scenario are given in **Table 3.6** and **Table 3.7**.

Table 3.6: Summary Highway Network Performance- WoS and WS- Low Growth Vs Core Scenario – 2031

Scenario	Parameter	Unit	2031 WoS AM	2031 WoS PM	2031 WS AM	2031 WS PM
Core	**Total Travel Time**	pcu. hrs./hr.	19097	19914	19098	19872
	Travel Distance	pcu. kms./hr.	878241	894134	886609	905672
	Overall Average Speed	kph	46	45	46	46
Low Growth	**Total Travel Time**	pcu. hrs./hr.	15957	16248	16011	16406
	Travel Distance	pcu. kms./hr.	841472	864341	848194	874686
	Overall Average Speed	kph	53	53	53	53
% Diff	**Total Travel Time**		-16.4%	-18.4%	-16.2%	-17.4%
	Travel Distance		-4.2%	-3.3%	-4.3%	-3.4%
	Overall Average Speed		14.6%	18.5	14.2%	16.9%

Table 3.7: Summary Highway Network Performance- WoS and WS- High Growth Vs Core Scenario – 2031

Scenario	Parameter	Unit	2031 WoS AM	2031 WoS PM	2031 WS AM	2031 WS PM
Core	**Total Travel Time**	pcu. hrs./hr.	19097	19914	19098	19872
	Travel Distance	pcu. kms./hr.	878241	894134	886609	905672
	Overall Average Speed	kph	46	45	46	46
High Growth	**Total Travel Time**	pcu. hrs./hr.	22658	22922	22824	23312
	Travel Distance	pcu. kms./hr.	914695	941419	924113	957058
	Overall Average Speed	kph	40	41	41	41
% Diff	**Total Travel Time**		18.6%	15.1%	19.5%	17.3%
	Travel Distance		4.2%	5.3%	4.2%	5.7%
	Overall Average Speed		-12.2%	-8.5%	-12.7%	-9.9%

3.6.8 Additional Sensitivity Tests

In addition to the WS scheme evaluated as part of the forecasting process, further sensitivity tests were undertaken on the highway network to determine the robustness of the core scenario. The additional tests undertaken were identified, through current guidance as follows:

- Impact of the May 2018 webTAG Data book values on VoT and VOC;
- Long term extrapolation of benefits over appraisal period based on Section 2.4 of webTAG unit A1.1 Cost-Benefit Analysis (May 2018); and
- Impact of 2018 Road Traffic Forecasts data.

3.6.8.1 Impact of May 2018 webTAG Data book values

In May 2018, webTAG data book was updated by the DfT. As part of the FBC, DfT requested a sensitivity test be undertaken to assess the impact of the webTAG values on the traffic forecasts. Accordingly, JACOBS (legacy CH2M) undertook a sensitivity test considering the VoT and VOC values based on May 2018 Data Book. The test was undertaken only for 2031 WS scenario and compared against the previous 2031 WS scenario which was based on '*TAG data book- forthcoming change, November 2016'* released in July 2016. The **Table 3.8** shows the vehicle values of time and distance in terms of pence per minute (PPM) and pence per kilometre (PPK).

Table 3.8 : Vehicle Values of Time 2014 prices (pence per minute/km)

Purpose	July 16 PPM	July 16 PPK	May 18 PPM	May 18 PPK
HBW/HBO	27.11	6.76	25.28	7.01
EMP	48.45	11.97	45.19	11.98
HGV	32.89	48.80	30.67	48.47

The table shows that the VoT for the various purposes have declined slightly but VOC are similar to previous webTAG values for all user classes.

Table 3.9 : Public Transport Values of Time 2014 prices (person pence/min)

Purpose	July 16 Bus	July 16 Rail	May 18 Bus	May 18 Rail
HBW	25.05	25.05	23.41	23.41
HBO	11.43	11.43	10.69	10.69
EMP	21.2	61.7	19.81	57.67

The **Table 3.9** shows that VoT for PT modes follows a similar pattern to private vehicles with slight decline across all purposes since the 2016 release.

The 2031 with Scheme demand model was rerun with the new cost. It shows very little impact on Highway and PT network performance. Following tables show the performance comparison between the old and the new cost.

Table 3.10: Highway Network Summary Statistics Comparison

Description	Units	2031 (July 2016) AM	2031 (July 2016) PM	2031 (May 2018) AM	2031 (May 2018) PM
Transient Queues	pcu. hrs./hr.	3007	3050	2990	3061
Over-capacity Queues	pcu. hrs./hr.	3538	3809	3563	3819
Total Travel Time	pcu. hrs./hr.	19098	19872	19086	19875
Travel Distance	pcu. kms./hr.	886609	905672	885400	904725
Overall Average Speed	Kph	47	46	46	46
Total Trips Loaded	Pcu/hr	90264	88945	90279	88967
Average Travel Time	Mins	13	13	13	13

Description	Units	July 2016 vs May 2018 AM	July 2016 vs May 2018 PM
Transient Queues	pcu. hrs./hr.	-0.6%	0.4%
Over-capacity Queues	pcu. hrs./hr.	0.7%	0.3%
Total Travel Time	pcu. hrs./hr.	-0.1%	0.0%
Travel Distance	pcu. kms./hr.	-0.1%	-0.1%
Overall Average Speed	Kph	-0.4%	-0.2%
Total Trips Loaded	Pcu/hr	0.0%	0.0%
Average Travel Time	Mins	-0.1%	0.0%

Table 3.10 shows that the impact of the May 2018 VoT and VOC values on the WTM highway network is negligible with the various network statistics showing minimal variations compared to the core scenario forecasts. There are slight increases in over capacity queues and total travel time during the peaks due to the decrease in VoT making urban routes get more attractive. In line with the findings **Figure *3-8*** shows the insignificant flow differences in all peaks due to changes in generalised cost. The plots show link flows on the longer and faster routes reduce slightly due to the reduction in VoTs. Urban routes characterized by lower speeds are shown to experience slight increases in flow as a result.

Figure 3-8: Actual Flow Difference Plots (AM,IP,PM) for 2031 WS between July 2016 and May 2018 Generalised Cost

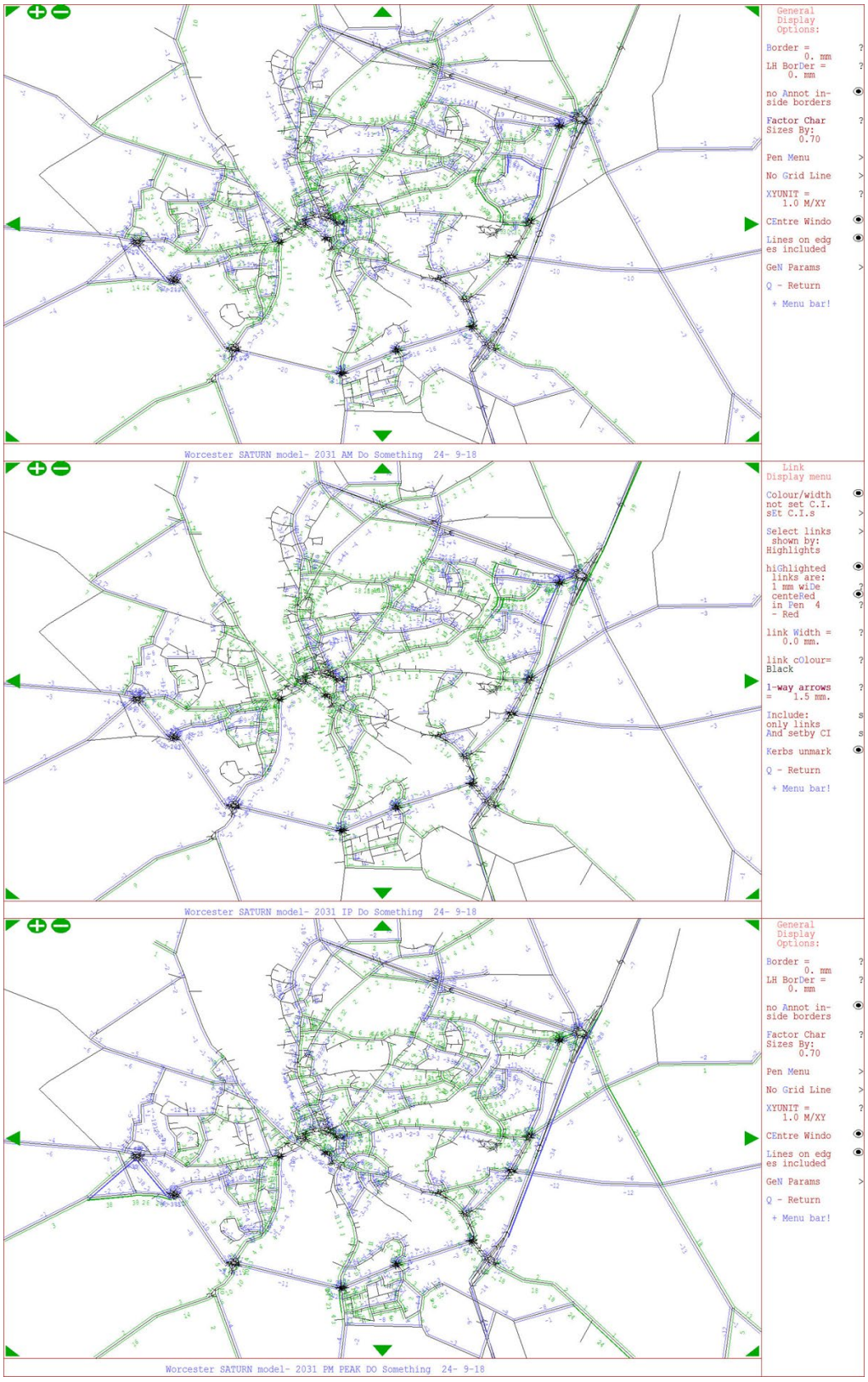


Table 3.11 compares the summary statistics for public transport trips due to the changes in webTAG data values. It shows a slight reduction (2.9% to 3.4%) in the total number of boarding passengers across all time periods with average journey times per passenger remaining comparable. The impact of new VoT and VOC are negligible.

Table 3.11 : Public Transport Network Summary Statistics Comparison

Metric	2031 (July 2016) AM	2031 (July 2016) PM	2031 (May 2018 AM	2031 (May 2018) PM
Total Number of Boarding Passengers	1271	1351	1229	1312
Average Journey Time per Passenger (hours)	0.24	0.23	0.23	0.23
Total Passenger kilometres	7874	8270	7529	8014
Average Operating Speed of Buses (kph)	35.9	37.2	35.9	37.2

Metric	July 2016 vs May 2018 AM	July 2016 vs May 2018 PM
Total Number of Boarding Passengers	-3.3%	-2.9%
Average Journey Time per Passenger (hours)	-4.2%	0.0%
Total Passenger kilometres	-4.4%	-3.1%
Average Operating Speed of Buses (kph)	0.0%	0.0%

3.6.8.2 Long term extrapolation of benefits – 2038 forecasts

DfT published new guidelines on Cost Benefit Analysis in May 2018 that includes a new section on assessing longer term benefit in the horizon of 20 years from scheme appraisal year. For this Full Business Case, the scheme appraisal year is 2018. A 2038 forecast model was therefore developed to assess the long-term benefits of the scheme.

The model forecasts for 2021 and 2031 were based on the adopted South Worcestershire Development Plan (2016-2031) and constrained to TEMPro v7.2 forecasts. The 2038 forecasts were based on growth factors from TEMPro v7.2 for the period 2031 to 2038 for light vehicles and the 2015 NTM forecasts for heavy vehicles. The 2038 forecast demand was assigned to both WoS and WS scenarios and outputs extracted for highway network performance and public transport network summary statistics.

Table 3.12 : 2038 Highway Network Summary Statistics

Description	Units	2014 Base AM	2014 Base PM	2038 WoS AM	2038 WoS PM	2038 WS AM	2038 WS PM
Transient Queues	pcu. hrs./hr.	2407	2367	3149	3361	3265	3307
Over-capacity Queues	pcu. hrs./hr.	1509	1406	4315	4536	4221	4512
Total Travel Time	pcu. hrs./hr.	15308	15207	20396	31314	20487	21325
Travel Distance	pcu. kms./hr.	805363	813203	898017	915912	908109	927168
Overall Average Speed	Kph	53	54	44	43	44	44
Total Trips Loaded	Pcu/hr	81987	80911	93808	92447	93818	92479
Average Travel Time	Mins	11	11	13	20	13	14

Description	Units	2038 WoS vs Base AM	2038 Wos vs Base PM	2038 WS vs WoS AM	2038 WS vs WoS PM
Transient Queues	pcu. hrs./hr.	30.8%	42.0%	3.7%	-1.6%
Over-capacity Queues	pcu. hrs./hr.	186.0%	222.6%	-2.2%	-0.5%
Total Travel Time	pcu. hrs./hr.	33.2%	105.9%	0.4%	-31.9%
Travel Distance	pcu. kms./hr.	11.5%	12.6%	1.1%	1.2%
Overall Average Speed	Kph	-17.0%	-20.4%	0.7%	1.2%
Total Trips Loaded	Pcu/hr	14.4%	14.3%	0.0%	0.0%
Average Travel Time	Mins	18.2%	84.5%	0.8%	-32.0%

Table 3.12 shows that transient queue in WS scenario increases in AM peak but decreases in PM peak while compared to WoS scenario. Overcapacity queue decreases in both peaks. The overall speed also increases in WS scenario in all peak periods.

Table 3.13 : 2038 Public Transport Network (Bus) Summary Statistics

Metric	2038 WoS AM	2038 WoS PM	2031 WS AM	2031 WS PM
Total Number of Boarding Passengers	1132	1218	1132	1217
Average Journey Time per Passenger (hours)	0.23	0.23	0.23	0.23
Total Passenger kilometres	6793	7382	6788	7377
Average Operating Speed of Buses (kph)	36.0	37.1	36.0	37.0

Metric	2038 WoS vs WS AM	2038 WoS vs WS PM
Total Number of Boarding Passengers	0.0%	-0.1%
Average Journey Time per Passenger (hours)	0.4%	0.9%
Total Passenger kilometres	-0.1%	-0.1%
Average Operating Speed of Buses (kph)	0.0%	0.0%

From **Table 3.13** it also can be concluded that the impact of scheme on bus network in 2038 is negligible.

3.6.8.3 Impact of 2018 Road Traffic Forecasts

The Road Traffic Forecast 2018 from the National Traffic Model (NTM) was released in September 2018. A sensitivity test was undertaken to understand the impact of new traffic forecast. The test utilised the previous 2031 with scheme and without scheme scenario by replacing the HGV demand with the 2018 forecasts. The previous RTF forecast indicated that goods vehicle traffic is estimated to grow by between 6.6 % and 16.8% by 2021 and 2031 respectively. The 2018 NTM reveals that the HGV forecast is predicted to grow by between -0.63 % and 0.30% by 2021 and 2031 respectively in the model area. The test was undertaken only for 2031 scenario and the results presented in **Table 3.14** and **Table 3.15**.

Table 3.14 : Network Statistics Comparison for 2031 WoS Scenario

Description	Units	OBC NTM AM	OBC NTM PM	2018 NTM AM	2018 NTM PM
Transient Queues	pcu. hrs./hr.	2931	3137	2871	2815
Over-capacity Queues	pcu. hrs./hr.	3651	3849	3167	2907
Total Travel Time	pcu. hrs./hr.	19097	19914	18547	18693
Travel Distance	pcu. kms./hr.	878241	894134	875313	898614
Overall Average Speed	Kph	46	45	47	48
Total Trips Loaded	Pcu/hr	90244	88919	89644.8	88513
Average Travel Time	Mins	13	13	12	13

Description	Units	OBC NTM vs 2018 NTM AM	OBC NTM vs 2018 NTM PM
Transient Queues	pcu. hrs./hr.	-2.0%	-10.3%
Over-capacity Queues	pcu. hrs./hr.	-13.3%	-24.5%
Total Travel Time	pcu. hrs./hr.	-2.9%	-6.1%
Travel Distance	pcu. kms./hr.	-0.3%	0.5%
Overall Average Speed	Kph	2.6%	6.9%
Total Trips Loaded	Pcu/hr	-0.7%	-0.5%
Average Travel Time	Mins	-4.6%	-2.3%

Table 3.15 : Network Statistics Comparison for 2031 WS Scenario

Description	Units	OBC NTM AM	OBC NTM PM	2018 NTM AM	2018 NTM PM
Transient Queues	pcu. hrs./hr.	3007	3050	2971	2794
Over-capacity Queues	pcu. hrs./hr.	3538	3809	3037	2989
Total Travel Time	pcu. hrs./hr.	19098	19872	18559	18837
Travel Distance	pcu. kms./hr.	886609	905672	883983	910418
Overall Average Speed	Kph	47	46	48	48
Total Trips Loaded	Pcu/hr	90263.8	88945	89673	88570
Average Travel Time	Mins	13	13	12	13

Description	Units	OBC NTM vs 2018 NTM AM	OBC NTM vs 2018 NTM PM
Transient Queues	pcu. hrs./hr.	-1.2%	-8.4%
Over-capacity Queues	pcu. hrs./hr.	-14.2%	-21.5%
Total Travel Time	pcu. hrs./hr.	-2.8%	-5.2%
Travel Distance	pcu. kms./hr.	-0.3%	0.5%
Overall Average Speed	Kph	2.1%	5.9%
Total Trips Loaded	Pcu/hr	-0.7%	-0.4%
Average Travel Time	Mins	-2.4%	-4.5%

As per 2018 NTM forecast the HGV growth from Base year 2014 to 2031 is almost zero. As a result of reduced HGV demand, both the WS and WoS scenario are showing improved network performance as expected. **Figure 3-9** and **Figure 3-10** shows the actual flow differences in WoS and WS network respectively for the AM, IP and PM peak hours compared to the core scenario forecasts. In both the AM and IP peaks, flow changes are negligible in the WoS and WS scenarios in the local road network. The changes on the M5 are more pronounced. In the PM peak, the flow changes are greater in both WoS and WS along most routes compared to other peaks. The highest changes along the M5 reflective of strategic nature of HGV trips. Further, as the HGV demand is not modelled through the VDM process, the changes in the WoS and WS scenarios are of similar magnitude when compared to the core scenario forecasts. In all cases the changes in flows along the scheme link is negligible.

Figure 3-9: Actual Flow Difference Plots (AM, IP, PM) for 2031 WoS between Previous NTM and 2018 NTM Growth

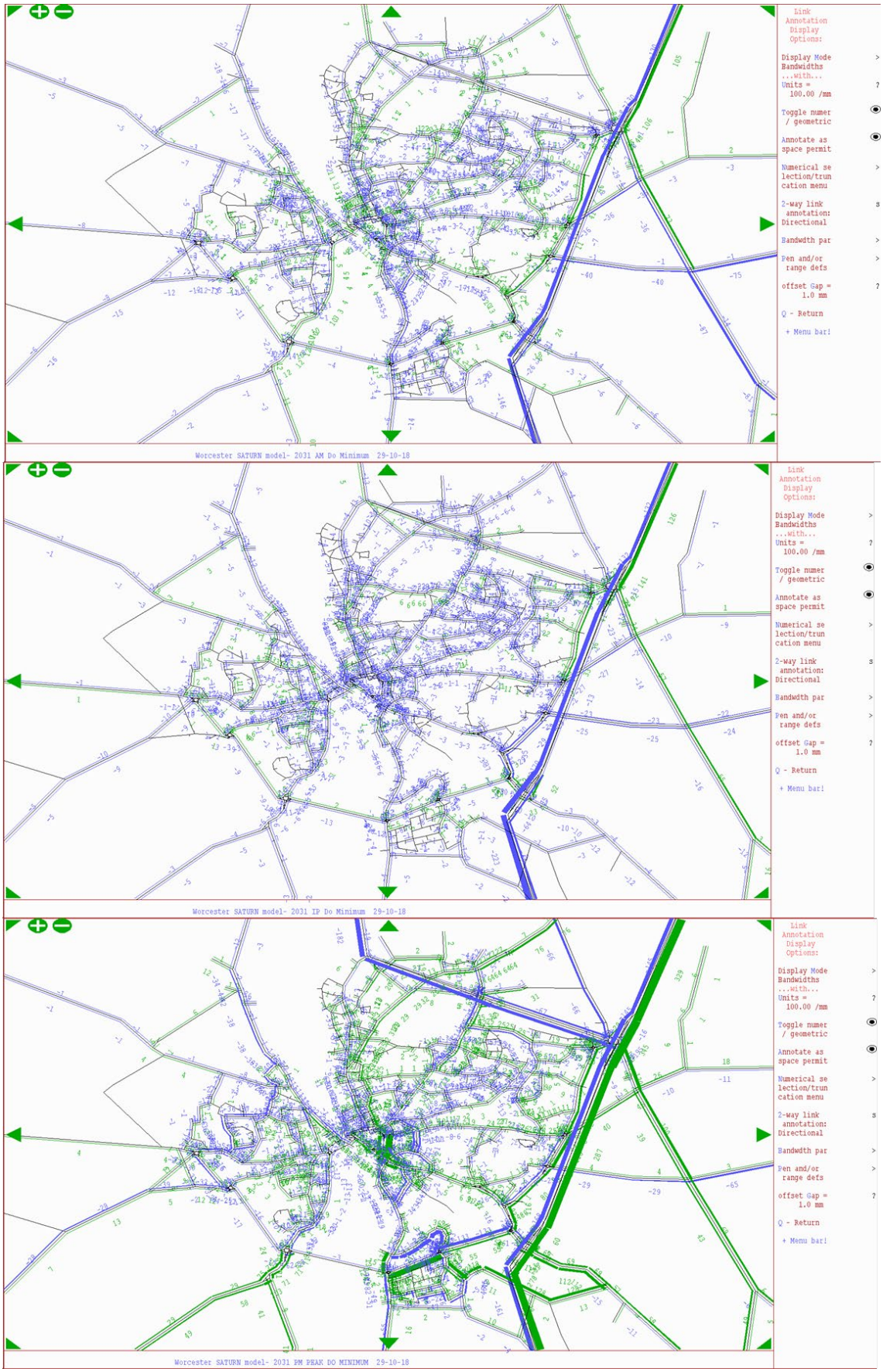
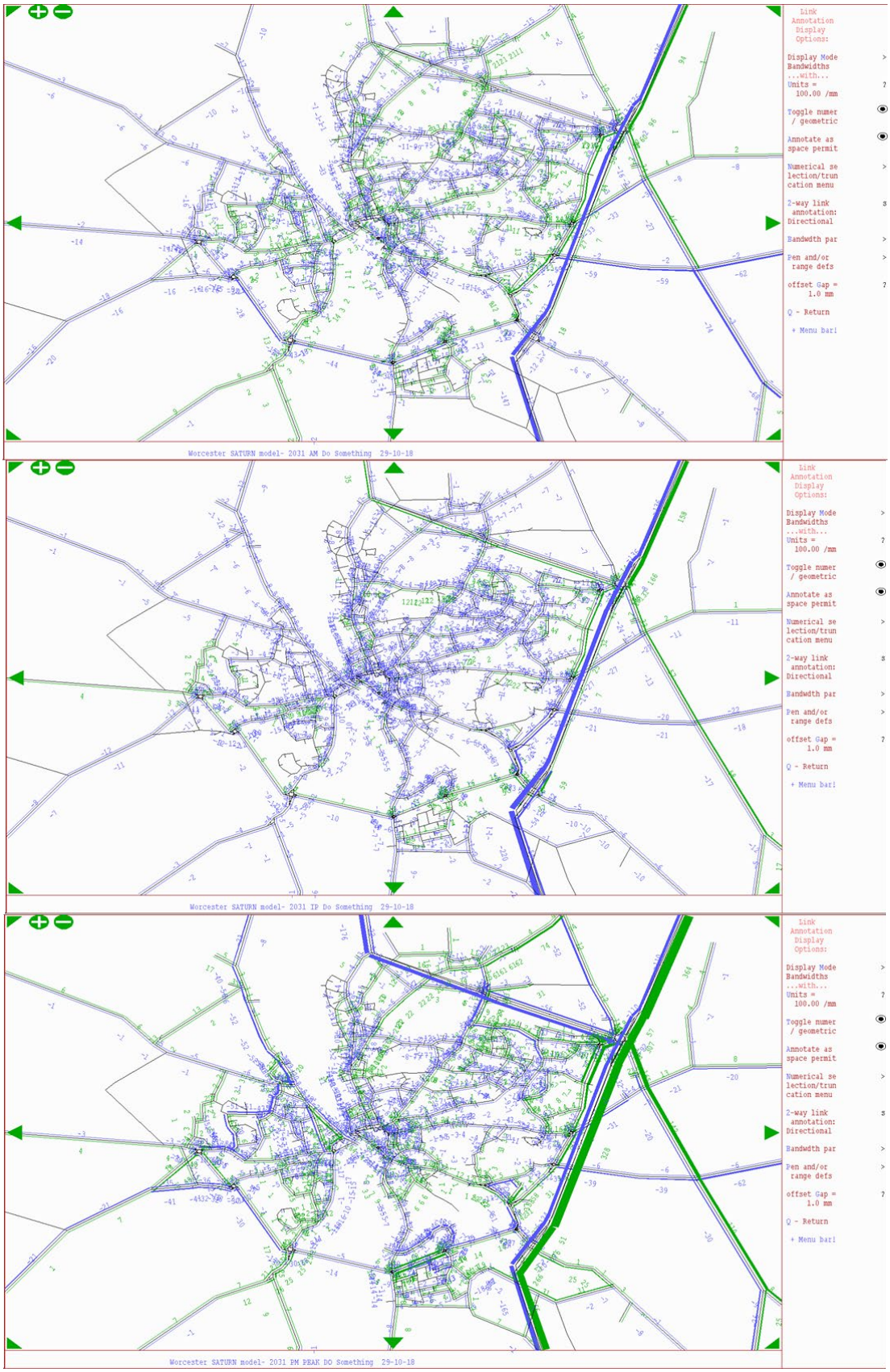


Figure 3-10: Actual Flow Difference Plots (AM, IP, PM) for 2031 WS between Previous NTM and 2018 NTM Growth



3.7 Summary of Traffic Modelling

Analysis of the traffic modelling work undertaken has shown that the provision of additional highway capacity on the A4440 Worcester SLR in the WS scenarios results in additional trips routing via the scheme compared to the WoS scenario.

The A4440 Worcester SLR Improvements Phase 4 scheme, and the additional vehicle trips it attracts, results in a re-distribution of trips compared to the WoS scenario. This re-distribution of trips in turn results in a decrease in the number of trips on the radial routes through Worcester city centre and an increase in trips on the Southern Link Road.

Due to the significant increase in overall trip growth expected within Worcester and Worcestershire, traffic flows on the A4440 Worcester SLR with the Phase 4 scheme in place, increase by between 45% and 66% compared to the WoS scenario.

Journey times on the A4440 Worcester SLR improve as a result of the scheme modelled through the WS scenario. In the 2031 WS forecast journey times are 4-8.5 minutes less than the 2031 WoS journey times. This means that the 2031 WS forecast journey times are better than base year conditions and thus represents a significant improvement which will be realised in the form of journey time saving and journey time reliability.

The outline business case was submitted in February 2017 followed by an addendum in March 2017. Since then, new webTAG Data book and National Traffic Model forecast tables have been published along with new approach to transport appraisal guidelines for long-term benefit extrapolation., In order to understand the impact of these changes, additional sensitivity tests were undertaken in addition to webTAG recommended standard sensitivity tests. The results show that the changes to the webTAG tables have negligible impact on the model forecasts. The change in HGV growth rates lead to reduced demand resulting in slight flow reduction in the urban networks and greater changes on the motorway network.