Annex D – M80 Operational Assessment Hornshill and Old Inns Junction

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M80 Stepps to Haggs DBFO

Transport Scotland

M80 Operational Assessment Hornshill and Old Inns Junctions

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M80 Stepps to Haggs DBFO

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Document history and status

Revision	Date	Description	By	Review	Approved
Rev 0	11 August 2015	Draft v0 for client review			
Rev 1	21 December 2015	Final			

Contents

1. Introduction

1.1 General

The M80 Operational Assessment Stage 1 Report identified the current operational issues on the M80 between Junction 3 Hornshill and Junction 8 at the M876. The report provided detail on the location, extent, duration and consequences of the operational issues on the M80. This Stage 2 report has been prepared to identify options and provide recommendations to mitigate the issues identified at Hornshill and Old Inns Junctions.

1.2 Background

The M80 Stepps to Haggs DBFO project, completed in August 2011, provides an 18 kilometre section of motorway, both off-line and on-line from the previous A80. It is considered that the completed works provide improved transport links and operational performance of the route between Glasgow, Stirling and the North East. However, the constructed design provides a similar level of mainline capacity to the former A80, providing two lanes instead of three, and therefore it was acknowledged that traffic management measures may be required to accommodate future demand and operational issues. The M80 project did not include any infrastructure revisions to the south of Hornshill or north of the Haggs junction therefore the operational issues within these locations are a function of existing layout and traffic demand.

Fundamentally there are four lanes of traffic demand approaching either extent of the M80 scheme. To the south, there are two lanes from the M73 and M80 (M8), and to the north, two lanes on both the M80 and M876. It is considered that although these routes are not operating at maximum theoretical capacity, the total demand entering the M80 scheme, which is predominantly 2 lanes per carriageway, causes operational issues during the peak periods at particular locations.

The Stage 1 report established that the key delays observed during the AM peak are primarily located on the northbound carriageway upstream from Old Inns Junction. There are also delays at Hornshill Junction in the southbound direction during the AM peak as a result of congestion blocking back from the M8/M80 merge at Junction 1 Provan.

During the PM peak, the delays are mainly experienced in the southbound direction at M80 /M876 Junction 8. There is also a delay at the Hornshill northbound diverge resulting in potential safety issues due to excessive queues on the diverge.

The Stage 1 report also considered driver undertaking on the southbound auxiliary lane between the Castlecary Viaduct and Old Inns junction. Police Scotland indicated that this could be an issue; however, there was no clear evidence that undertaking was creating an operational issue on this section.

1.3 Stage 1 Recommendations

The Stage 1 report concluded with the following recommendations:

- At Old Inns junction, revisions to road markings and signing may encourage drivers to use the full length of the slip road. Ramp metering may also be considered as a mitigation measure;
- A review of the operation of Hornshill junction should be undertaken to advise on potential improvements, such as traffic signals or alterations to the diverge lane markings, roundabout entry and lane discipline on the circulatory carriageway; and
- At the M80/M876 merge a revised layout of the merge could improve operational issues.

1.4 Stage 2 Scope

Further to discussions with Transport Scotland (TS) it was agreed that this Stage 2 assessment would focus on the operational issues at Hornshill and Old Inns junctions.

Operational issues occur at Hornshill during both the AM and PM peaks. During the AM peak, traffic is blocking back from the M8/M80 junction and impacting on the operation of the southbound M80 at Hornshill. The M8/M80 junction out-with the extents of the M80 Stepps to Haggs DBFO scheme and it is proposed that the AM peak issue is considered as part of a separate study. However, high level mitigation is considered within this report. The PM peak operational issue at Hornshill relates to the queuing from Hornshill roundabout onto the northbound diverge. This Stage 2 assessment considers how this issue can be mitigated.

The Old Inns junction has been considered on the basis of the operational issues experienced in the AM peak period. While similar issues may occur in the PM peak, this is to a lesser extent, and therefore the AM peak period has been assessed as the worst case scenario.

It was proposed that the operational issues of the M80/M876 junction be considered within a separate study and therefore it has not been examined within this assessment.

2. Hornshill Junction – Potential Mitigation Options

2.1 Overview

As detailed in the Stage 1 report Hornshill junction experiences operational issues in both the AM and PM peak periods.

The AM peak issues relate to traffic blocking back from the M8/M80 Provan junction which is out with the extents of the M80 Stepps to Haggs DBFO scheme. Notwithstanding this, minor mitigation measures have been considered for the AM peak.

The northbound diverge can experience excessive queuing during the PM peak. The queuing has the potential to block back onto the mainline of the M80 in the future and in order to mitigate against this occurring in the short to medium term appropriate mitigation measures have been considered on the diverge.

2.2 Existing Conditions

A site visit was undertaken at Hornshill Junction to observe traffic behaviour, during the peak periods of 10 March 2015. A turning count and queue length survey were undertaken on the same date to provide additional site data further to fixed camera surveys undertaken in November 2014 as part of the Stage 1 assessment.

As identified in the Stage 1 report, the principal issue during the AM peak was queuing on the M80 southbound merge. While the slow moving vehicles are a result of queuing back from the M8/M80 junction at Provan the situation is exacerbated by merging vehicles failing to make use of the full length of the merge lane and instead merging onto the mainline at the earliest opportunity. It is considered that this also affected behaviour on the mainline with vehicles slowing to allow merging vehicles to enter the carriageway. It is considered that promoting use of the full length of the merge lane would act to increase its capacity and, in turn, reduce the amount of queuing on the merge.

During the PM peak the main issue is queuing vehicles on the M80 northbound diverge. It is considered that the primary cause of queuing is limited visibility for M80 diverge drivers approaching the give way line and speeds of traffic on the circulatory carriageway of the roundabout, effectively reducing the capacity. The limited visibility is due in part to the alignment of the diverge with respect to the circulatory carriageway.

2.3 Baseline Model

In order to accurately model the existing performance of the northbound diverge and the upstream circulating carriageway, LINSIG junction modelling software was used. This software provides the ability to model both priority control and signal controlled junctions.

The analysis focussed on the PM peak hour, given the operational issues observed during this period. Iterative reductions in the give way saturation flow were undertaken until the modelled queue lengths closely represented the level of queuing observed during the commissioned surveys. The junction analysis results are included in Table A1 in Appendix A.

2.4 Potential Mitigation Measures

While the AM peak issue is mainly attributable to the downstream merging issues with the M8/M80 merge it is recommended that the M8/M80 queuing issue will be subject to a separate study. Notwithstanding this, the installation of signs with the legend ‘Use full length of merge’ and queue warning signs could provide some benefit.

Within the PM peak the visibility and saturation flow issue was investigated. There are several methods of increasing the saturation flow at a give way or stop line, the most effective generally involves increasing the visibility at priority controlled junctions or the introduction of signal control where the former is not feasible or effective.

Investigation into the potential of increasing visibility for M80 northbound diverge vehicles was undertaken and it was found that modest improvements in give way saturation flow could be made by advancing the give way line into the circulating carriageway. It was found however that the magnitude of the increase in saturation flow would be relatively low as visibility at the give way line cannot be increased significantly. Therefore reductions in queuing would be marginal.

The effect of signalisation at this location was therefore investigated and it was found that benefits could be derived by providing two stage signal control at this node of Hornshill roundabout. It is proposed that the optimal solution would be to introduce signalisation at this arm of the junction. The survey data does not indicate significant operational issues on the other approach arms at this time and therefore the signalisation is limited to the northbound diverge. This does not preclude signals being installed in the future on other parts of the junction.

A comparison of the results in Table A1 in Appendix A shows significant improvement in performance of the junction with reductions in queue lengths on the diverge with no blocking back onto the northbound M80. In addition, overall junction delay is reduced significantly and the junction shows significant additional capacity to accommodate potential future traffic growth.

Further details of the analysis undertaken at the roundabout is shown in Appendix A.

The proposed layout of the mitigation is illustrated in drawing B1839907/1A. This layout was discussed with Transport Scotland's Standards Branch with the general layout being acceptable. The layout has been submitted to Standards Branch for their approval in principle. Further detail and design considerations will be taken forward for implementation which will include consultation with North Lanarkshire Council (NLC), as the circulatory carriageway is within their ownership. A Stage 1 Road Safety Audit will also be undertaken.

2.5 Summary and Recommendations

The implementation of traffic signals would provide significant benefit and mitigate the existing issue of queuing on the northbound diverge as minor increases in driver visibility onto the circulatory carriageway are not predicted to provide any significant improvements to the current layout.

Therefore it is recommended that the proposed signalised layout is implemented at the northbound diverge of the Hornshill junction and the signals should operate on a full-time basis.

While the junction currently benefits from having ducting in-situ on the diverge the outline budget estimate for the proposal has been costed on the basis of civils and ducting works being required to implement the proposed signalisation. The outline design and costings for the traffic signal infrastructure including poles, ducting and control units has been prepared by Siemens UK. Cost's for lining has been based on 2015 construction rates. It is anticipated that the costs for the mitigation proposals will be approximately £125K.

The installation of signs with the legend 'Use full length of merge' and queue warning signs on the southbound merge may provide some benefit during the AM peak and should also be considered for implementation.

Drawing number / Rev
B1839907/1/A

Diagram 1004
4m Mark, 2m Gap, 100mm Wide

Existing Diagram 1003.1 Retained.
1m Mark, 1m Gap, 200mm Wide

Diagram 1001
200mm Wide

Non-prescribed Roundabout Guidance Marking
300mm Mark, 600mm Gap, 150mm Wide

Diagram 1004
4m Mark, 2m Gap, 100mm Wide,
(5 markings on approach to stop line)

Diagram 1001
200mm Wide

Diagram 1038
4m Length

Diagram 1004
4m Mark, 2m Gap, 100mm Wide

Diagram 1035
1.6m High

KIRK STEPPS

Diagram 1038
4m Length

KIRK M80(N)

Diagram 1035
1.6m High

Existing anti-skid surfacing

Existing Diagram 1005 Marking
1m Mark, 5m Gap, 100mm Wide

50m anti-skid surfacing

Diagram 1038
4m Length

KIRK M80(N)

Diagram 1035
1.6m High

Legend
Primary Signal Head
Secondary Signal Head

Lane destinations subject to consultation and agreement with Transport Scotland and local authorities.

Rev	Rev. Date	Purpose of revision	Drawn	Checkd	Rev'd	Appr'd
A	14/12/2015	Anti-skid surfacing added	DM	CW		

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Client
Transport Scotland

Project
M80 Operational Assessment

Drawing title
Hornshill Proposed Signalisation
M80 (NB) Offslip /
Hornshill Circulating Carriageway

Drawing status

Scale	1:500 @ A3	DO NOT SCALE
Jacobs No.	B1839907	
Client no.		

Drawing number: B1839907/1
Rev: A

C:\Users\marshalld\Documents\M80\M80 Hornshill\M80 Hornshill NB Offslip_Circulating Signals (diagrams).dwg - 21/12/2015 16:25:12 - Hornshill Portrait - marshalld

3. Old Inns Junction – Potential Mitigation Options

3.1 Location

Old Inns Junction (J6) is located on the M80 to the northeast of Cumbernauld. The surrounding road network includes the A8011, Castlecary Road, and Eastfield Road, the junction layout is shown in the Figure 3.1 below.

Figure 3.1 : Old Inns Junction

3.2 Existing Conditions

At present, significant congestion occurs on the northbound M80 during the AM peak period on the approach to and through Old Inns Junction. This issue was identified within the Stage 1 Report.[1] The vehicles on the northbound main line are slow moving; the reason for this is the volume of northbound merging vehicles and the resulting driver behaviour on the mainline. In order to accommodate the merging traffic, the drivers on the main line reduce their speed and/or change lanes at and on approach to the junction. These actions in turn cause the formation of pockets of queues upstream as a result of a ripple effect of slowing and slow moving traffic at the Old Inns junction. The queuing conditions then result in merging drivers attempting to merge as soon as possible onto the mainline, instead of using the full merge length, which exacerbates the situation.

The slow moving traffic extends for 3 to 4 miles south of Old Inns Junction and typically occurs between 07:15 and 08:30.

The Automatic Number Plate Recognition (ANPR) study undertaken as part of the Stage 1 assessment confirmed that traffic was leaving the M80 at Low Wood, due to the queuing from Old Inns, and re-joining at Old Inns or Castlecary via the A8011 (running through the Cumbernauld Town Centre) and to a lesser extent using Eastfield Road (located on the north side of Cumbernauld. The ANPR study found that 292 vehicles between 0700 and 1000 were diverting via the A8011 and re-joining at Old Inns Junction. This adds to the merging demand and exacerbates the performance issues at the junction.

The M80 VISSIM model used for Castlecary junction testing was used to create the base model. This model covers the M80 from a point south of Junction 4a Low Wood northwards beyond Junction 7 Haggs. The model extent is shown in Figure 3-2. The coding of this base model is discussed in detail in Appendix A.

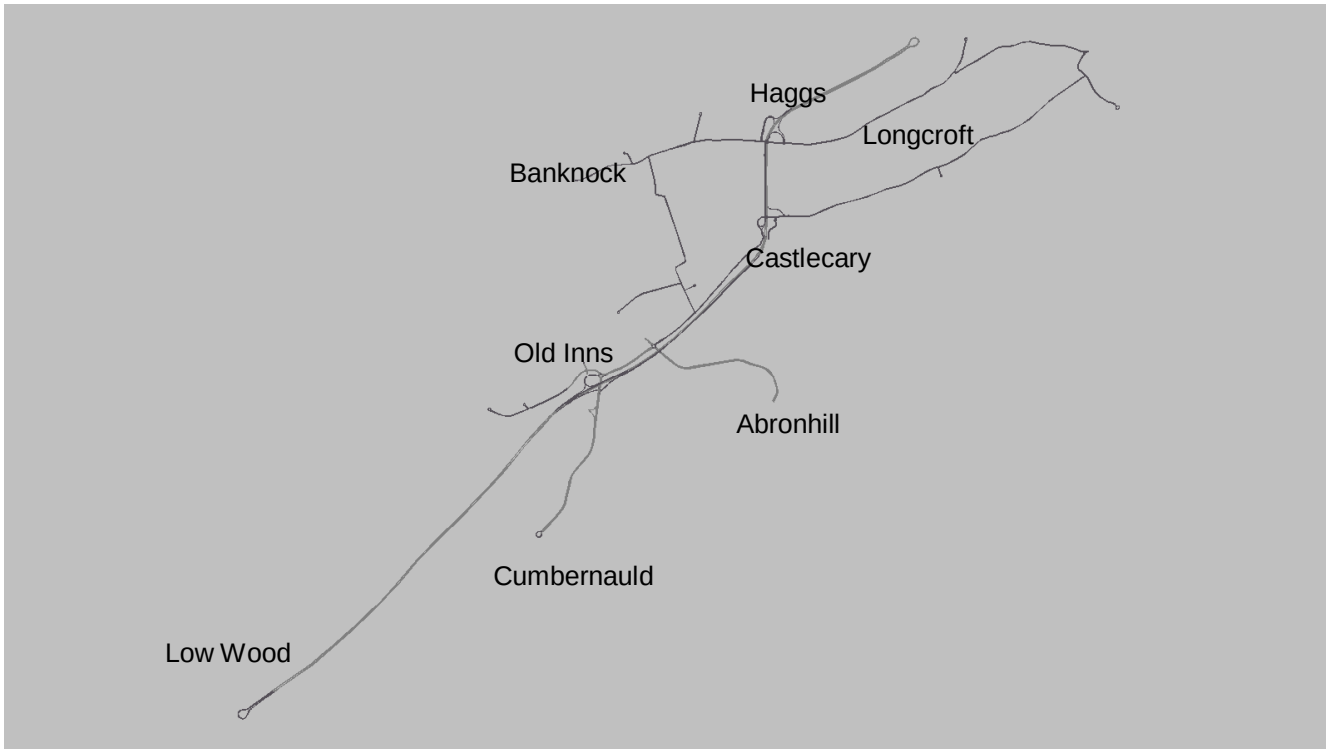

Figure 3.2 : M80 VISSIM model extent

[1] M80 Stepps to Haggs DBFO M80 Operational Assessment Stage 1 – Hornshill Junction 3 to M80 / M876 Junction 8

3.3 Proposed Mitigation Measures at Old Inns Junction

In order to test potential mitigation measures, various options were coded and tested using VISSIM. These are detailed in Appendix A and include:-

- Option 1 – Extend the double white line within the extents of the existing northbound merge;
- Option 2 – Extend the length of the northbound merge;
- Option 3 – Decrease the green time at the A8011 Wilderness Brae signals;
- Option 4 – Closure of the northbound merge;
- Option 5 – Extend the double white line by 230m and increase the length of the northbound merge;
- Option 5 A – Extend the double white line by 600m and increase the length of the northbound merge; and
- Option 6 – Introduction of a peak speed limit reduction on the M80 with a ramp meter and increased length of the northbound merge.

The proposed double white lining has been amended to solid white lining following consultation with Standards Branch. In terms of the VISSIM modelling the line type was not a factor within the modelling parameters', therefore the change in proposed line type has not altered the modelling output.

The initial testing of Options 1 to 4 inclusive did not demonstrate significant benefit and no further assessment was undertaken due to the following:

- Option 1 – reduced merge length exacerbates the current situation;
- Option 2 – resulted in increased journey times;
- Option 3 – caused significant queuing on the A8011 upstream to the Braehead Roundabout towards Cumbernauld town centre; and
- Option 4 – results in queuing at Old Inns roundabout due to the traffic flow which has diverted from using the Old Inns merge. The congestion at Old Inns roundabout causes queuing on the diverge which blocks back to the M80 resulting in stationary traffic on the mainline.

Further detailed analysis is provided within Appendix B.

Options 5, 5A and 6 were subject to further assessment as these options may improve the operation of the M80 and maximise through traffic. The following outlines the options and results of the tests.

Option 5 (Extend merge by 230m)

- Revise the junction layout to include a 230m solid white line followed by a 230m auxiliary lane and a 75m taper. The extended auxiliary lane would be 230m greater than the existing lane and would be formed within the existing hard shoulder.
- Currently, merging traffic generally joins the M80 at the earliest opportunity and has just turned from a relatively tight bend, on a rising gradient. Therefore the longer merge section and extension of the solid line permits merging traffic to increase speed to that of the mainline. By extending the merge lane, the point at which the vehicles can merge would be located where the M80 is on a slight downward gradient (0.6%), rather than the current location where slow merging traffic joins the M80 on a slight incline.

Option 5A (Extend merge by 600m)

- Revise junction layout to include a 600m solid white line followed by a 230m auxiliary lane and a 75m taper. The extended auxiliary lane is formed in the existing hard shoulder.
- As with Option 5 this option proposes that the merge is relocated further north on the M80 where it will gain a slight advantage in that there is an increased downhill gradient over the merge length. The downhill grade here is approximately -2.5% compared to approximately -0.6% in Option 5. Therefore traffic,

particularly HGVs, will have recovered from the climb up to the Old Inns junction and traffic speeds on the mainline are predicted to be slightly higher.

The proposed layout for these options are illustrated in drawings B1839907/01/OIC 1A and B1839907/01/OIC 2 A and provide the detailed lining revisions for each option. Both Options 5 and 5A have an alternative to hard shoulder running where the lane widths are amended within the existing cross section (including the hard shoulder) to provide consistent lane widths over the extents of the improvement.

Option 6 (Reduced Speed limit, merge extension and ramp meter)

- Introduction of 40 mph speed limit from the south of Low Wood until the end of Old Inns merge to regulate traffic speed and reduce the ripple effect.
- Redesign junction layout to include a 230 metre solid white line followed by a 230 metre auxiliary lane and a 75 metre taper
- Introduction of a ramp meter on the merge-slip to control the frequency with which the vehicles from the merge enter the main line traffic. It is predicted that the introduction of a ramp meter on the merge will also deter traffic from diverting off the M80 to re-join at Old Inns Junction it may not prevent traffic from continuing to divert via Castlecary. However, works to permit all movements at the Castlecary Junction have been completed and includes traffic calming through Castlecary village. Therefore diverting from the M80 and re-joining at Castlecary may be less attractive given the slight delay predicted through the village due to traffic calming measures.
- The benefits to journey times of this option, as detailed below, would also be a factor which is predicted to result in less traffic diverting from the M80 and using the M80 from the A8011 and Eastfield Road diversion routes as identified in the Stage 1 assessment.

The network performance of the base model and the various other options are discussed in Appendix E.

3.4 Modelling Analysis Results

The network performance of the above options in comparison to the base model is summarised below:

Option 5 (Extend merge by 230m)

- Option 5 is predicted to allow 5% more traffic to pass the Old Inns junction within the assessed period in comparison to the base model;
- Journey times between Low Wood and Haggs are predicted to improve on average by 24 seconds (per vehicle) between 0700 and 0900;
- The lengths of the pockets of queuing vehicles (caused by the ripple effect of traffic slowing down at Old Inns) are predicted to reduce by 22% on the northbound carriageway upstream of Old Inns junction; and
- The amended white lining options in Option 5 will range in cost between £35K and £50K for use of the existing hard shoulder and an amended cross-section respectively.

Option 5A (Extend merge by 600m)

- This option is predicted to result in a 8% increase in through traffic passing Old Inns junction compared to the base model;
- Journey times from Low Wood to Haggs is predicted to decrease by an average of 53 seconds between 0700 and 0900;
- This option is predicted to reduce the length of the pocket of queues by an average of 38% upstream of the Old Inns junction;
- The amended white lining options in Option 5A will range in cost between £45K and £70K for use of the existing hard shoulder and an amended cross-section respectively.

Drawing number / Rev
B1839907/01/OIC 1/A

Key
- New Road Marking
- Removal of Existing Road Marking

Non-prescribed white 500mm hatching. Red uni-directional studs 9m crs on edge line (85 metres)

Diagram 1012.2
Continuous 200mm wide, Raised rib, 500mm spacing. Red uni-directional studs 9m crs (380 metres)

Diagram 1010
1m mark, 1m gap, 200mm wide. Green uni-directional studs 8m crs (305 metres)

Removal of Diagram 1012.2
Continuous 200mm wide, Raised rib, 500mm spacing. Red uni-directional studs 9m crs (305 metres)

Removal of Diagram 1012.2
Continuous 200mm wide, Raised rib, 500mm spacing. Red uni-directional studs 9m crs (75 metres)

Diagram 1040.5
End of hard shoulder marking. White 500mm hatch markings. Red uni-directional studs 8m crs on edge line. (115 metres)

Diagram 1012.2
Continuous white line, 200mm wide, raised rib, 250mm spacing. Red bi-directional studs 3m crs (230 metres)

Removal of Diagram 1010
1m mark, 1m gap, 200mm wide. Green uni-directional studs 8m crs (305 metres)

Wardpark North Industrial Estate
NAPIER ROAD
M80
M876
El Sub Sta
Mast (Telecommunication)
Cumbernauld Business Park
Drain
Path

Notes

Slip road extended along hard shoulder by a distance of approximately 230m.

Proposal comprises revised lining only, with no carriageway alignment necessary.

Proposal subject to agreement with Transport Scotland Standards Branch.

Alternative proposal with cross-section changes would result in the following amendments:

Removal
- Diagram 1012.2 – Hardstrip (610m, 200mm wide, Raised rib, 500mm spacing. Red uni-directional studs 9m crs)
- Diagram 1005.1 – Centre Line (610m of 7m-2m, 150mm wide, white bi-directional studs 18m crs)

Apply
- Diagram 1012.2 – Hardstrip (610m, 200mm wide, Raised rib, 500mm spacing. Red uni-directional studs 9m crs)
- Diagram 1005.1 – Centre Line (610m of 7m-2m, 150mm wide, white bi-directional studs 18m crs)

Rev	Rev. Date	Purpose of revision	Drawn	Checked	Rev'd	Apprv'd
A	17/12/2015	Addition of hard shoulder hatching	DM	CW		

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Client: Transport Scotland

Project: M80 and M876 Operational Assessment

Drawing title: Potential Road Marking Ammendments at Old Inns Northbound Merge - Option 5

Drawing status

Scale	1:1000 @ A1	DO NOT SCALE
Jacobs No.	B1839907	
Client no.		
Drawing number	B1839907/01/OIC 1	Rev A

C:\Users\marshallk\Documents\M80\M80 Old Inns\M80 Old Inn_Change of Road Markings_Option 5 (including hardstanding)v2.dwg - 17/12/2015 12:32:25 - Option 5 - marshallk

Drawing number / Rev

B1839907/01/OIC 2/A

Key

- New Road Marking
- Removal of Existing Road Marking

Diagram 1040,5
End of hard shoulder marking.
White 500mm hatch markings.
Red uni-directional studs
8m crs on edge line (115 metres)

Removal of Diagram 1012,2
Continuous 200mm wide,
Raised rib, 500mm spacing,
Red uni-directional
studs 9m crs (75 metres)

Diagram 1012,2
Continuous white line, 200mm wide,
raised rib. 250mm spacing, Red
bi-directional studs 3m crs (610 metres)

Removal of Diagram 1012,2
Continuous 200mm wide,
Raised rib, 500mm spacing,
Red uni-directional
studs 9m crs (610 metres)

Diagram 1012.2
Continuous 200mm wide,
Raised rib, 500mm spacing,
Red uni-directional
studs 9m crs (685 metres)

Diagram 1010
1m mark, 1m gap, 200mm
wide,
Green uni-directional
studs 8m crs (305 metres)

Diagram 1040,5
End of hard shoulder marking.
White 500mm hatch markings.
Red uni-directional
studs 9m crs on edge line
(85 metres)

Removal of Diagram 1010
1m mark, 1m gap, 200mm wide,
Green uni-directional
studs 8m crs (305 metres)

Notes

Slip road extended along hard shoulder by a distance of approximately 600m.

Proposal comprises revised lining only, with no carriageway alignment necessary.

Proposal subject to agreement with Transport Scotland Standards Branch.

Alternative proposal with cross-section changes would result in the following amendments:

Removal
- Diagram 1012.2 – Hardstrip (915m, 200mm wide, Raised rib, 500mm spacing. Red uni-directional studs 9m crs)
- Diagram 1005.1 – Centre Line (915m of 7m-2m, 150mm wide, white bi-directional studs 18m crs)

Apply
- Diagram 1012.2 – Hardstrip (915m, 200mm wide, Raised rib, 500mm spacing. Red uni-directional studs 9m crs)
- Diagram 1005.1 – Centre Line (915m of 7m-2m, 150mm wide, white bi-directional studs 18m crs)

Rev	Rev. Date	Purpose of revision	Drawn	Checkd	Rev'd	Apprv'd
A	17/12/2015	Addition of hard shoulder hatching.	DM	CW		

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Client: Transport Scotland

Project: M80 and M876 Operational Assessment

Drawing title: Potential Road Marking Ammendments at Old Inns Northbound Merge - Option 5(A)

Drawing status

Scale	1:2000 @ A1 — DO NOT SCALE
Jacobs No.	B1839907
Client no.	
Drawing number	B1839907/01/OIC 2
Rev	A

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Option 6 (Reduced Speed limit, merge extension and ramp meter)

- This option is predicted to result in a 14% increase in through traffic passing Old Inns junction compared to the base model;
- Journey times from Low Wood to Haggs is predicted to decrease by an average of 100 seconds between 0700 and 0900;
- This option reduces the length of pockets of queues on an average by 64% at Old Inns and to the south of the junction. Although the length of these pockets of stop/start conditions almost half, there continues to be slow moving vehicles over the same extent of the M80 but with improved journey times. The queue graphics in Appendix E illustrate this;
- It causes queues on the merge due to the introduction of a ramp meter, but the queue is not predicted to block back to the Old Inns roundabout and hence doesn't affect its operation;
- The costs of Option 6 would include Managed Motorway Infrastructure and because of the bespoke nature of the system it is difficult to accurately quantify at this stage, however, the Fife ITS system was approximately £13M over a 7km section of carriageway. Notwithstanding this, the costs for kerbing, white lining and ramp meter traffic signals would be approximately £100K. If a Managed Motorway system was to be considered on the M80 then further studies would be required to determine the extents of such a scheme to provide cost effectiveness when compared to partial implementation.

3.5 Summary and Recommendations

Of the six options assessed Options 5, 5A and 6 are considered to provide benefits. It is therefore recommended that the extension of the merge is considered, and ultimately a ramp meter and man line speed reduction would be necessary to mitigate the localised congestion during the AM peak period.

In addition to the modelled options, which all include the lengthening of the northbound merge, there are other low cost remedial measures that could also be considered and potentially trialled for a short period.

A significant factor discussed in the Stage 1 report included the interaction between mainline traffic and merging traffic and how the existing inter-visibility influences the behaviour of mainline traffic. The mainline traffic and their cooperative behaviour, that is giving way to merging traffic or lane changing, results in slowing of mainline traffic, observed upstream of the Old Inns junction. The use of screening between the merge traffic and mainline traffic may assist in reducing early cooperative behaviour by mainline traffic which may minimise the impact of the queuing issues on the northbound M80. It is proposed that consideration is given to trialling the screening of the merge with consultation undertaken with Transport Scotland.

The installation of signs with the legend 'Use full length of merge' may also result in some benefit as this will encourage drivers to make use of the full merge length and provide additional time to find a suitable gap. This may also minimise the impact on the mainline traffic. Queue warning signs on the northbound approach of the M80 towards the congestion area should also be considered for installation to work in tandem with existing VMS information.

While there are improvements that can be gained on the M80, the proposed mitigation measures will not fully remove the congestion issues in the peak periods. The options which provide the most benefit vary from the minimal amendments of Options 5 and 5A to the features of a Managed Motorway included within Option 6. Therefore these can be viewed as short term mitigation and long term mitigation given the level of costs associated with Option 6. On the basis of the relatively low cost of Options 5 and 5A (approximate maximum costs of £70K) it is recommended that these options are taken forward for consideration.

The assessment is based on current traffic demand levels, and therefore the situation is likely to further deteriorate, with operational issues extending further and the duration of the issue also extending. Ultimately, if no significant capacity improvements are made, such as additional lanes on the mainline, it will be necessary to manage the demand and aim to reduce the level or impact of car commuters. In the short term the options identified can be progressed in stages, as the cost of each stage would not be completely abortive. Therefore an improvement strategy could consist of the following:-

- Install the low cost measures; screening visibility and signing, with the aim of encouraging a change in driver behaviour;
- Extend the merge by 230m or immediately by 600m, which is largely a re-lining exercise; and
- Option 6 could also be brought in via stages, with a mainline and slip road speed limit reduction, followed by the introduction of a ramp meter.

It is anticipated that Option 6 may be considered as part of a wider study into managing the motorway network and the cost of the full corridor management would be significant. There would also be a need to examine the impact on adjacent routes and junctions, such as Castlecary and Auchenkilns, however it is likely that these measures will be required in the future if the operation of the network is to be improved and maintained at an appropriate level of service.

Transport Scotland, Standards Branch have been consulted on the implementation of Options 5 and 5A and on the basis of their initial response a solid white line is proposed in lieu of a double white line arrangement.

The revised layouts have been submitted to Standards Branch for their approval in principle. It should be noted that the removal of the hard shoulder and changes in carriageway cross section for both options 5 and 5A will result in a Departure from Standard.

Following approval in principle to the layouts, a Stage 1 Road Safety Audit shall be programmed**.**

Appendix A. Hornshill Technical Details

A.1 Signalisation of M80 northbound diverge

The proposed introduction of signal control at the junction of the M80 northbound diverge and Hornshill circulating carriageway was modelled using LINSIG software. In order to accurately model the potential future performance of the junction with signals, geometric parameters were measured from OS mapping and as-built drawings.

A simple two phase arrangement, run over two stages (M80 northbound diverge as one phase and stage and circulating traffic as the other phase and stage), was chosen as this offers the most efficient and simple method of traffic control at this location. No pedestrian provision was allowed for at the proposed signals, in line with the current provision at the junction. Figure A1 below shows the arrangement as modelled in LINSIG. Two lanes have been modelled for the diverge and the circulating carriageway, the circulating carriageway will require lane markings to designate the inside lane to the A806 for Kirkintilloch while the outside lane will be used to access the M80 northbound merge and Cumbernauld Road towards Stepps.

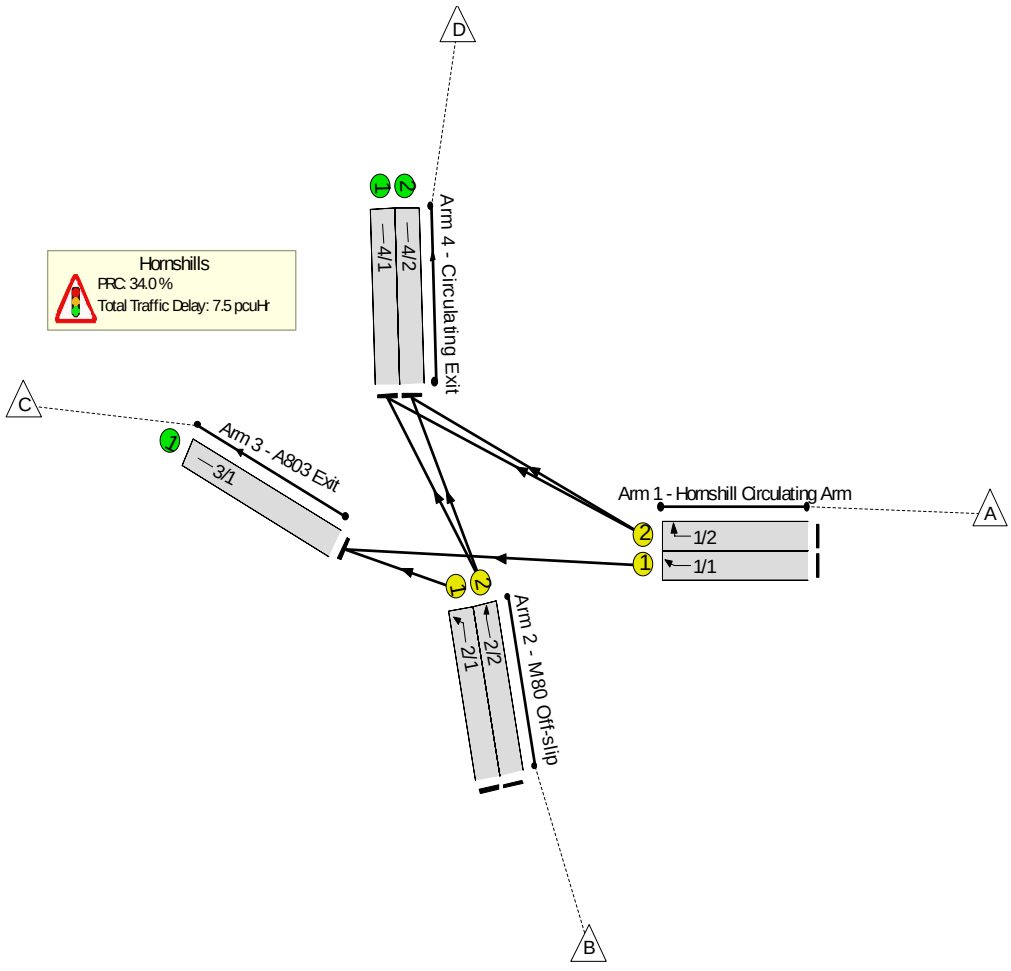

Figure A1: Modelled Signalised Junction Layout

The results of the LINSIG analysis indicate that the extents of queuing on the M80 northbound diverge can be significantly reduced to levels that will not impact on the operation of the northbound M80 and minimise the risk of rear end shunts on the diverge. Queueing will be introduced on the circulating carriageway (as currently

vehicles on this approach have right of way), however, queue lengths are maintained at an acceptable level using efficient staging and short cycle times. The results of the junction analysis are shown below in Table A1:

Arm	PM Peak – Existing Priority Control		PM Peak – Proposed Signals	
	Degree Saturation (%)	Mean Max Queue (PCU)	Degree Saturation (%)	Mean Max Queue (PCU)
Hornshill Circulating Arm Ahead to A806 Kirkintilloch	18.6%	0	65.8%	6
Hornshill Circulating Arm Right to M80 North	9.1%	0	19.5%	2
M80 Diverge Left to A806 Kirkintilloch	101.7%	54	67.2%	9
M80 Diverge Ahead to Stepps	101.5%	37	39.4%	5
Junction Delay (pcuHr)	30.94		8.04	
Junction PRC (%)	-13		34.0	
Cycle Time (s)	NA		60	

Table A1: Comparison of Junction Analysis Results

Appendix B. Old Inns Network Coding

The various models coded to address the existing queuing at Old Inns are:

- Base model 2014
- Option 1 – Extending the white line within extents of existing merge
- Option 2 – Extend length of merge
- Option 3 – Decrease green time at A8011 signal
- Option 4 – Closure of merge slip
- Option 5 – Extend white line and increase length of merge (230 m of solid white line followed by 230 m auxiliary lane with 75 m of taper)
- Option 5 A – Extend white line and increase length of merge (600 m solid white line followed by 230 m auxiliary lane with 75 m taper.)
- Option 6 – Introduction of speed limit with ramp meter and increased merge length

The models are described in detail in the below sections.

B.1 Base network

The base model is derived from the previously coded M80 VISSIM model which was used for Castlecary junction testing. The base model represents the road network before the opening of Castlecary bus gate.

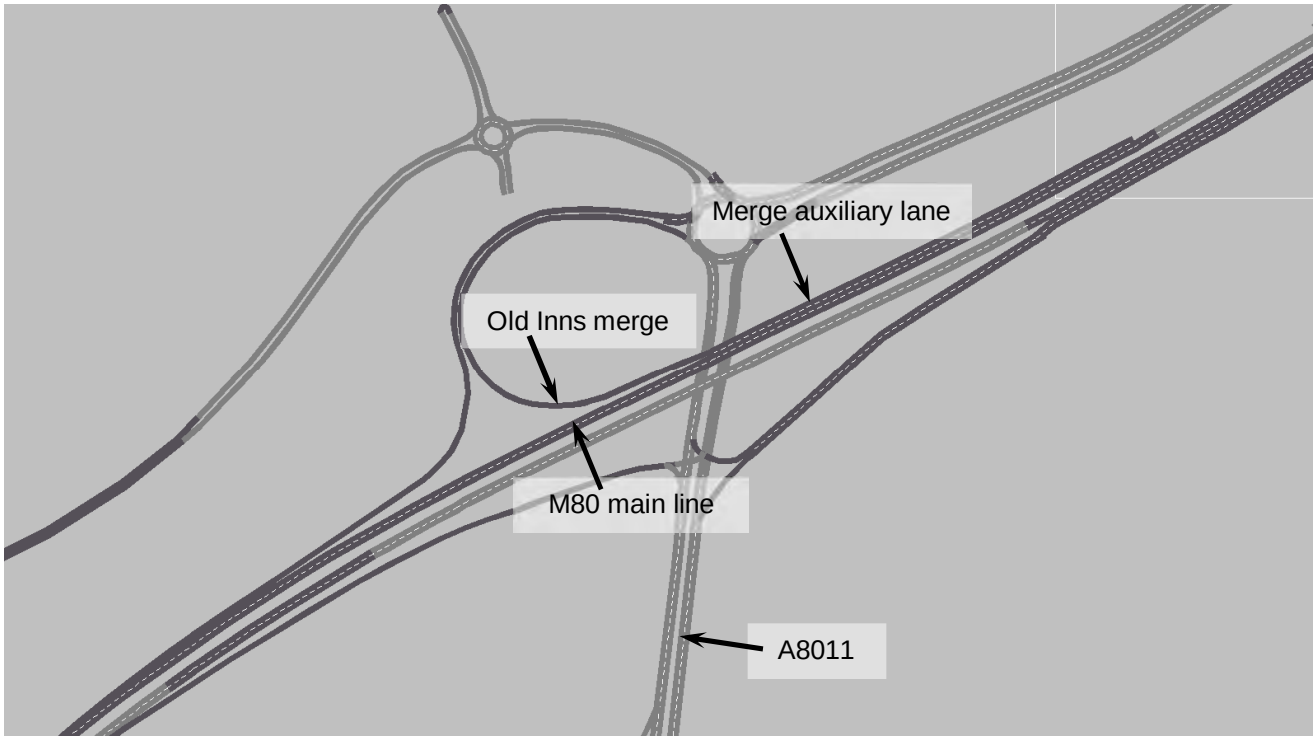

Figure B.1 : Base model at Old Inns junction

The base model represents the existing queueing at Old Inns junction, with operational issues on the mainline and slip road merge. Although the traffic on the main line has priority over the merging traffic at the junction, the vehicles on the main line eventually slow down to allow the traffic to merge onto the main line. This results in the queuing on the main line which builds up during the AM peak period causing queues on the M80 main line upstream past Low Wood.

In order to replicate this behaviour at Old Inns the driver behaviour at this junction has been modified. The driver behaviour on the northbound main line and the merge slip road are modified to achieve the slow moving traffic and queuing. Also, Old Inns merge is located on an uphill gradient. This contributes to reduced acceleration and shorter visibility distance. These conditions are achieved through changing the following parameters:

- Activating cooperative lane change and advanced merging;
- Increasing the standstill distance;
- Reducing look ahead distance; and
- Reducing standstill acceleration and acceleration at 50 mph.

These parameters are defined in Appendix F.

Various options have been modelled to address the queuing at Old Inns and are detailed in the sections below.

B.2 Option 1

In this option, a solid white line road marking of 80m has been applied after the nose of the merge. This result in a reduction in the merge length of lane to 150m with the 75m taper length maintained. The road layout of Old Inns junction in Option 1 is shown in Figure B.2. This option's traffic flow, journey times and queue lengths are reported in Appendix E.

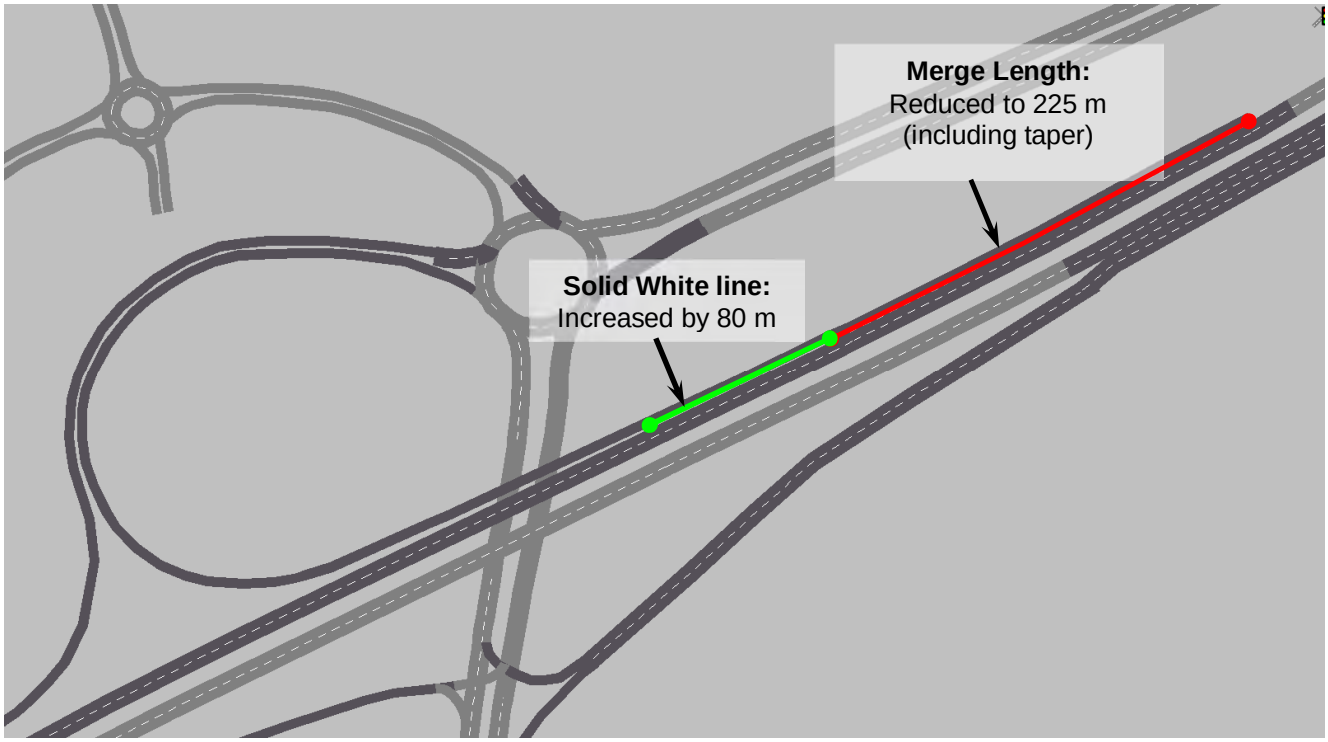

Figure B.2 : Option 1 at Old Inns junction

In this option, the aim was to encourage merging traffic further along the slip with the intention of maintaining the free flow of mainline traffic. This does require a reduction in the current merging length which is predicted to exacerbate the slowing of mainline traffic, as vehicles have a shorter distance to merge. This results in higher queueing and increased journey times as detailed in Appendix E.

B.3 Option 2

In Option 2, the length of the auxiliary lane is extended by 890 metres until the overbridge of Forrest Road. This option utilises the hard shoulder to accommodate the extension of the auxiliary lane. The road layout for Option 2 is shown below in Figure B.3.

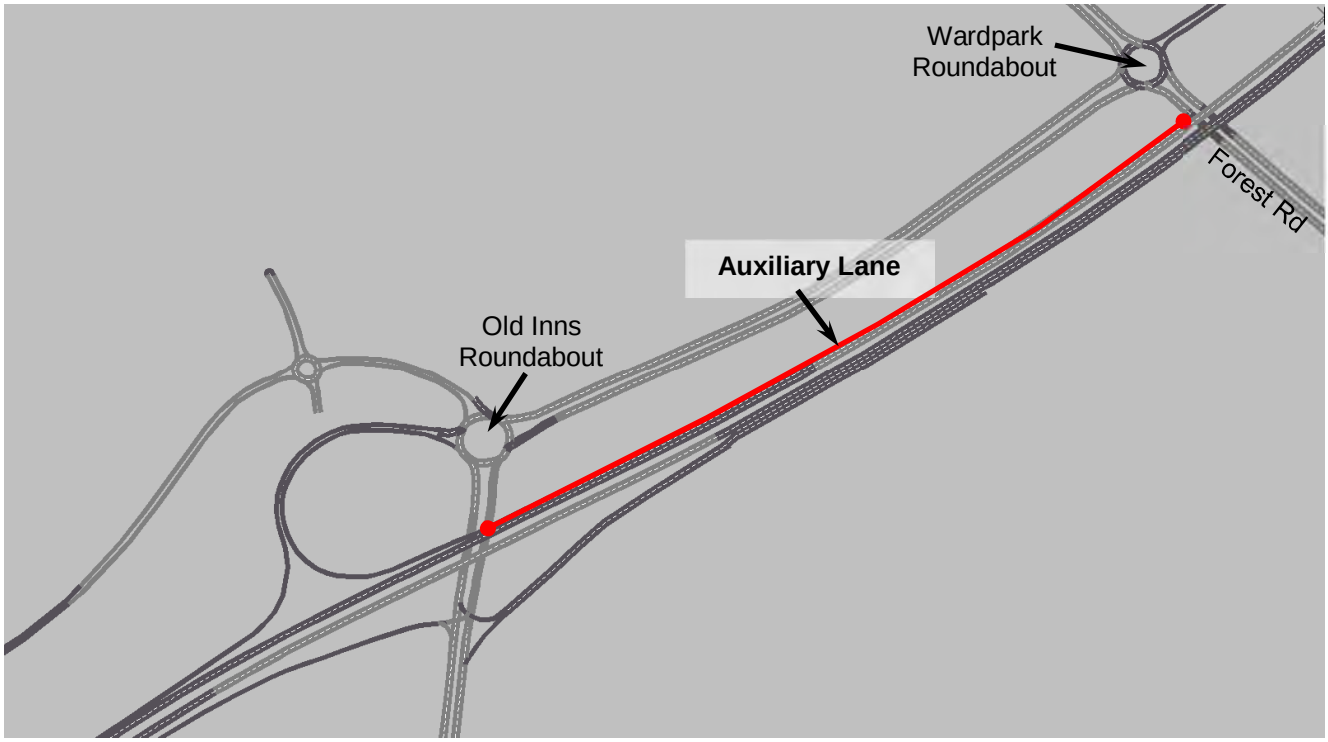

Figure B.3 : Option 2 at Old Inns junction

The principle of extending the length of the auxiliary lane is to provide an increased length for merging traffic to accelerate to the standard speed of the motorway and allow increased opportunity to merge with the main line traffic.

It can be seen from the results in Appendix E, that this option improves traffic flows and reduces queue lengths. However, journey times over the extents of the model are predicted to slightly increase.

B.4 Option 3

In this option, the green time of the signals at A8011 is modified to manage the flow approaching the Old Inns roundabout and the northbound merge. The green time of the northbound traffic on the A8011 has been reduced by 15 seconds to allow increased intervals between platoons of merging traffic with a view to allow the main line flow to recover from the slow moving traffic caused due to merging. Figure B.4 shows the location of the signals on the A8011.

The network performance of this option is discussed in Appendix E. I t is predicted that the reduction of green time at the A8011 signals will improve the network performance on the M80 main line but will cause significant queuing on the A8011 upstream to the Braehead Roundabout towards Cumbernauld Town Centre.

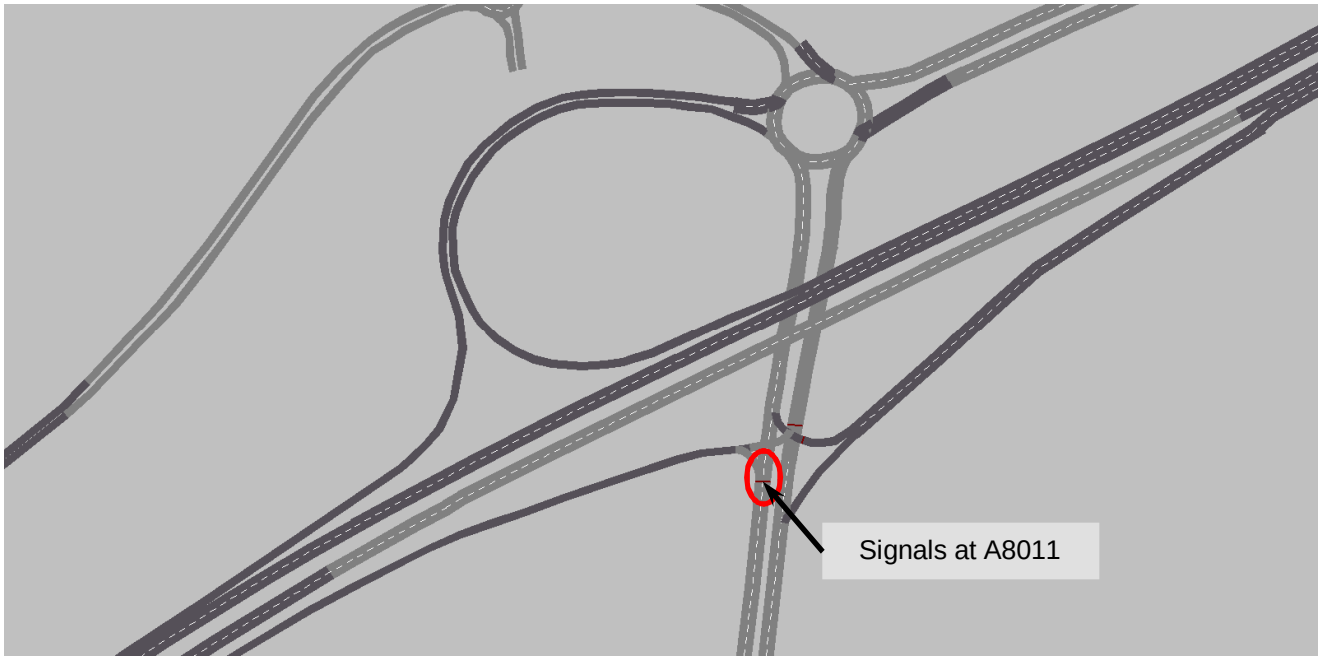

Figure B.4: Location of signals at A8011

B.5 Option 4

In Option 4, the closure of the northbound merge has been assessed. Figure B.5 shows the junction layout at Old Inns roundabout with the exit arm to the northbound merge closed, thus preventing any traffic to join the northbound on the M80.

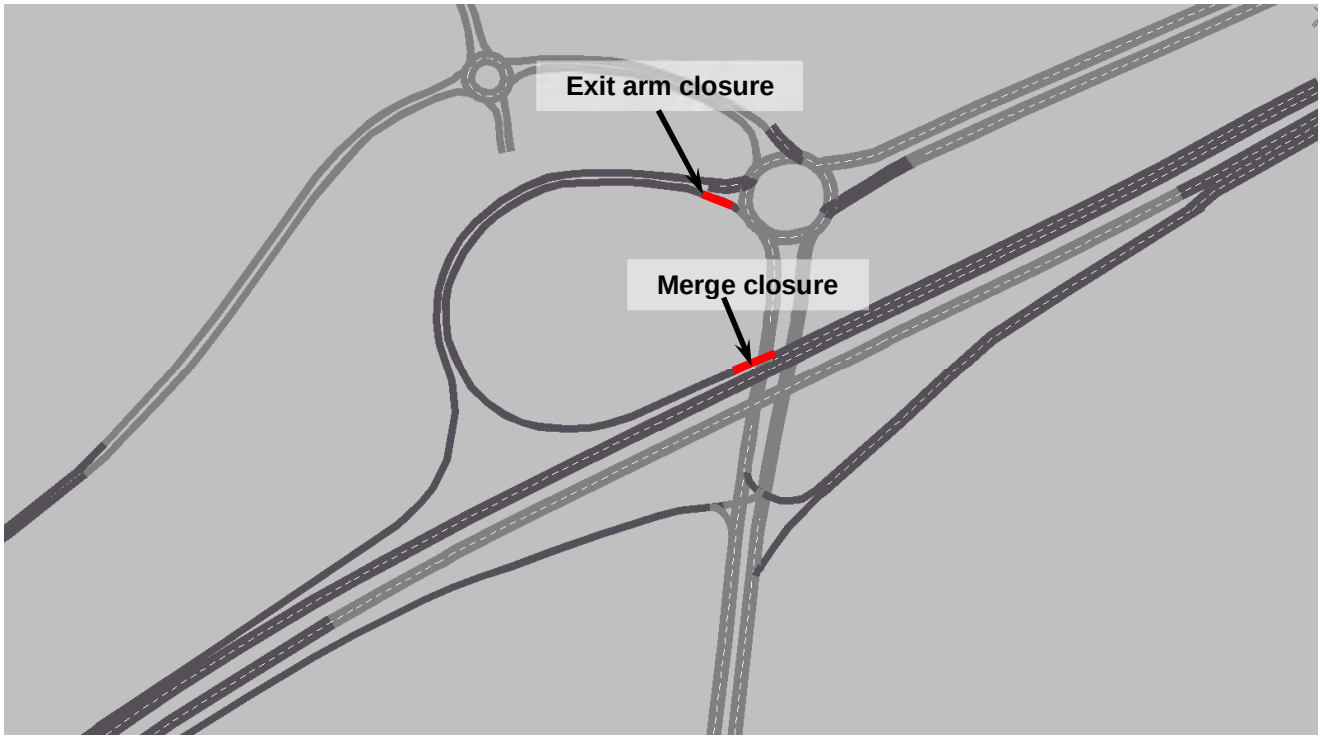

Figure B.5: Option 4 at Old Inns

While there is no intention to close the northbound merge, the assessment was undertaken to establish if the removal of merging traffic would enhance the free flow of traffic on the main line. The results of this option as detailed in Appendix E presents the contrary. The closing of the merge results in vehicles travelling from the A8011 and Eastfield Road routing east on Castlecary Road to head north on the M80. This results in queuing at Old Inns roundabout due to the traffic flow which has diverted from using the Old Inns merge. The congestion at Old Inns roundabout causes queuing on the diverge which blocks back to the M80 resulting in stationary traffic on the mainline.

B.6 Option 5

Option 5 is a combination of Option 1 and Option 2. In this option, the solid white line road marking after the nose is extended by 230 metres; the auxiliary lane is extended to the north and formed within the existing hard shoulder. Figure B.6 shows the junction layout at Old Inns for this option.

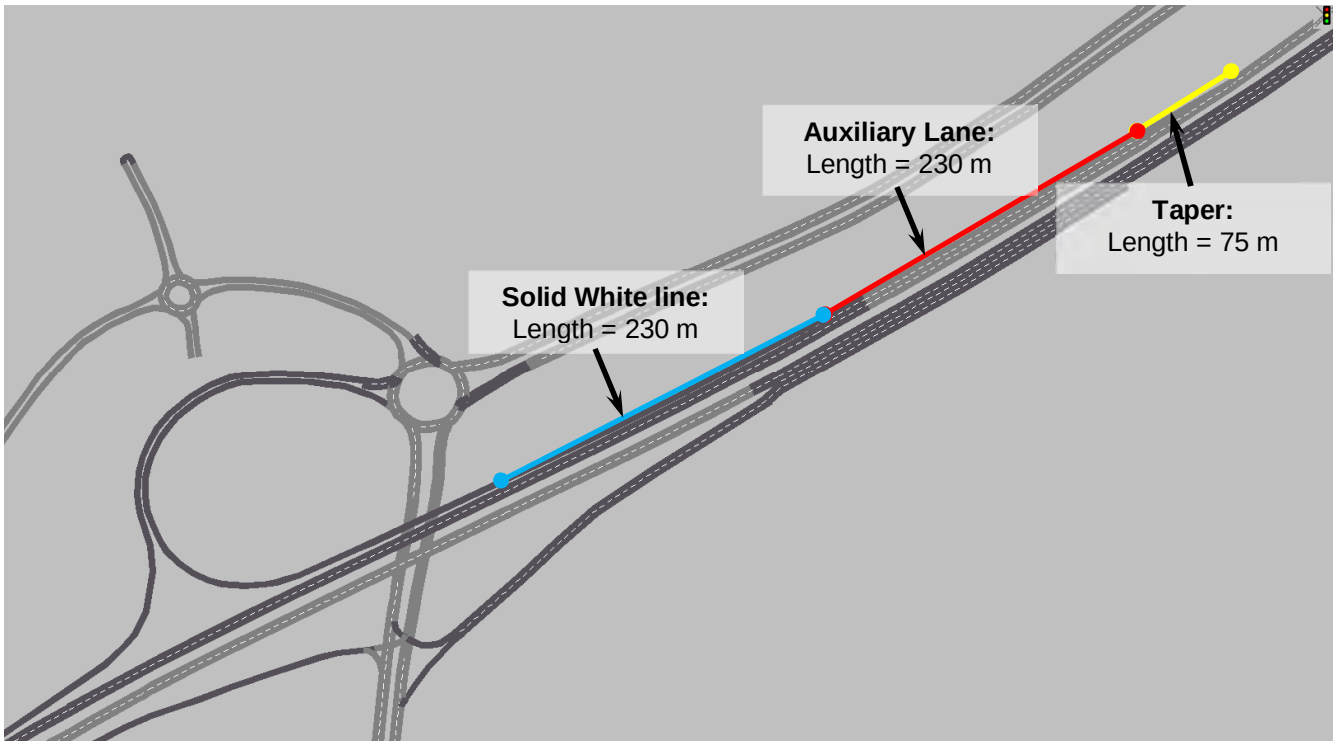

Figure B.6 : Option 5 at Old Inns

The network performance of this option is detailed in Appendix E. This option exhibits improved journey times and less slow moving vehicles and while the length of queues are reduced they are not removed.

B.7 Option 5 A

Option 5A is similar to Option 5; however, the solid white line marking is extended by 600 metres. This length was applied in order that traffic would be merging on a down gradient and theoretically mainline traffic speeds would benefit from the gradient in the same way the uphill gradient, south of the Old Inns junction contributes to slow moving northbound traffic. Figure B.7 shows the junction layout at Old Inns for this option.

The network performance of this option, as detailed in Appendix E, is similar to Option 5.

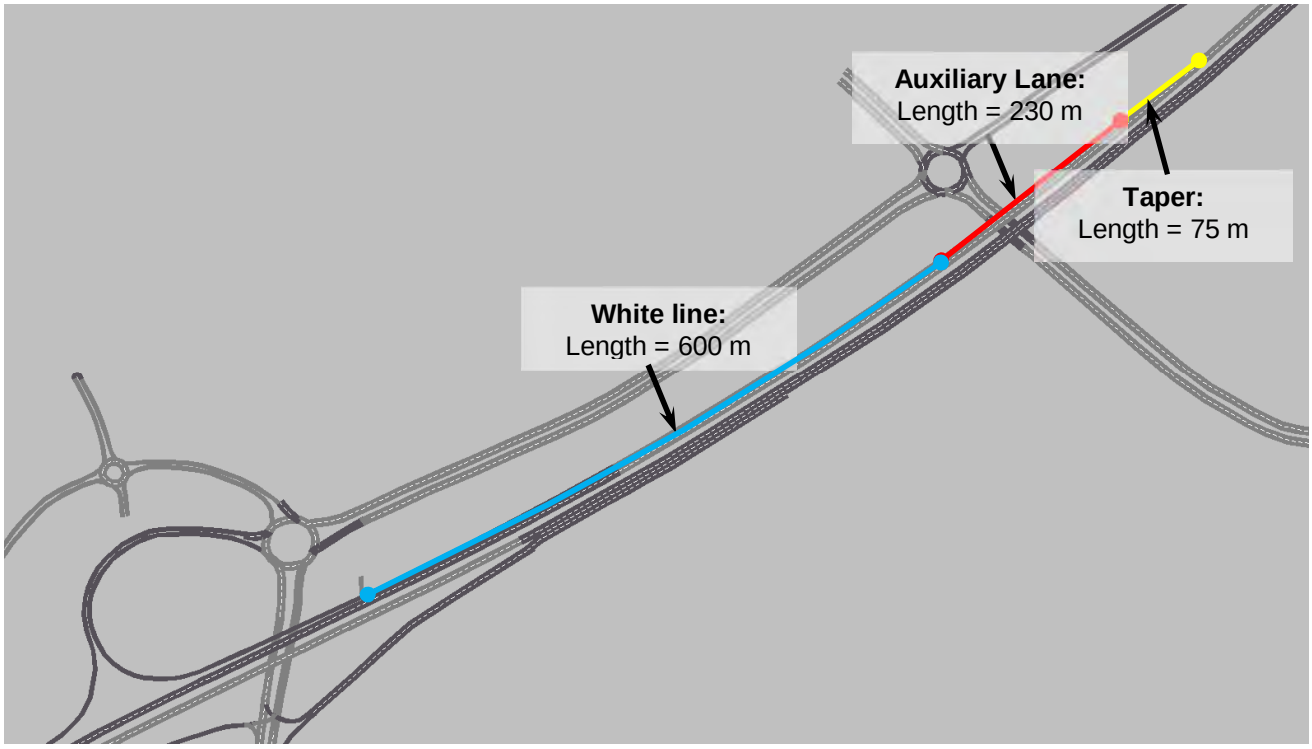

Figure B.7 : Option 5A at Old Inns

B.8 Option 6

In Option 6, the various measures introduced to improve the M80 network performance are as follows:

- The junction layout is similar to Option 5 as shown in Figure B.8; the solid white line road marking after the merge nose is 230 metres, the auxiliary lane is 230 metres and the taper is 75 metres;
- A peak hour speed limit of 40 mph was introduced for the northbound traffic upstream of the Low Wood junction to a point downstream of the Old Inns junction. The principle of introducing this speed limit is to provide consistent speeds and smoother traffic flow by removing the stop-start nature of a congested motorway and thus reduce the ripple effect upstream of the Old Inns junction. It is predicted that this measure may form part of wider managed motorway measures for the M80 as a whole;
- A ramp meter is introduced at the merge-slip at Old Inns junction. Its location is shown in Figure B.8. The ramp meter would control the rate of traffic merging with the main line. The modelled ramp meter has a cycle time of 12 seconds with 7 seconds of green time. The introduction of the ramp meter is predicted to result in queuing on the merge but it is not predicted to block back onto the Old Inns roundabout;
- In the Stage 1 assessment, it was determined that rat running occurred on the A8011 due to drivers avoiding the M80 congestion upstream from the Old Inns junction. The rat running traffic leave the M80 at the Low Wood junction to re-join the M80 at Old Inns or Castlecary via Cumbernauld town centre or Eastfield Road. From a single day survey there were approximately 300 vehicles between 0700 and 1000 undertaking this diversionary route. There were a further 50 using the A8011 but joining at the Castlecary junction. It is expected that the introduction of ramp meter at the merge will displace the 350 vehicles from A8011 to the M80 main line as a result of improved flows on the M80 and additional delay on the Old Inns merge.

The results of this option are detailed in Appendix E. From the assessment of all options it is concluded that Option 6 provides the most favourable benefits with reduced journey times, higher traffic flow and limited queuing on the M80 main line.

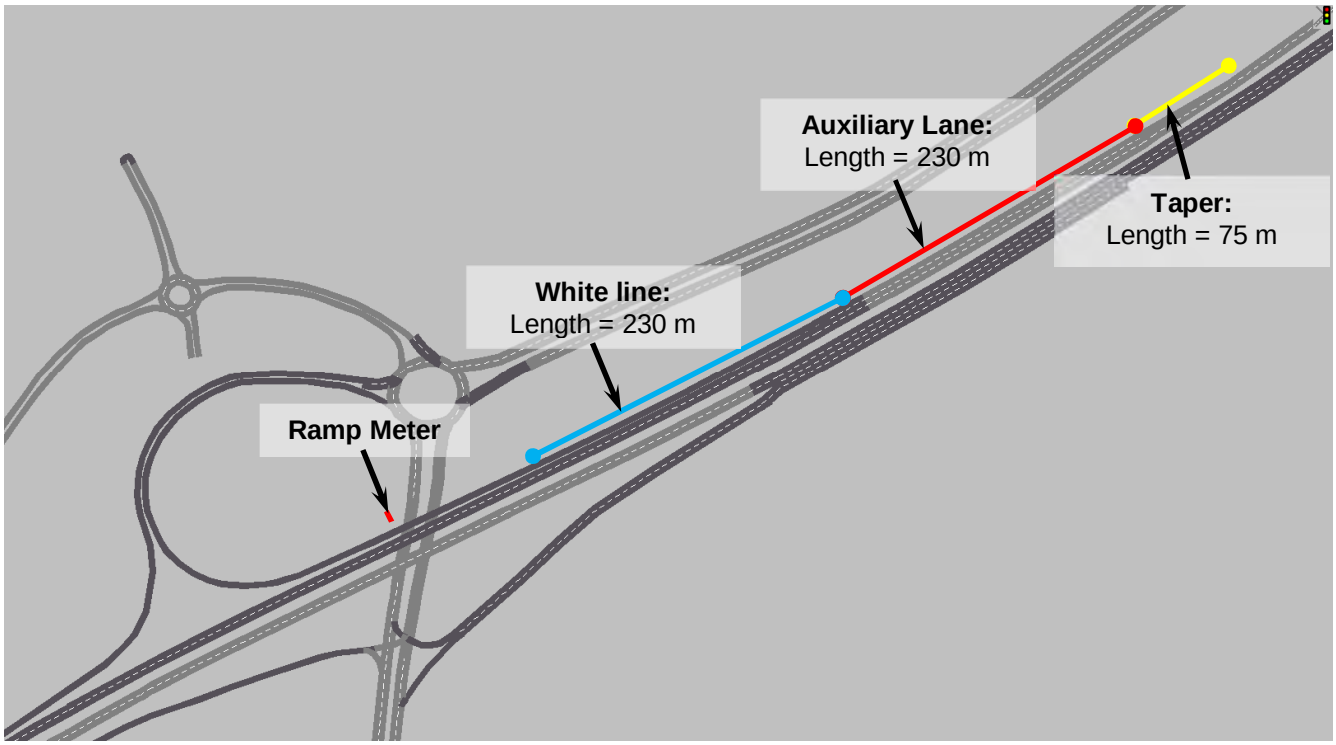

Figure B.8 : Option 6 at Old Inns

B.9 Proposal Constraints

The options which make use of the existing hard shoulder in order to extend the length of the merge will result in a number of departures being applicable. Therefore Transport Scotland Standards Branch has been consulted on the potential options to be taken forward.

Based on the existing cross section the extended merge would have a lane width of 3.3m in comparison to the current 3.7m. There would also be the absence of a hard shoulder over the length of the extended merge lane. There is the option to amend the full cross section in order to provide a 3.5m wide merge lane. This would result in departures from the current 3.65m running lanes to a minimum of 3.5m lanes.

Appendix C. Old Inns Trip Distribution

Trip distribution applied in this model is similar to that in the Castlecary junction testing VISSIM model. The 2012 model demand has been factored based on the year 2014 ATC counts at Old Inns and Haggs. A doubly constrained growth factor model (Furness method) was used to obtain the demand matrices for the year 2014.

Appendix D. Old Inns Model Validation

The base model is primarily validated in terms of traffic flows. Journey times and queues are validated based on observations during site visits. Four site visits were undertaken in February and November 2014 during the M80 Stage 1 assessment. Queue lengths and journey times were calculated for both for northbound and southbound journeys between M80/ M73 and M80/ M876 junctions in the morning and evening peak periods.

D.1 Traffic flows

D.1.1 Location of traffic counters

Figure D.1 shows the location of the data collection points at Old Inns junction on the M80 main line, on the merge and the diverge which are used to assess the traffic flow in each link.

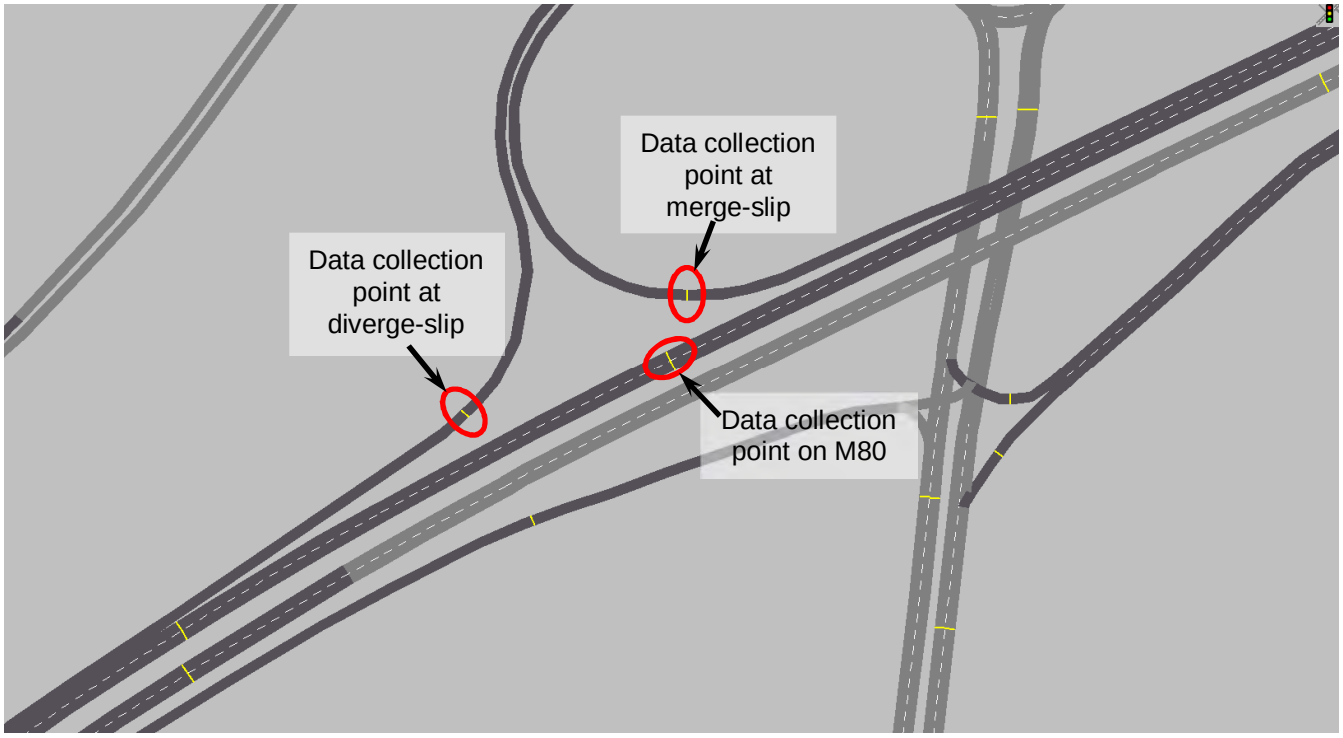

Figure D.1 : Location of data collection points at Old Inns junction

The base model is validated in terms of traffic flow through the counters in the model located at Old Inns junction and their corresponding ATC information. Table D.1, Table D.2 and Table D.3 shows the traffic flow counts from the model and the ATC counts. It also shows that the variation between the base model and the ATC counts falls below 15% in all cases. The Design Manual for Roads and Bridges (DMRB), Volume 12.2.1, acceptability guideline is a 15% variation in traffic flows. Hence, the model is validated in terms of traffic flows.

Table D.1 : Traffic flows on M80 main line

Time Period	Traffic flows (number of vehicles)		Difference in traffic flows with respect to ATC counts (in %)
	From model	From ATC counts – NTC00469	
0700-0800	2967	3159	-6.07%
0800-0900	2929	2759	6.17%

Table D.2 : Traffic flows on M80 merge

Time Period	Traffic flows (number of vehicles)		Difference in traffic flows with respect to ATC counts (in %)
	From model	From ATC counts – NTC00471	
0700-0800	889	905	1.75%
0800-0900	792	929	14.75%

Table D.3 : Traffic flows on M80 diverge

Time Period	Traffic flows (number of vehicles)		Difference in traffic flows with respect to ATC counts (in %)
	From model	From ATC counts – NTC00470	
0700-0800	326	319	-2.26%
0800-0900	333	340	1.94%

D.2 Journey times

Journey times calculated from the model for the entire section of M80 main line, from the south of Low Wood to the north of Haggs (as shown in Figure E.4) is compared to the journey times observed during site visits. It was calculated that the average speed is approximately 27 mph between 0700 and 0900, based on, both the modelled journey times and observed journey times. It should be noted that in the observed journey times there is considerable variance from the average speed of 27 mph and it is not a consistent speed through the network. Thus, it is justified that the model is in concurrence with the existing conditions in terms of journey times.

Table D.4 shows that journey times observed for the northbound traffic starting from Low Wood at 0740. It shows that there is a difference of 3% in the observed and model average speeds, which is in accordance with DMRB acceptance range.

Table D.4 : Journey time comparison

Scenario	Time period	Distance travelled (in miles)	Journey time (in s)	Average speed (mph)	Difference in average speed based on observation (in %)
Observation during site visit	0740 AM	6.5	1395	16.8	-
Base model	0740 AM	2.9	609	17.2	3%

D.3 Queues and Vehicle Speeds

Queues are determined for the base model from queue counters within the model located between Old Inns and Low Wood (as shown in Figure E.8). It is concluded that the queuing behaviour and vehicle speeds produced in the model are generally in accordance with the queuing and speed characteristics observed during the site visits. Hence, it can be concluded that the modelled queues are representative of existing conditions.

Appendix E. Old Inns Results and Analysis

E.1 Traffic flow analysis

E.1.1 M80 main line traffic flow

Table E.1 presents the traffic flow on the M80 main line at Old Inns for the various options. It also shows the change in traffic flow in the options in comparison with the base model. Increases in traffic flows demonstrate more throughput during the modelled hours which represent reductions in delays and queuing.

Table E.1 : Traffic flows on M80 main line at Old Inns

Scenario	Traffic flows (number of vehicles)		Changes in flows in comparison with base model (in %)	
	0700-0800	0800-0900	0700-0800	0800-0900
Base Model – 2014	**2967**	**2929**	**-**	**-**
Option 1 – white line extension	2719	2736	-8%	-7%
Option 2 – merge length extension	3150	3126	6%	7%
Option 3 – signal modification on A8011	3052	3034	3%	4%
Option 4 – merge slip closure	2890	1154	-3%	-61%
Option 5 – white line and merge extension	3088	3093	4%	6%
Option 5A – white line and merge extension	3188	3180	7%	9%
Option 6 – speed restriction and ramp meter	3369	3341	14%	14%

Figure E.1 shows the change in traffic flow on the M80 main line at Old Inns in each option on comparison with the base model.

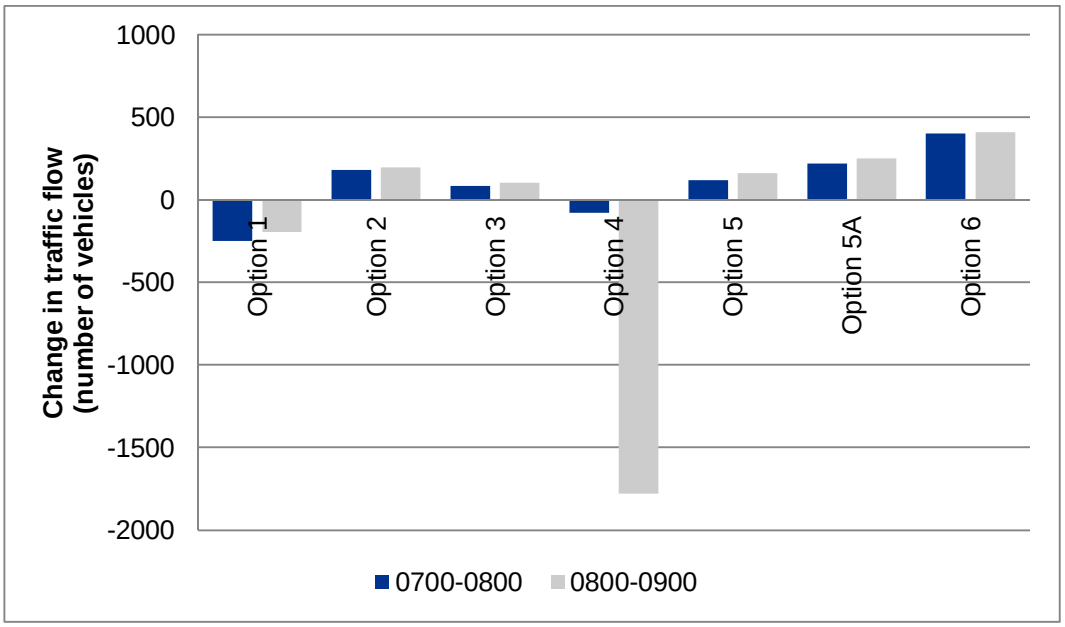

Figure E.1 : Change in traffic flow on M80 main line with respect to base model

Table E.1 and Figure E.1 show that Option 6 performs better than the other options in terms of M80 traffic flows and Option 4, the merge closure, is the least favourable option.

E.1.2 Merge traffic flows

Table E.2 presents the traffic flow for the various options on the merge at Old Inns junction and its comparison with the base model.

Table E.2 : Traffic flows on merge at Old Inns

Scenario	Traffic flows (number of vehicles)		Changes in flows in comparison with base model (in %)	
	0700-0800	0800-0900	0700-0800	0800-0900
Base Model - 2014	**889**	**792**	**-**	**-**
Option 1 – white line extension	888	860	0%	9%
Option 2 – merge length extension	889	859	0%	8%
Option 3 – signal modification	786	833	-12%	5%
Option 4 – merge slip closure	0	0	-100%	-100%
Option 5 – white line and merge extension	888	859	0%	8%
Option 5A – white line and merge extension	888	861	0%	9%
Option 6 – speed restriction and ramp meter	664	677	-25%	-15%

Figure E.2 shows the change in traffic flow on the merge at Old Inns in each option in comparison with the base model.

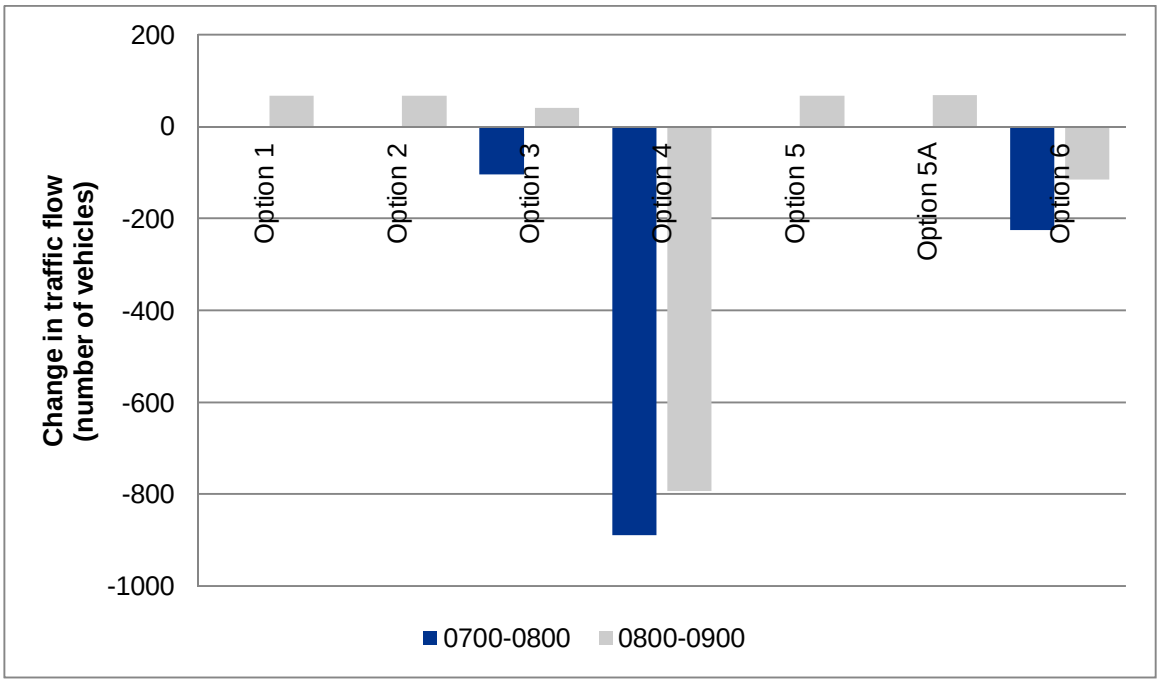

Figure E.2 : Change in traffic flow on merge slip with respect to base model

E.1.3 Diverge traffic flows

Table E.3 presents the traffic flow for the various options on the diverge at Old Inns junction and its comparison with the base model.

Table E.3 : Traffic flows on diverge slip at Old Inns

Scenario	Traffic flows (number of vehicles)		Changes in flows in comparison with base model (in %)	
	0700-0800	0800-0900	0700-0800	0800-0900
Base Model - 2014	**326**	**333**	**-**	**-**
Option 1 – white line extension	301	315	-8%	-6%
Option 2 – merge length extension	348	367	7%	10%
Option 3 – signal modification	336	359	3%	8%
Option 4 – merge slip closure	261	122	-20%	-63%
Option 5 – white line and merge extension	340	364	4%	9%
Option 5A – white line and merge extension	351	374	8%	12%
Option 6 – speed restriction and ramp meter	359	380	10%	14%

Figure E.3 shows the change in traffic flow on the diverge at Old Inns in each option in comparison with the base model.

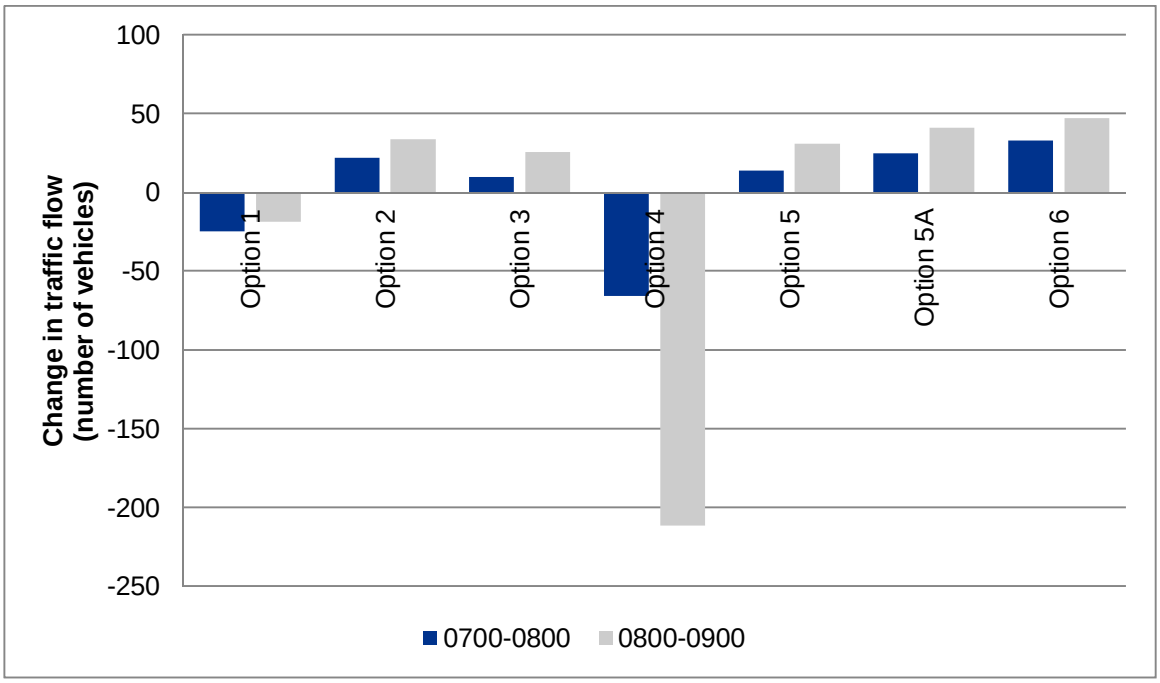

Figure E.3 : Change in traffic flow on diverge-slip with respect to base model

E.2 Journey times

Journey times are calculated for two different lengths of the M80 road network:

- The length of the M80 main line represented in the model, a distance of 10.9 kilometres from south of Low Wood to east of the M876 junction
- From Low Wood to the extents of the Old Inns merge, a distance of 4.7 kilometres

E.2.1 Journey time sections

Figure E.4 and Figure E.5 show the two different lengths of M80 main line used for journey time analysis.

Figure E.4 : M80 main line

Figure E.5 : Low Wood to Old Inns

E.2.2 Journey time analysis

E.2.2.1 M80 main line

Table E.4 shows the journey times for the M80 main line section for the various options and its change with respect to base model journey times.

Table E.4 : Journey times for M80 main line

Scenario	Journey times (in seconds)		Changes in journey times in comparison with base model (in %)	
	0700-0800	0800-0900	0700-0800	0800-0900
Base Model - 2014	**850**	**1006**	**-**	**-**
Option 1 – white line extension	887	1085	4%	8%
Option 2 – merge length extension	848	1056	0%	5%
Option 3 – signal modification	822	977	-3%	-3%
Option 4 – merge slip closure	772	2065	-9%	105%
Option 5 – white line and merge extension	821	986	-3%	-2%
Option 5A – white line and merge extension	805	945	-5%	-6%
Option 6 – speed restriction and ramp meter	793	861	-7%	-14%

Figure E.6 graphically represents the change in journey times for the M80 main line with respect to the base model journey times.

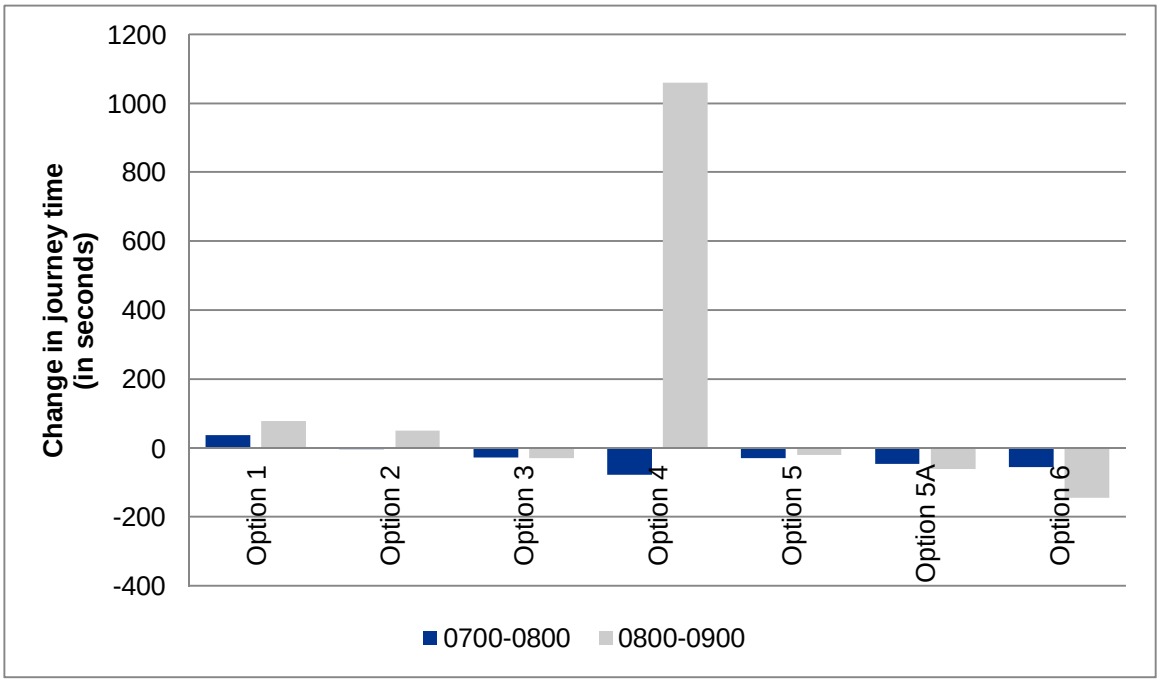

Figure E.6 : Change in journey times for M80 main line

E.2.2.2 Low Wood to Old Inns

Table E.5 shows the journey times for the Low Wood to Old Inns section for the various options and its change with respect to base model journey times.

Table E.5 : Journey times for Low Wood to Old Inns

Scenario	Journey times (in seconds)		Changes in journey times in comparison with base model (in %)	
	0700-0800	0800-0900	0700-0800	0800-0900
Base Model - 2014	**505**	**579**	-	**-**
Option 1 – white line extension	551	640	9%	10%
Option 2 – merge length extension	447	555	-12%	-4%
Option 3 – signal modification	478	555	-5%	-4%
Option 4 – merge slip closure	451	1592	-11%	175%
Option 5 – white line and merge extension	471	547	-7%	-6%
Option 5A – white line and merge extension	433	498	-14%	-14%
Option 6 – speed restriction and ramp meter	405	436	-20%	-25%

Figure E.7 represents the change in journey times for the Low Wood to Old Inns section with respect to the base model journey times.

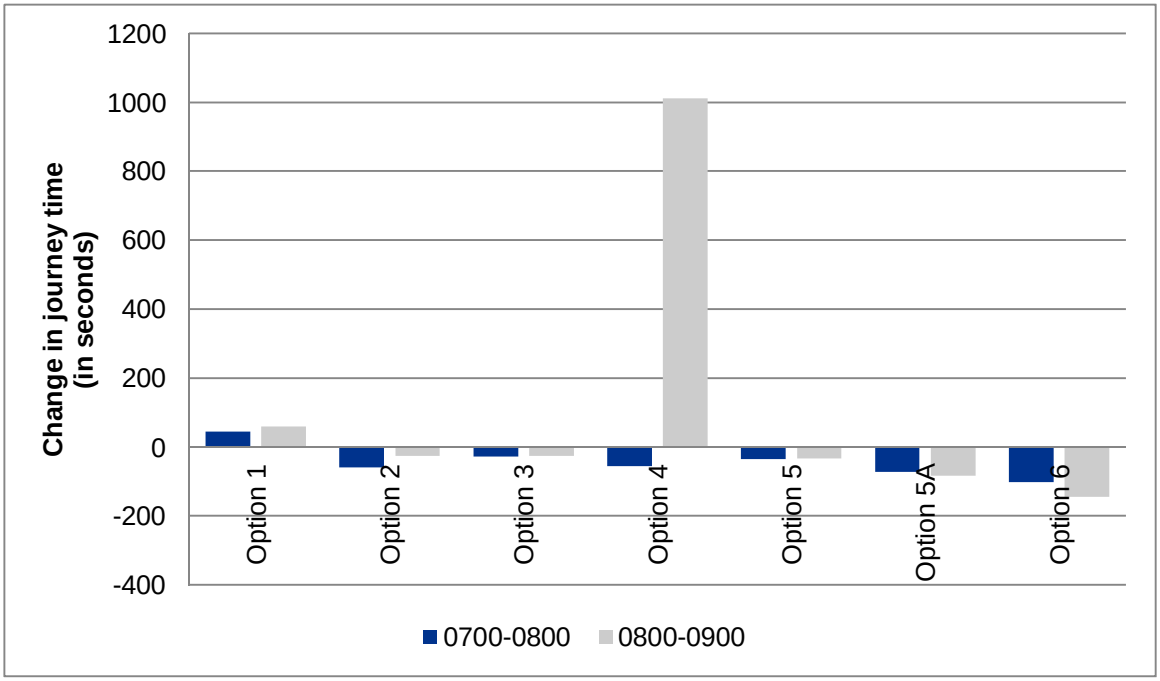

Figure E.7 : Change in journey times for Low Wood to Old Inns

E.3 Queues

E.3.1 Location of queue counters

Within the model, queue counters are placed at regular intervals from Old Inns junction downstream past Low Wood junction to determine the predicted level of queueing on M80. The counters on the M80 are at approximately 300 m intervals to determine the ripple effect on the M80 northbound traffic caused by the congestion issues at Old Inns junction. Figure E.8 and Figure E.9 show the location of queue counters to the south of Old inns junction and on the northbound merge.

For queue analysis, a vehicle is said to be in a queue if its speed is less than 3 mph in the beginning of the queues and has not exceeded 6 mph in the end of the queue.

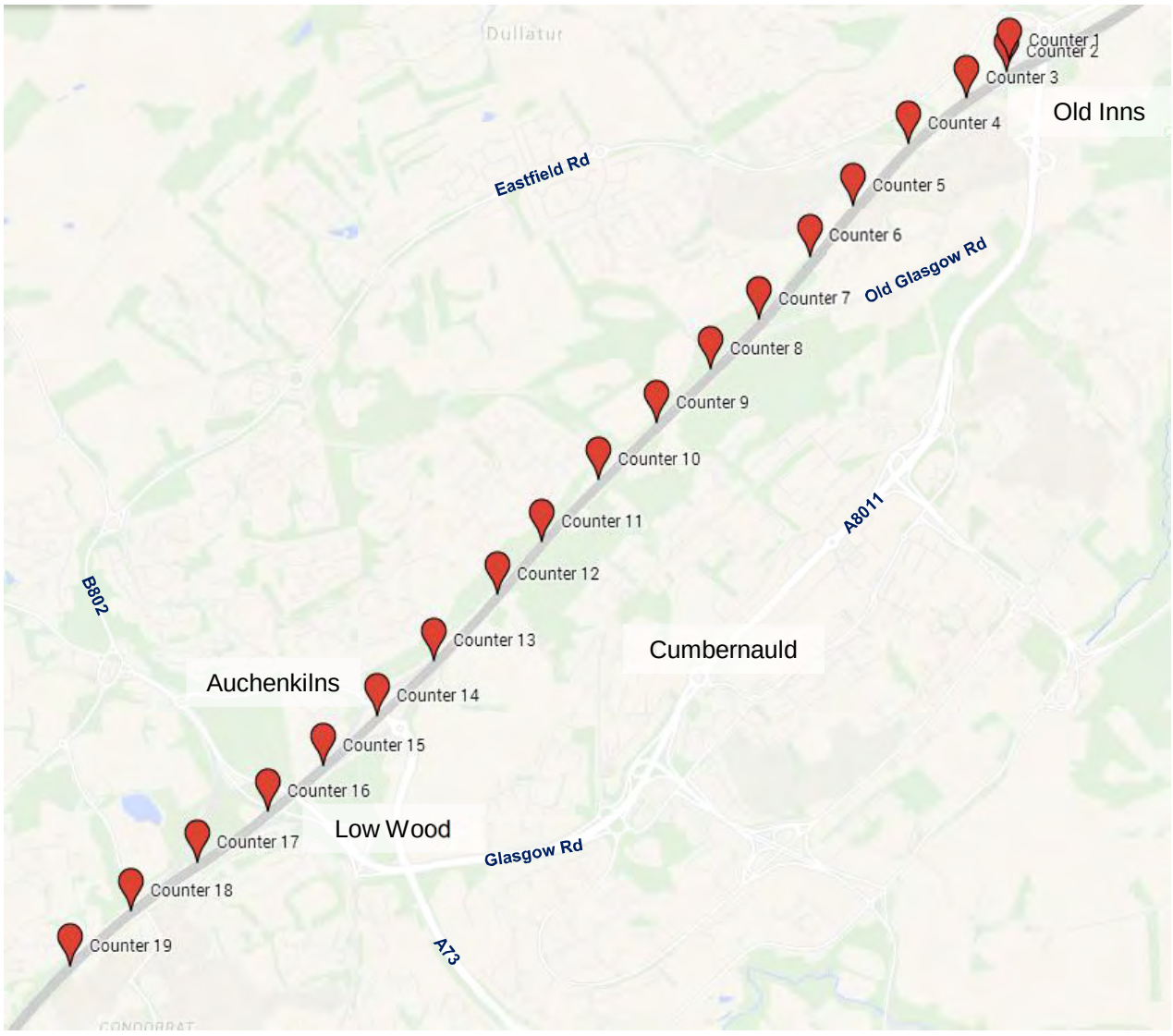

Figure E.8 : Location of queue counters to the south of Old Inns junction

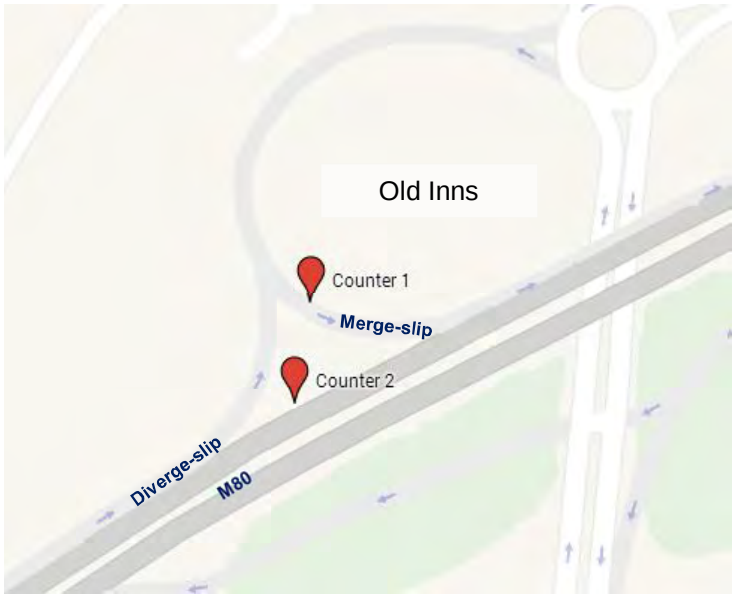

Figure E.9 : Location of queue counters at Old Inns junction

E.3.2 Queue Analysis

Figure E.10 shows the change in queue lengths at each counter for all the options on comparison with the base model.

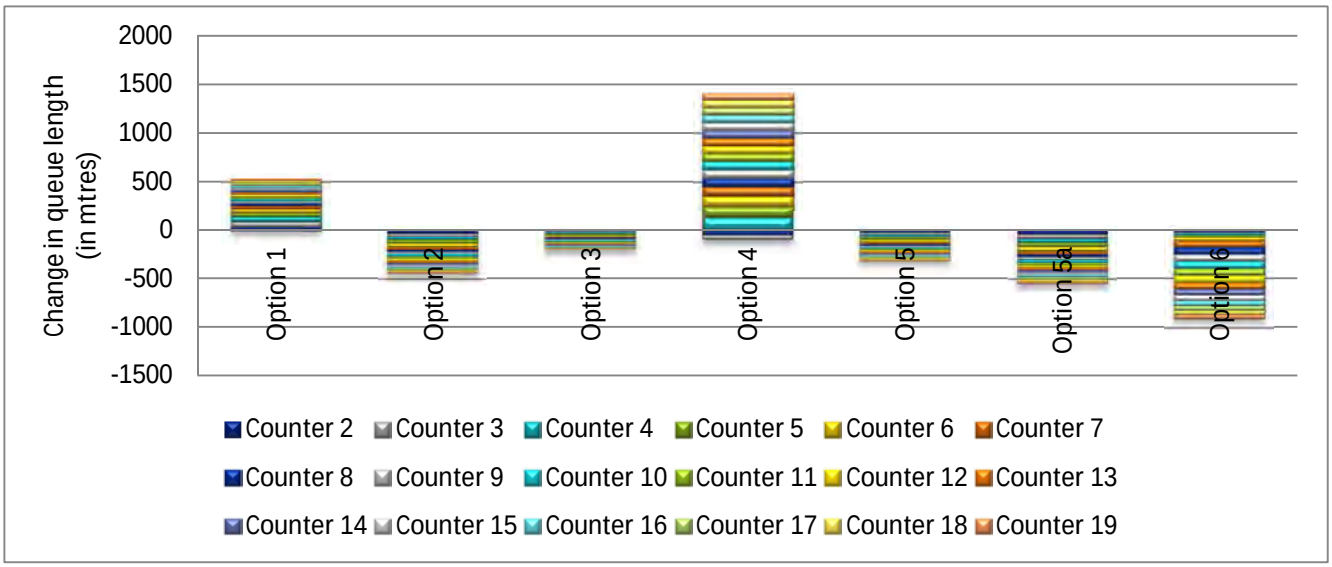

Figure E.10 : Difference in queue length with respect to base model

E.4 Analysis Conclusion

E.4.1.1 Traffic Flows

Figure E.1 shows that the main line traffic flow in Option 4 drops by 3% and 61% during 0700-0800 and 0800-0900, respectively. This is caused by stationary traffic on the M80 main line because of the merge closure. It shows that in Option 6 there is a 14% increase in traffic during 0700-0800 and 0800-0900. This is caused by the steady flow of traffic on the main line and the reduction in slow moving vehicles at the Old Inns junction which limits the ripple effect to the south of the junction.

Figure E.2 shows that, in Option 6 there is a fall (25% and 13% during 0700-0800 and 0800-0900, respectively) in traffic flow from the merge. This is caused by the displacement of 350 vehicles from the A8011 to the M80 main line. Figure E.3 shows that Option 6 facilitates traffic flow on the diverge by 10% and 14% during 0700-0800 and 0800-0900, respectively.

Option 6 accommodates the maximum traffic flow at Old Inns junction in comparison to the other options.

E.4.1.2 Journey times

The analysis for journey times is consistent with that of traffic flow which shows that Option 6 provides the most benefit and Option 4 the least benefit.

Figure E.6 shows that Option 6 journey times for the M80 main line (i.e., from the south of Low Wood to the north of Haggs) reduces by 56 seconds during 0700-0800 and 146 seconds during 0800-0900. Figure E.7 shows that the journey times from Low Wood to Old Inns reduces by an average of 120 seconds between 0700 and 0900 for Option 6.

E.4.1.3 Queue Analysis

It can be seen in Figure E.10 that Option 4 has the maximum queuing while Option 6 has the least queuing with respect to the base model. Closure of the merge (Option 4) causes significant queuing on the M80 main line due to the congestion at Old Inns roundabout.

E.5 Observed queues and vehicle speeds in the models

The lanes in the base model and Option 6 are colour coded based on the speed of the vehicles in their respective northbound lanes. The colour coding is shown in Figure E.11.

It can be seen from the below figure that lanes coded in the first two categories – pink (0 mph to 5 mph) and red (5 mph to 10 mph) are likely to consist of queuing traffic.

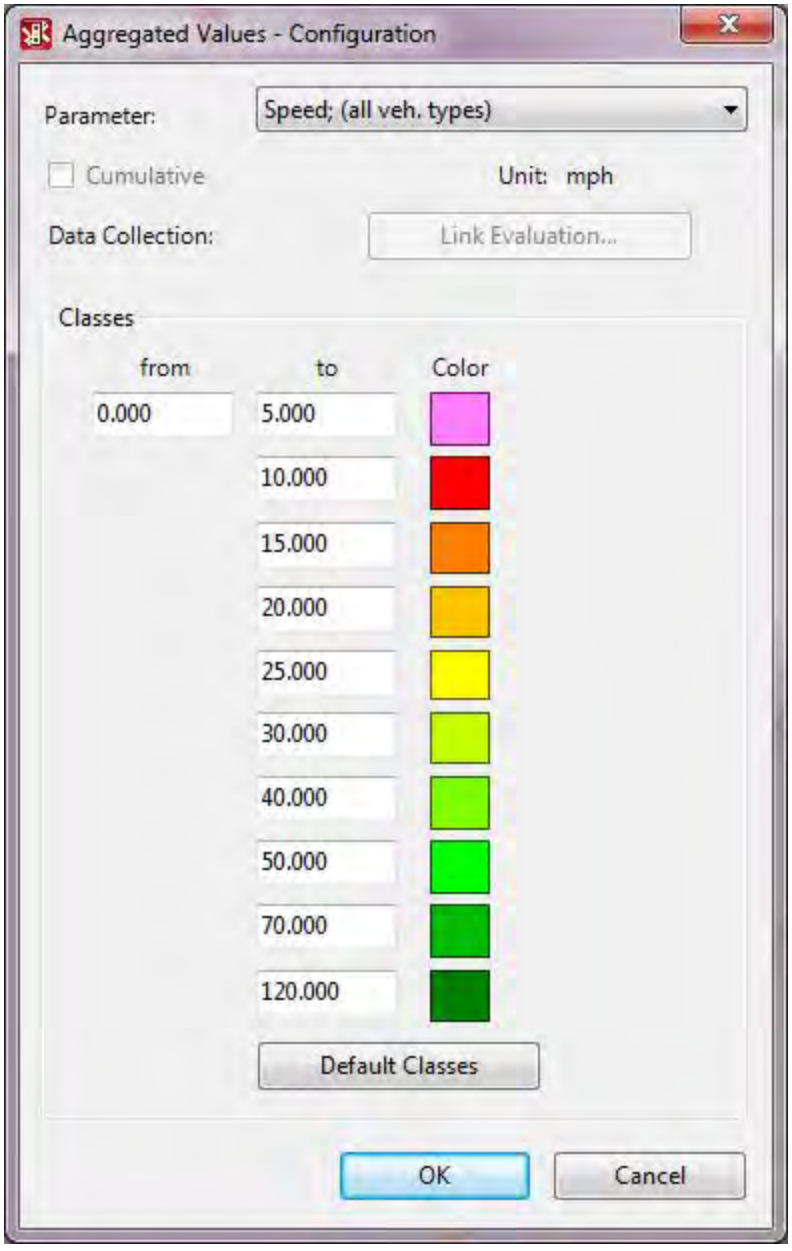

Figure E.11 : Colour coding for queues based on speed of vehicles

E.5.1.1 At time period 0730

Figure E.12 : Queues observed in base model

Figure E.13 : Queues observed in Option 6

E.5.1.2 At time period 0800

Figure E.14 : Queues observed in base model

Figure E.15 : Queues observed in Option 6

E.5.1.3 At time period 0830

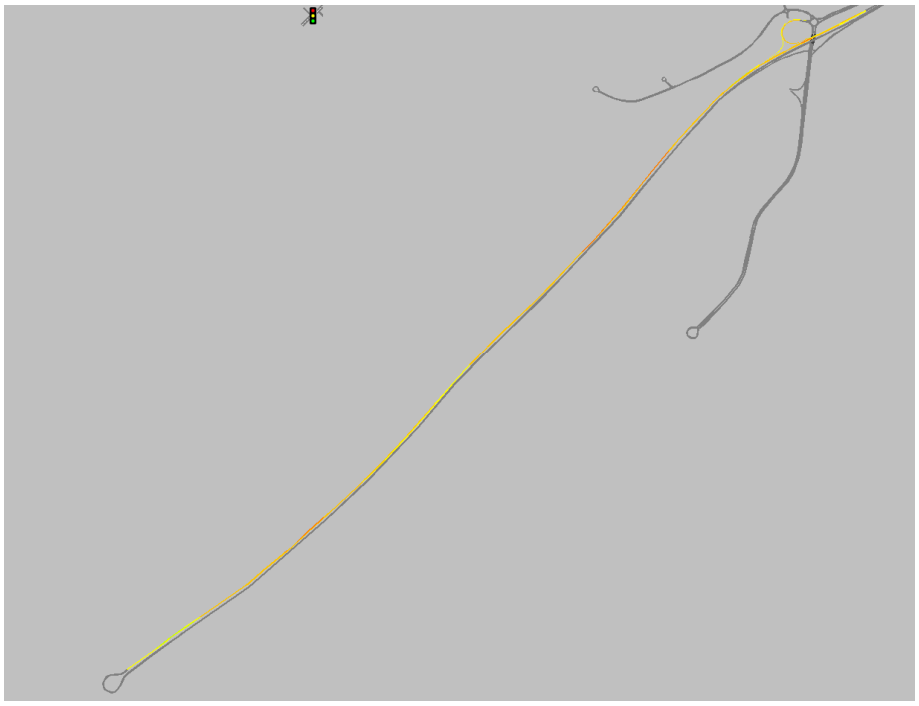

Figure E.16 : Queues observed in base model

Figure E.17 : Queues observed in Option 6

E.5.1.4 At time period 0900

Figure E.18 : Queues observed in base model

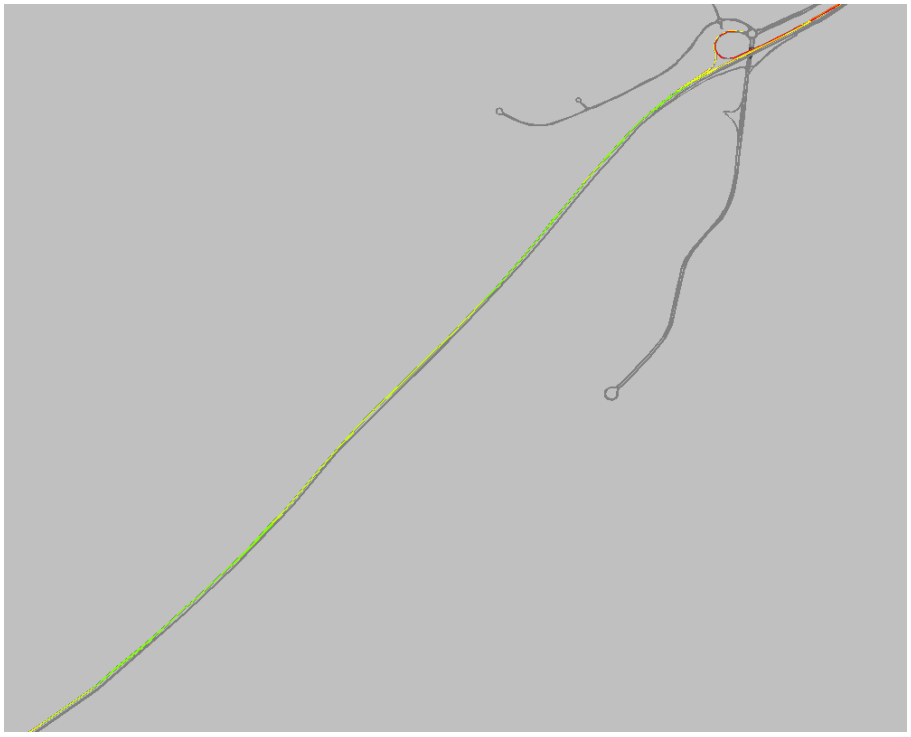

Figure E.19 : Queues observed in Option 6

The above figures (Figure E.12 to Figure E.19) show that the northbound traffic, between Low Wood and Old Inns, in the base model moves in the speed range of 15 mph to 25 mph whereas in Option 6, it moves in the speed range of 20 mph to 40 mph. Hence, it is concluded that in Option 6, there are less instances of queueing in the northbound traffic than the base model, thus, improving the journey times.

Appendix F. VISSIM definitions

F.1.1 Vehicle Parameters

The vehicle parameters are defined below:

- **Standstill distance** defines the desired distance between stopped cars. It has no variation.
- **Headway time** is the time (in seconds) that a driver wants to keep. The higher the value, the more cautious the driver is.
- The **safety distance** is defined in the model as the minimum distance a driver will keep while following another car. In case of high volumes this distance becomes the value with the strongest influence on capacity.
- **Following variation** restricts the longitudinal oscillation or how much more distance than the desired safety distance a driver allows before he intentionally moves closer to the car in front. If this value is set to e.g. 10 m, the following process results in distances between dx_safe and dx_safe + 10 m. The default value is 4.0 m which results in a quite stable following process.
- **Threshold for entering 'Following'** controls the start of the deceleration process, i.e. when a driver recognizes a preceding slower vehicle. In other words, it defines how many seconds before reaching the safety distance the driver starts to decelerate.
- **Following thresholds** control the speed differences during the 'Following' state. Smaller values result in a more sensitive reaction of drivers to accelerations or decelerations of the preceding car, i.e. the vehicles are more tightly coupled.
- **Speed dependency of oscillation:** Influence of distance on speed oscillation while in following process. If set to 0 the speed oscillation is independent of the distance to the preceding vehicle. Larger values lead to a greater speed oscillation with increasing distance.
- **Oscillation acceleration:** Actual acceleration during the oscillation process.
- **Standstill acceleration:** Desired acceleration when starting from standstill (limited by maximum acceleration defined within the acceleration curves)
- **Acceleration at 80 km/h:** Desired acceleration at 80 km/h (limited by maximum acceleration defined within the acceleration curves).

F.1.2 Cooperative Lane Change

If vehicle A observes that a leading vehicle B on the adjacent lane wants to change to the (A) lane, then vehicle A will try to change lanes itself to lane (B) in order to make room for B.

Vehicle A behaves as if it had to change lanes for a connector far in the distance, accepting only the base values for necessary lane changes for its own deceleration and for the trailing vehicle C on the new lane.

Vehicle A does not change cooperatively to a lane which is less suited for its own route, and it does not change lanes cooperatively if vehicle B is more than 6.71 mph (=3 m/s) faster or if the collision time would exceed 10 seconds with the speed of vehicle A increased by 6.71 mph.