M3 Junction 9 Improvement Scheme

Highways England

Initial Assessment of Scheme Impact

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1. Introduction

1.1 Background

Highways England commissioned Jacobs to undertake a package of Advance Works focussed on the preparation of modelling tools expected to be used in the analysis of the M3 Junction 9 Improvement Scheme ("J9 scheme") in PCF Stage 3. The tool expected to be used is the M3M27 Smart Motorway Intervention model (M3M27 SMI), developed for Highways England in 2017 by a consortium of Arcadis and CH2M.

The M3M27 SMI model was developed on the basis of Highway's England South East Regional Traffic Model (SERTM) and was judged by Highways England to be fit for the purpose of modelling of interventions on the M3 and M27 motorways. It was used to support the M3M27 SMI scheme throughout PCF Stage 3 and provided results for the final business case. This model was identified by Highways England as the most suitable platform for the implementation of additional, targeted refinements as part of Advance Works and subsequent use in support of the J9 scheme throughout Stage 3. This work was ongoing at the time of writing this technical note.

In anticipation of adopting a new, improved modelling platform for the J9 scheme in PCF Stage 3, Highways England commissioned Jacobs to undertake initial, high-level tests of the scheme impacts and provide indicative assessment of likely benefits. This is expected to inform Highways England whether the new modelling platform is likely to corroborate the conclusions about Value for Money of the scheme reached on the basis of the outputs from PCF Stages 1 and 2[1]. This work was undertaken in the M3M27 SMI model provided to Jacobs "as is" by the M3M27 SMI team.

1.2 Purpose and content of this technical note

This technical note summarises the output of the work described in Section 1.1 above and describes the methodology, assumptions, results and limitations of this work. It does not constitute a formal PCF deliverable and has been prepared solely to provide an additional indication of the likely impact of the scheme. This Technical Note has been prepared for the purposes of Highways England, and Jacobs does not accept any liability for any use or reliance on this technical note by third parties.

The approach and underlying assumptions used in this analysis were agreed with Highways England. In undertaking this analysis Jacobs relied on the model handed over in a very short timescale by the lead consultants delivering the M3M27 SMI model (Arcadis) acting on behalf of Highways England's SMI team. No explicit verification of this information, such as the reported quality of the model, were undertaken. The information was presumed to be accurate and the model was used "as is". In addition, the indicative assessment of costs and benefits presented here relies in information provided by Highways Englandand sourced from the Stage 2 analysis. This technical note should be read in full and for the full details of model development the readers should consult the M3M27 SMI model documentation. The findings and conclusions presented here are indicative and may be subject to change following the completion of the planned model improvements and the full update of all appraisal components.

The remainder of this technical note is organised as follows:

- Section 2, Methodology - Describes the approach, scenarios modelled and key assumptions;
- Section 3, Results - Summarises the headline results of the test;
- Section 4, Model Performance - Lists the headline model performance statistics; and
- Section 5, Conclusions - Summarises the strengths and limitations of this analysis.

[1] PCF Stages 1 and 2 used different versions of the sub-regional traffic model for South Hampshire owned by Hampshire County Council. Whilst this model was considered to be the best available tool at that time, the now available SERTM-based model for this area is expected to offer higher levels of analytical assurance necessary for Stage 3 and ensure highest possible consistency of the analysis with the M3 Smart Motorway scheme.

2. Methodology

2.1 Approach

The indicative tests of the J9 scheme described in this technical note were based on the existing version of the M3M27 SMI model, provided by the Smart Motorway team for use in this study. The analysis focused on estimating indicative Present Value (PV) of transport user benefits.

The M3M27 model is implemented using SATURN strategic modelling software and based on the template of Highways England South East Regional Traffic Model (SERTM). The Fully Modelled Area broadly covers Hampshire as well as parts of Dorset, Wiltshire, Berkshire, Surrey and Sussex, but the model also captures key long distance route options across the rest of the Strategic Road Network, and is similar to the SERTM model. The model has been calibrated and validated as part of the M3M27 SMI model, including the variable demand model (VDM) based on DfT's DIADEM software.

Forecasts prepared as part of the M3M27 SMI project are based on the NTEM7.2[2] dataset, and include the relevant developments and schemes along M3 J9-14 (as well as along M27) known at that time. As such the model contains a good representation of M3 J9-14 Smart Motorway scheme and related traffic forecasts, which forms a crucial interaction with the J9 scheme.

We implemented J9 scheme infrastructure within the M3M27 SMI model network, and the rerun the model to provide estimates of journey time and vehicle operating cost changes. This included the full runs of VDM to the same standard as the M3M27 SMI model.

In this indicative assessment we re-estimated PV of transport user benefits using the outputs of the model described above. No other elements of appraisal such as the accident or environmental impacts were revisited. The figures for these impacts presented in Section Three were assumed to be the same as in Stage 2 appraisal and supplied by Highways England. Similarly, no other changes to the traffic model were implemented as part of this work and no further model detail is reported here[3] apart from the headline performance statistics discussed in Section Four.

2.2 Scenarios

The following scenarios are available from the M3M27 SMI model:

- Do-Minimum (no M27 SMI and no M3 SMI);
- Do-Something 1 (with M27 SMI, but no M3 SMI); and
- Do-Something 2 (with M27 SMI and M3 SMI).

The last scenario listed above represents the fully implemented set of Smart Motorway Interventions on the South Hampshire Strategic Road Network, and was assumed as the Do-Minimum scenario for the purpose of this indicative assessment. This scenario is available for the following modelled years and time periods):

- 2021 (AM, IP, PM) – SMI opening year; and
- 2036 (AM, IP, PM) – SMI design year.

Both modelled years and all time periods were used in the tests described in this note. Based on these, the following scenarios were defined for the indicative tests described here:

- J9 Do-Minimum (M3M27 SMI Do-Something 2 was adopted as the Do-Minimum scenario for this assessment as it includes the full implementation of the M3 & M27 Smart Motorway Interventions); and
- J9 Do-Something based on the above, but with the addition of the J9 scheme infrastructure. The J9 infrastructure option 14 (the preferred option) was implemented in this scenario.

[2] National Trip End Model version 7.2, Department for Transport, March 2017.
[3] Further detail related to the M3M27 SMI model can be found in M3M27 SMI Local Model Validation Report and Traffic Forecasting Report available from Highways England.

2.3 Assumptions

This section lists the key assumptions made in the indicative assessment described in this note:

- Modelled years & opening year - The expected opening year of the J9 scheme is 2023, two years after the modelled year. To enable efficient handling of this difference in the Transport Users Benefit Appraisal (TUBA) software, we adopted a simplifying assumption; we assumed the 2021 modelled year to be an approximation of the 2023 opening year and the 2036 modelled year to be an approximation of the 2038 design year, and labelled them as such in the appraisal process. We believe that this is a proportionate, but conservative assumption as we would expect the congestion in 2023 & 2038 to be slightly higher than in 2021 & 2036, and the higher magnitude of journey time savings in such conditions is not captured here. We assumed no further demand growth beyond 2038.

- Time periods & annualisation factors – We adopted the annualisation factors used in the M3M27 SMI study without further modification. They are standard and consistent with the methodology used in SERTM. It is an average hour model for each modelled time period and the results are expanded to each respective full time period in a straightforward manner. We also adopted the M3M27 SMI annualisation factors for the weekend and bank holiday benefits without any modification. We judge this to be proportionate given their smaller magnitude and relevance to this corridor. Table 2-1below summarises the annualisation factors.

Period	Annualisation factor
AM – 07:00 – 10:00 (Average Weekday)	759
IP – Average of 10:00 – 16:00 (Average Weekday)	1518
PM – 16:00 – 19:00 (Average Weekday)	759
Weekend	416
Bank Holidays	24

Table 2-1: Annualisation factors.

- We adopted the reference case forecasts from the M3M27 model without modification. This is proportionate and appropriate, given that the uncertainty log[4] was developed specifically for the M3 / M27 corridor. The definition of committed schemes is based on the M3M27 SMI model. The Do-Minimum adopted in this test assumes the completion of the M3M27 SMI as well as the Smart Motorway Interventions on the M3 motorway (Junction 2 to 4A) and M4 motorway (Junction 3-12). Only the core scenario was used.

- We used TUBA version 1.9.10 in this test. This version includes the latest downward revision of the GDP forecast, which influences the growth in value of time used in appraisal. The result of this is a reduction in the value of future travel time savings when compared with the assessments undertaken in earlier versions of TUBA, in particular TUBA 1.9.8. This should be kept in mind when comparisons between the estimates reported here and Stage 1 estimates are made: the differences are driven by the change in the modelling tools as well as the changes in the assumptions about the GDP growth.

- The M3M27 SMI study reported difficulties with achieving high standard of convergence due to the size of the model. Unexpected changes in traffic were reported in locations unrelated to the M2M27 study area and were judged to be spurious. To control for such effects, the M3M27 SMI study applied a mask which isolates the effects in the area of influence of the scheme. The tests reported here used the M2M27 SMI model "as is" and retained this approach.

[44] Uncertainty log is a list of committed and likely developments and schemes relevant to the assessment of the scheme.

3. Results

3.1 Present Value of Transport User Benefits

The indicative Present Value (PV) of transport user benefits estimated in this test is **£122.5 million**. The breakdown of benefits in the standard Transport Economic Efficiency (TEE) table format (user benefits only) is presented in Table 3-1 below. The figures are presented in 2010 prices and values in the standard format set out in WebTAG guidance. This does not include environmental and accident impacts or any impacts during construction and maintenance.

Non-business: Commuting	
User Benefit	Value (£):
Travel time	30,147,609
Vehicle operating costs	-3,885,517
User charges	-102,172
Indirect Tax Revenues	1,426,087
During Construction & Maintenance	0
SUBTOTAL	27,586,007
Non-business: Other	
User Benefit:	Value (£):
Travel time	59,014,626
Vehicle operating costs	-1,002,579
User charges	-165,862
Indirect Tax Revenues	-4,289,327
During Construction & Maintenance	0
SUBTOTAL	53,556,858
Business	
User Benefit:	Value (£):
Travel time	49,596,906
Vehicle operating costs	-16,527,238
User charges	-69,583
Indirect Tax Revenues	8,341,026
During Construction & Maintenance	0
SUBTOTAL	41,341,111
Present Value of Transport Economic Efficiency Benefit (TEE)	
TOTAL (£):	122,483,976

Table 3-1: Indicative transport user benefits in TEE table format.

The majority of the benefits come from travel time savings. The scheme results in negative vehicle operating cost changes, likely associated with increases in average speeds and rerouting to a corridor with improved journey times. There is also a negligible change in user charges expected to arise from small changes in flows across tolled bridges or roads across the network.

Table 3-2 below provides an indicative analysis of the monetised costs and benefits. These are based on the indicative transport user benefits presented in Table 3-1 above and existing (not revisited) estimates of the environmental impacts, accidents and Broad Transport Budget impacts. The greenhouse gases impacts are re-estimated based directly on the outputs from TUBA undertaken as part of the indicative assessment of transport user benefits.

Indicative Analysis of Monetised Costs and Benefits	
Cost and Benefit Category	Value (£):
Noise *	-604,268
Local Air Quality *	-567,806
Greenhouse Gases **	-2,390,000
Journey Quality	n/a
Physical Activity	n/a
Accidents *	4,372,900
Economic Efficiency: Consumers (Commuters)	26,159,920
Economic Efficiency: Consumers (Other)	57,846,185
Economic Efficiency: Business Users & Providers	33,000,085
Wider Public Finances (Indirect Taxation Revenues)	5,477,786
Present Value of Benefits (see notes) (PVB)	**123,294,802**
Broad Transport Budget ***	82,379,000
Present Value of Costs (see notes) (PVC)	**82,379,000**
Net Present Value (NPV)	40,915,802
Benefit to Cost Ratio (BCR)	**1.50**

* Assessment of environmental impacts and accidents was supplied by Highways England from the Stage 2 analysis. No review or analysis of these impacts was undertaken as part of this indicative assessment

** Greenhouse gas impacts are taken directly from TUBA runs undertaken as part of this indicative assessment and are based on model years 2021 and 2036. No mask was applied to the greenhouse gases TUBA output.

*** The Broad Transport Budget impacts were supplied by Highways England from the Stage 2 analysis. No review or analysis of the components of the Broad Transport Budget impacts was undertaken as part of this indicative assessment.

Table 3-2: Indicative Analysis of Monetised Cost and Benefits.

The indicative Present Value of Benefits (PVB), based on the assumptions and components described above is approximately £123.3m. It includes transport user benefits, greenhouse gas and indirect tax estimates from this indicative assessment as well as the noise, air quality and accident impacts from the Stage 2 analysis. The Present Value of Cost (PVC) was supplied by Highways England from the Stage 2 analysis and is £82.4m. No review of the components or assumptions included in this estimate was undertaken. The Benefits to Cost Ratio implied by this set of estimates would be 1.5.

These indicative estimates will be revisited upon the completion of Stage 3 and may be subject to change.

3.2 Results by Sector

The PV of transport user benefits disaggregated by sector is summarised below. Table 3-2 presents ten sectors with the highest benefits, and Table 3-3 presents five sectors with the highest dis-benefits. Maps depicting the definition of the sectors adopted in this study are included in Appendix A.

Sector:	Benefits:
Hampshire - North East	£49,969,807
Hampshire - South East	£12,472,418
Southampton	£12,253,192
Winchester East	£11,095,412
Surrey	£10,251,550
Eastleigh	£8,411,384
Oxfordshire	£7,319,048
Hampshire - North West	£5,026,323
West Midlands	£4,953,494
East Midlands	£4,453,452

Table 3-3: Sectors with highest benefits.

Sector:	Dis-benefits:
Berkshire	-£14,752,371
London	-£9,345,551
East of England	-£6,463,708
Development*	-£3,292,652
Dorset	-£1,971,688

*sector representing development zones in the M3M27 corridor; in the final model these zones will be allocated to respective districts in which they are located; the separation of this group here is an artefact of the provisional definition of the reporting sectors and has no significance for the analysis

Table 3-4: Sectors with highest dis-benefits.

The pattern is intuitive in general. The largest volume of benefits accrues in sectors located close to the scheme, expected to benefit the most, such as Hampshire, Southampton and Winchester. Dis-benefits can be observed in parts of Berkshire, London or even as far as East of England, however these are of smaller magnitude. It is likely that these dis-benefits arise from more traffic attracted to the M3/M34 corridors thanks to the implementation of the scheme, with corresponding slight adverse impact on the local traffic on routes downstream from Junction 9. Such effects are not unusual in highway appraisal, although, given the nature of the scheme, we did not expect to observe impacts as far afield as East of England. It is worth noting that potential improvements to the model that might improve convergence would bring greater confidence in the reliability of such effects.

4. Model Performance

4.1 Comparison of M3J9 flows with M3M27 SMI results

In order to assess the plausibility of the M3J9 results in the short timescale, we compared the modelled flows on the M3 and M27 motorways obtained from this test with the M3M27 SMI results reported in the Traffic Forecasting Report for that project. Table 4-1, Table 4-2 and Table 4-3 show the comparison for AM peak, interpeak and PM peak respectively. The M3M27 DS2 (M3&M27 SMI included) formed the Do-Minimum scenario in this assessment and direct comparisons are possible only between these two sets of results (last two columns). However, for completeness, the tables also show the remaining M3M27 SMI scenarios (not used in this assessment) to illustrate the order of magnitude of flow changes under different scenarios.

2036 AM				
	DM	M27	M27+M3	M3 J9 DM
M27 J12-J11	5,335	5,925	5,601	5,864
M27 J11-10	4,455	4,948	4,754	4,913
M27 J10-J9	4,086	4,571	4,393	4,548
M27 J9-10	4,961	5,367	5,303	5,272
M27 J10-11	5,454	5,929	5,863	5,837
M27 J11-12	6,047	6,528	6,460	6,504
M3 J10-9	4,445	4,450	5,147	5,127
M3 J9-8	2,643	2,627	2,937	2,940
M3 J8-9	2,434	2,419	2,598	2,619
M3 J9-10	4,266	4,294	4,728	4,739

Table 4-1: 2036 AM peak flow comparison (vehicles)

2036 IP				
	DM	M27	M27+M3	M3 J9 DM
M27 J12-J11	4,768	4,945	4,928	4,893
M27 J11-10	4,279	4,512	4,502	4,508
M27 J10-J9	4,005	4,229	4,217	4,227
M27 J9-10	3,935	4,144	4,178	3,961
M27 J10-11	4,251	4,495	4,523	4,304
M27 J11-12	4,550	4,552	4,565	4,553
M3 J10-9	3,842	3,858	4,199	4,161
M3 J9-8	2,375	2,379	2,523	2,513
M3 J8-9	2,451	2,438	2,614	2,627
M3 J9-10	4,266	4,294	4,728	4,739

Table 4-2: 2036 IP peak flow comparison (vehicles)

2036 PM				
	DM	M27	M27+M3	M3 J9 DM
M27 J12-J11	5,675	6,133	6,133	6,088
M27 J11-10	5,179	5,735	5,731	5,658
M27 J10-J9	4,824	5,340	5,335	5,267
M27 J9-10	5,015	5,633	5,551	5,456
M27 J10-11	5,615	6,232	6,152	6,123
M27 J11-12	5,758	6,216	6,142	6,130

M3 J10-9	4,232	4,228	4,509	4,478
M3 J9-8	2,618	2,603	2,722	2,688
M3 J8-9	2,766	2,766	3,023	3,092
M3 J9-10	4,211	4,206	5,354	5,430

Table 4-3: 2036 PM peak flow comparison (vehicles)

Table 4-1, Table 4-2, and Table 4-3 show generally good correlation between the motorway flows in the M3M27 SMI DS2 and M3J9 DM. The largest differences can be seen in the AM peak results, with the inter-peak and PM peak outputs more similar to the M3M27 SMI results. These differences are likely to be due to the newer version of the SATURN software used in these tests[5]. The latest version of SATURN achieves better convergence, particularly in the 2036 AM peak models (see section 4.2) and results in more realistic flows on the congested parts of the networks. However, these differences are small and provide confidence in the M3J9 results obtained in these indicative tests. The comparison of other headline statistics in these model runs is presented in Appendix B.

4.2 Convergence

The J9 Do-Minimum scenario achieved route assignment convergence in fewer loops than the original M3M27 SMI Do-Something 2 scenario. There is an improvement in GAP values, and P% values[6] even though exactly the same network was used. We believe that this improvement is brought by the newer version of the SATURN software used in these tests and the software release notes support this conclusion. The full tables with model convergence statistics can be found in Appendix B. DIADEM convergence statistics are also slightly improved in comparison to the M3M27 SMI results. We believe that this is also driven by the improvement in the route assignment. The full tables of DIADEM convergence statistics can be found in Appendix C.

4.3 Run times

Model run are made up of the following main stages:

- DIADEM – SATURN (Demand Model / Highway Assignment)
- Matrix build, final assignments and cost skims
- TUBA model

The number of tests has been constrained by long model run times, which are highly dependent on the specification of the machines used to run the models. Table 4-4 shows a difference in model run times (for the 2036 Do-Something scenario) depending on the specification of the hardware.

Model Specification	Laptop - 4 cores / 4 threads, 2.3Ghz, 16Gb RAM	Desktop - 4 cores / 4 threads, 3.2Ghz, 20Gb RAM	Desktop – 6 cores / 12 threads, 3.5Ghz, 32Gb RAM
DIADEM - SATURN	3 days, 7.5 hours	2 days, 19 hours	1 day, 6 hours
Matrix build, etc	8 hours	4 hours	2 hours
TUBA	20 hours	9 hours	Untested

Table 4-4: Model Run Times

4.4 Checks of TUBA results

To complement the review of the headline model statistics we examined the log of TUBA warnings. In the case of warnings arising from the J9 DM network, the warnings have been accepted as facets of the architecture of the inherited model and were not altered at this stage. However, their impact has still been assessed. We found all warnings to be negligible, insignificant or legitimate and not affecting the economic appraisal. The full categorisation and analysis of TUBA warnings can be found in Appendix D.

[5] SATURN version 11.4.06D
[6] Metrics used to measure convergence of SATURN assignment models

5. Conclusions

5.1 Summary

To complete this initial, indicative assessment of the likely benefits of the J9 scheme we used the existing version of the M3M27 SMI model, which has been judged by Highways England to be fit for the purpose of modelling of interventions on the M3 and M27 motorways. This assessment is based the scenarios defined as part of the M3M27 SMI model as a starting point. The J9 Do-Minimum assumes the completion of the M3 and M27 Smart Motorway Interventions. J9 Do-something assumes the addition of the J9 scheme Option 14.

Apart from minor adjustments to the appraisal approach, e.g. moving to more up to date versions of software, and minor amendments to the labelling of modelled years in TUBA input files, no other changes to the modelling system or the setup of user benefit calculation have been made. We used the model "as is" without further modifications or enhancements. These are planned as part of Stage 3.

Given the short amount of time available, and given the levels of assurance already assigned to the M2M27 SMI model, we consider this approach to be proportionate. Whilst the analysis was undertaken under a very short timescale, a number of tests and checks have been performed and these support the view that the model offers results from which meaningful conclusions can be drawn.

The indicative assessment based on these early estimates of user benefits in combination with the environmental, accident and Present Value of Costs impacts imported from the Stage 2 appraisal would imply a benefit to cost ratio of approximately 1.5.

5.2 Limitations

The M3M27 SMI model supplied for this analysis "as is" did not include any improvements in the local validation within the city of Winchester. However, the indicative assessment was implemented in the modelling suite with an overall acceptable level of assurance, suitable for testing interventions in the M3 corridor, and detail sufficient for the indicative analysis presented here. The improvements in the convergence of the assignment and demand components of this model achieved in this test provide greater confidence in the overall outputs, although further improvements will be sought as part of the model enhancements planned in Stage 3.

The analysis was undertaken in a short timescale and focused only on selected elements of the appraisal, without revisiting other estimates which were imported directly from the Stage 2 analysis. Both sets of estimates may be subject to change when the refinements of the M3M27 SMI model are implemented as part of Stage 3 (such as improved validation within Winchester) and full appraisal of all benefits is undertaken. Some elements, such the journey time delays during construction and maintenance were omitted in this indicative assessment due to short timescale; these will be considered as part of the Stage 3 analysis.

Finally, it should be noted that direct comparisons between the results of Stage 1 and 2 analyses and this indicative analysis are not possible due to changes in the model used (a new modelling suite was used in this indicative assessment) and updates in the appraisal inputs (new version of TUBA). The tests presented here provide an independent comparison with the previous results and broaden the range of available estimates of the likely impact of the scheme.

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Appendix A. Definition of TUBA Sectors

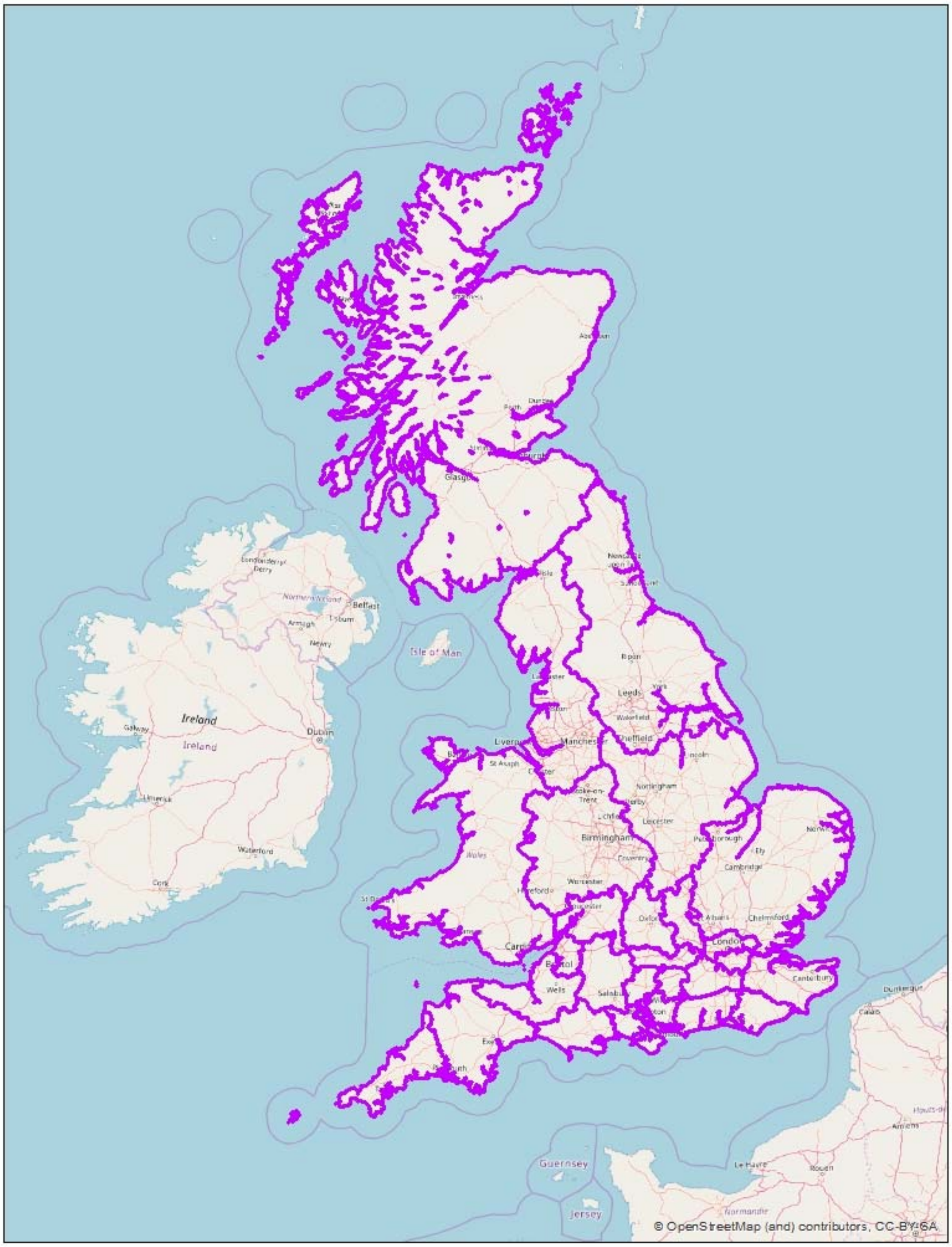

Figure A-1: Model sectors – All.

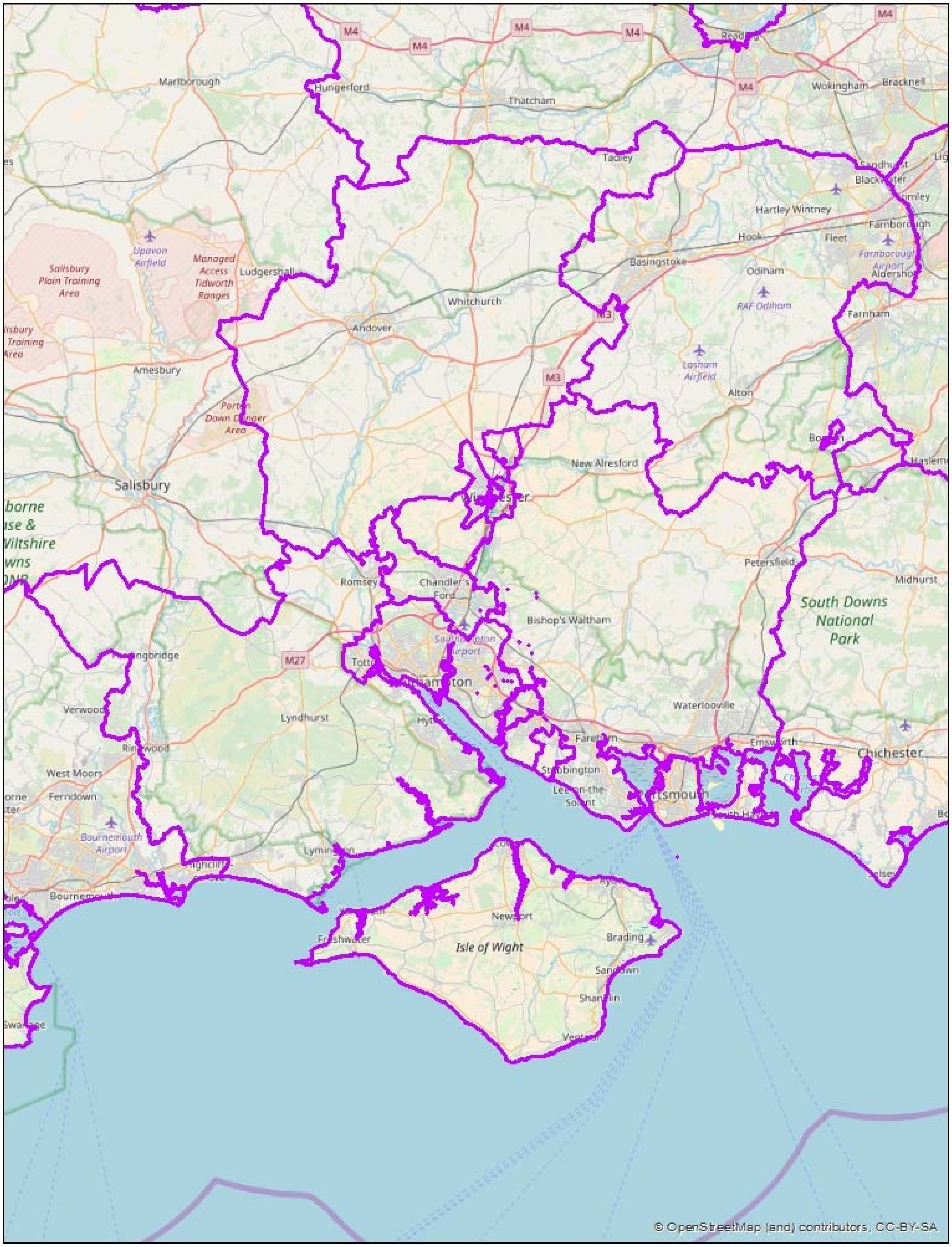

Figure A-2: Model sectors - Hampshire.

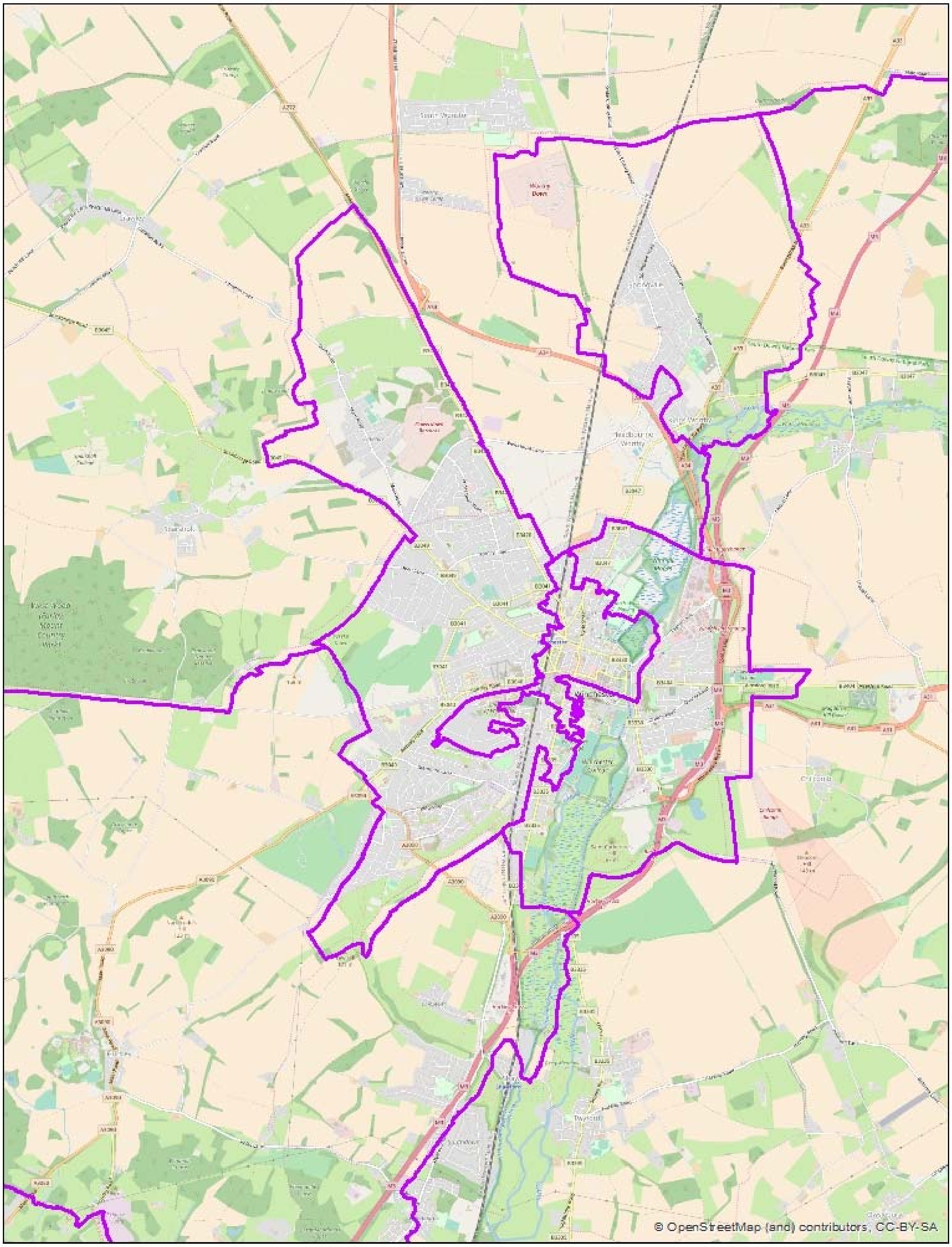

Figure A-3: Model sectors - Winchester.

Appendix B. Comparison of Headline Model Statistics

Tables containing full comparisons of model convergence statistics at each peak are included below:

AM:

2021 AM peak period	SMP DM	SMP M27 Scheme	SMP M27 + M3 Schemes	M3 J9 DM	M3 J9 DS
Transient Queues (pcu-hrs)	12,530	12,200	11,830	11,942	11,816
Over-Capacity Queues (pcu)	11,210	11,250	11,380	11,264	11,336
Link Cruise Times (pcu-hrs)	79,620	79,700	79,920	79,881	79,841
Average Speed (km/hr)	74	74	74	74	74
Loops	23	22	41	17	17
Gap	0.088	0.011	0.007	0.0094	0.0093
P%	98.4	98.6	99.1	98.1	98.4

Table B-1:AM 2021 model convergence statistics.

2036 AM peak period	SMP DM	SMP M27 Scheme	SMP M27 + M3 Schemes	M3 J9 DM	M3 J9 DS
Transient Queues (pcu-hrs)	18,520	17,840	17,560	17,765	17,543
Over-Capacity Queues (pcu)	19,870	19,600	755,890	19,969	20,067
Link Cruise Times (pcu-hrs)	102,700	102,400	103,100	103,211	103,181
Average Speed (km/hr)	71	71	69	71	71
Loops	120	120	120	24	23
Gap	0.0290	0.0260	0.0960	0.0117	0.0140
P%	93.2	96.9	96.6	98.3	97.9

Table B-2: AM 2036 model convergence statistics.

IP:

2021 interpeak	SMP DM	SMP M27 Scheme	SMP M27 + M3 Schemes	M3 J9 DM	M3 J9 DS
Transient Queues (pcu-hrs)	7,575	7,534	7,414	7,448	7,407
Over-Capacity Queues (pcu)	3,620	3,624	3,636	3,639	3,742
Link Cruise Times (pcu-hrs)	61450	61530	61600	61537	61451
Average Speed (km/hr)	79	79	79	79	79
Loops	17	18	18	20	17
Gap	0.0073	0.0075	0.0082	0.0063	0.0140
P%	97.9	98.6	98.5	98.35	97.92

Table B-3: IP 2021 model convergence statistics.

2036 interpeak	SMP DM	SMP M27 Scheme	SMP M27 + M3 Schemes	M3 J9 DM	M3 J9 DS
Transient Queues (pcu-hrs)	12,110	11,880	11,450	11,595	11,382
Over-Capacity Queues (pcu)	7,693	7,612	7,567	7,546	7,749
Link Cruise Times (pcu-hrs)	83,060	83,250	83,540	83,361	83,302
Average Speed (km/hr)	76	76	76	77	77
Loops	53	50	59	18	19
Gap	0.0130	0.0130	0.0140	0.0121	0.0113
P%	97.6	97.8	97.9	98.52	98.06

Table B-4: IP 2036 model convergence statistics.

PM:

2021 PM peak period	SMP DM	SMP M27 Scheme	SMP M27 + M3 Schemes	M3 J9 DM	M3 J9 DS
Transient Queues (pcu-hrs)	13,580	13,210	12,880	12,895	12,808
Over-Capacity Queues (pcu)	16,960	17,090	17,120	16,836	16,936
Link Cruise Times (pcu-hrs)	81,330	81,520	81,790	81,656	81,551
Average Speed (km/hr)	73	73	73	73	73
Loops	30	32	37	19	20
Gap	0.016	0.019	0.015	0.014	0.015
P%	97.9	97.8	98.0	98.3	98.2

Table B-5: PM 2021 model convergence statistics.

2036 PM peak period	SMP DM	SMP M27 Scheme	SMP M27 + M3 Schemes	M3 J9 DM	M3 J9 DS
Transient Queues (pcu-hrs)	20,060	19,420	19,110	19,380	19,086
Over-Capacity Queues (pcu)	27,380	27,650	27,740	27,989	27,722
Link Cruise Times (pcu-hrs)	105,200	105,400	105,800	105,767	105,695
Average Speed (km/hr)	70	70	70	70	70
Loops	120	120	120	26	25
Gap	0.042	0.036	0.033	0.026	0.022
P%	96.1	96.3	96.6	98.3	98.2

Table B-6: PM 2036 model convergence statistics.

Appendix C. DIADEM convergence statistics

Iteration	SMP DM		SMP M27 Scheme		SMP M27 + M3 Schemes		M3 J9 DM		M3 J9 DS	
	Full	Subset	Full	Subset	Full	Subset	Full	Subset	Full	Subset
1	9.20%	6.83%	9.21%	6.84%	9.23%	6.87%	9.27%	6.91%	9.27%	6.90%
2	4.27%	3.09%	4.28%	3.11%	4.28%	3.10%	4.30%	3.13%	4.29%	3.12%
3	2.10%	1.52%	2.10%	1.52%	2.09%	1.51%	2.11%	1.53%	2.10%	1.52%
4	1.11%	0.83%	1.06%	0.77%	1.05%	0.76%	1.07%	0.79%	1.05%	0.76%
5	0.58%	0.44%	0.60%	0.47%	0.54%	0.39%	0.56%	0.42%	0.56%	0.42%
6	0.30%	0.23%	0.34%	0.27%	0.31%	0.25%	0.31%	0.24%	0.31%	0.24%
7	0.19%	0.16%	0.19%	0.16%	0.19%	0.16%	0.18%	0.15%	0.20%	0.17%
8	0.12%	0.11%	0.13%	0.11%	0.14%	0.13%	0.13%	0.12%	0.15%	0.14%
9	0.08%	0.07%	0.10%	0.10%	0.10%	0.09%	0.12%	0.12%	0.10%	0.10%
10	-	-	-	-	-	-	0.09%	0.09%	-	-

Table C-1: 2021 DIADEM convergence statistics.

Iteration	SMP DM		SMP M27 Scheme		SMP M27 + M3 Schemes		M3 J9 DM		M3 J9 DS	
	Full	Subset	Full	Subset	Full	Subset	Full	Subset	Full	Subset
1	18.33%	15.06%	18.34%	15.08%	18.37%	15.10%	18.36%	15.10%	18.27%	15.00%
2	7.73%	6.19%	7.74%	6.20%	7.73%	6.19%	7.74%	6.19%	7.70%	6.15%
3	3.76%	3.01%	3.79%	3.05%	3.76%	3.01%	3.76%	3.01%	3.75%	2.99%
4	1.93%	1.57%	1.98%	1.63%	1.90%	1.54%	1.91%	1.55%	1.91%	1.55%
5	1.08%	0.91%	1.19%	1.04%	1.15%	0.99%	1.08%	0.91%	1.07%	0.90%
6	0.66%	0.59%	0.82%	0.77%	0.76%	0.71%	0.63%	0.56%	0.66%	0.59%
7	0.47%	0.45%	0.58%	0.57%	0.56%	0.55%	0.44%	0.42%	0.44%	0.42%
8	0.32%	0.33%	0.47%	0.49%	0.42%	0.44%	0.37%	0.37%	0.35%	0.36%
9	0.35%	0.37%	0.41%	0.44%	0.39%	0.42%	0.33%	0.35%	0.29%	0.30%
10	0.29%	0.31%	0.40%	0.43%	0.35%	0.38%	0.27%	0.29%	0.26%	0.28%
11	0.25%	0.27%	0.32%	0.35%	0.31%	0.34%	0.28%	0.30%	0.28%	0.30%
12	0.25%	0.28%	0.42%	0.46%	0.33%	0.37%	0.27%	0.30%	0.23%	0.25%
13	0.26%	0.28%	0.39%	0.43%	0.30%	0.33%	0.29%	0.32%	0.24%	0.26%
14	0.30%	0.33%	0.32%	0.36%	0.34%	0.38%	0.28%	0.31%	0.29%	0.32%
15	0.33%	0.37%	0.30%	0.33%	0.33%	0.37%	0.24%	0.27%	0.29%	0.32%

Table C-2: 2036 DIADEM convergence statistics.

Appendix D. Detailed interrogation of TUBA outputs

An examination of the nature of the TUBA warnings generated during TUBA runs has been completed. There are a total of 156,068 warnings given by TUBA. These are categorised as follows:

- 7 warnings pertaining to zones not being allocated sectors.
- 71,865 DS time greater than DM time warnings.
- 144 DM time greater than DS time warnings.
- 670 DS distance greater than DM distance warnings.
- 244 DM distance greater than DS distance warnings.
- 12,040 DM speed greater than limit warnings.
- 7,251 DM speed less than limit warnings.
- 12,052 DS speed greater than limit warnings.
- 7,253 DS speed less than limit warnings.
- 22 DM trips greater than limit warnings.
- 22 DS trips greater than limit warnings.
- 44,384 one of DM and DS time is 0, but not both, warnings.
- 114 one of DM and DS distance is 0, but not both, warnings.

The severity and cause of the errors has been broadly assessed, and the findings are below:

- Zones not allocated to sectors are development zones, representing new land developments expected to be on-ground and in the Affected Road Network (ARN). These zones are automatically allocated to a new, unused sector number by TUBA, which is how they would have been treated if manually assigned a sector.
- Warnings about DM and DS times differing are largely related to OD movements between zones around the A3 and A31. These are likely resulting from changes in driver routing due to the introduction of the scheme, and as the largest difference is only approximately 15 minutes these are not considered significant.
- Warnings about DM and DS distances differing are focused around areas of the ARN that would be affected by redistribution of routing choices due to the introduction of the scheme. Whilst some are quite drastic, they are largely between zone pairs that do not pass through the scheme area and will therefore be masked, so they are not considered significant.
- Warnings about DM and DS times being greater or less than the limit are largely either between mid-link loaded zones that load on to the network at the at the same node, or in inner city areas where very slow traffic can be expected. Therefore, they are not considered significant.
- All of the warnings about DM and DS trips being greater than the limit are all intra-zonal trips within very large zones (e.g. those representing regions). Being intra-zonal, these trips do not affect the network and therefore are not considered significant.
- All of the warnings about one of DM or DS distance or time being 0, but not both, are all for zone pairs with a distance or time of “0.00” changing to “0.00”. This implies the distance or time is less than 0.005 kilometres or seconds, therefore the changes are infinitesimal and are not considered significant.

In the case of warnings arising from the J9 DM network, the warnings have been accepted as facets of the inherited model that we cannot alter at this stage, as the J9 DM network is identical to the M3M27 SMI Do-Something 2 network. Nevertheless, these have been reviewed as part of these checks.