SATURN UGM
4th November 2016

M20 J3-5 SMP

Modelling Motorway Merges and Diverges

M20 J3-5 SMP Project Background

Development of a SATURN Highway Assignment Model to be used in the appraisal of a Smart Motorway Intervention (SMI) on M20 J3-5

Interim Advice Note 164 - The Economic Assessment of Managed Motorways – All Lanes Running provides an overview

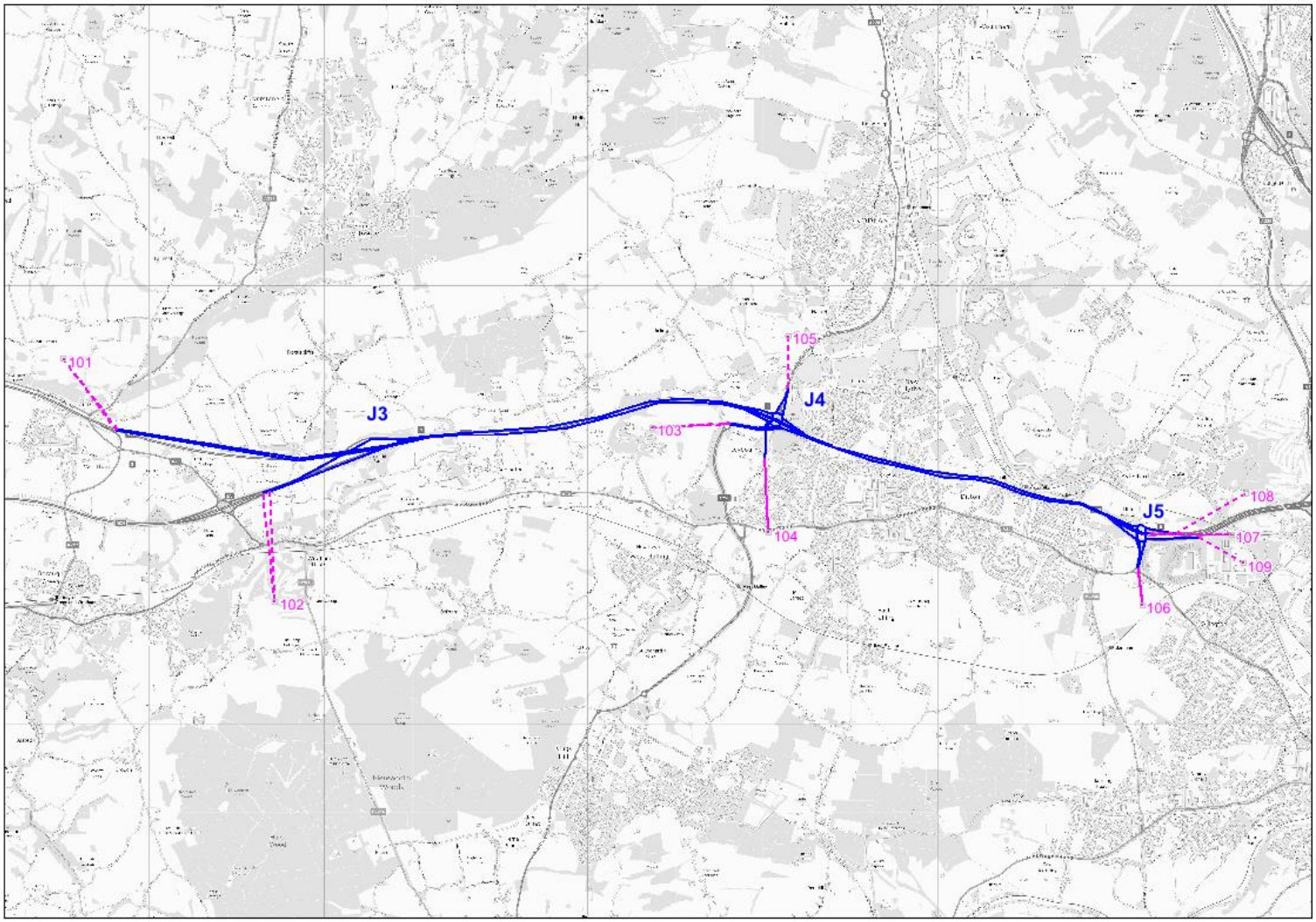
MM-ALR involves opening the hard shoulder to traffic – behaves as a normal running lane

Significant proportion of benefits derived from traffic on the motorway in particular at merges/diverges

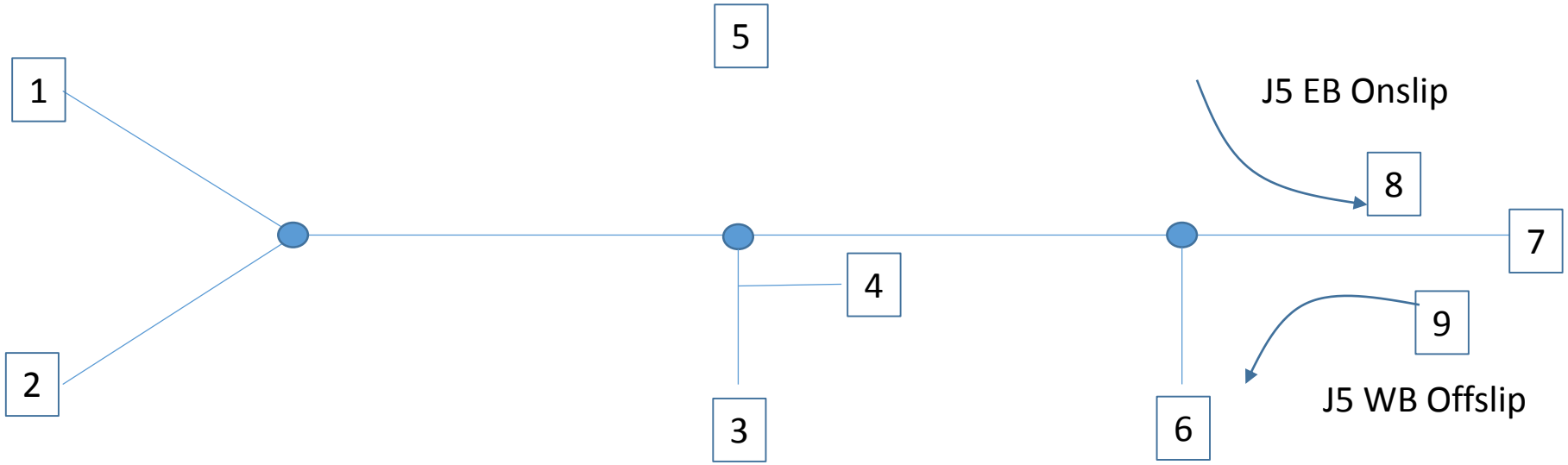
Important to get the model calibration as close as possible in these locations

Led to the use of the “Motorway Test Track” methodology

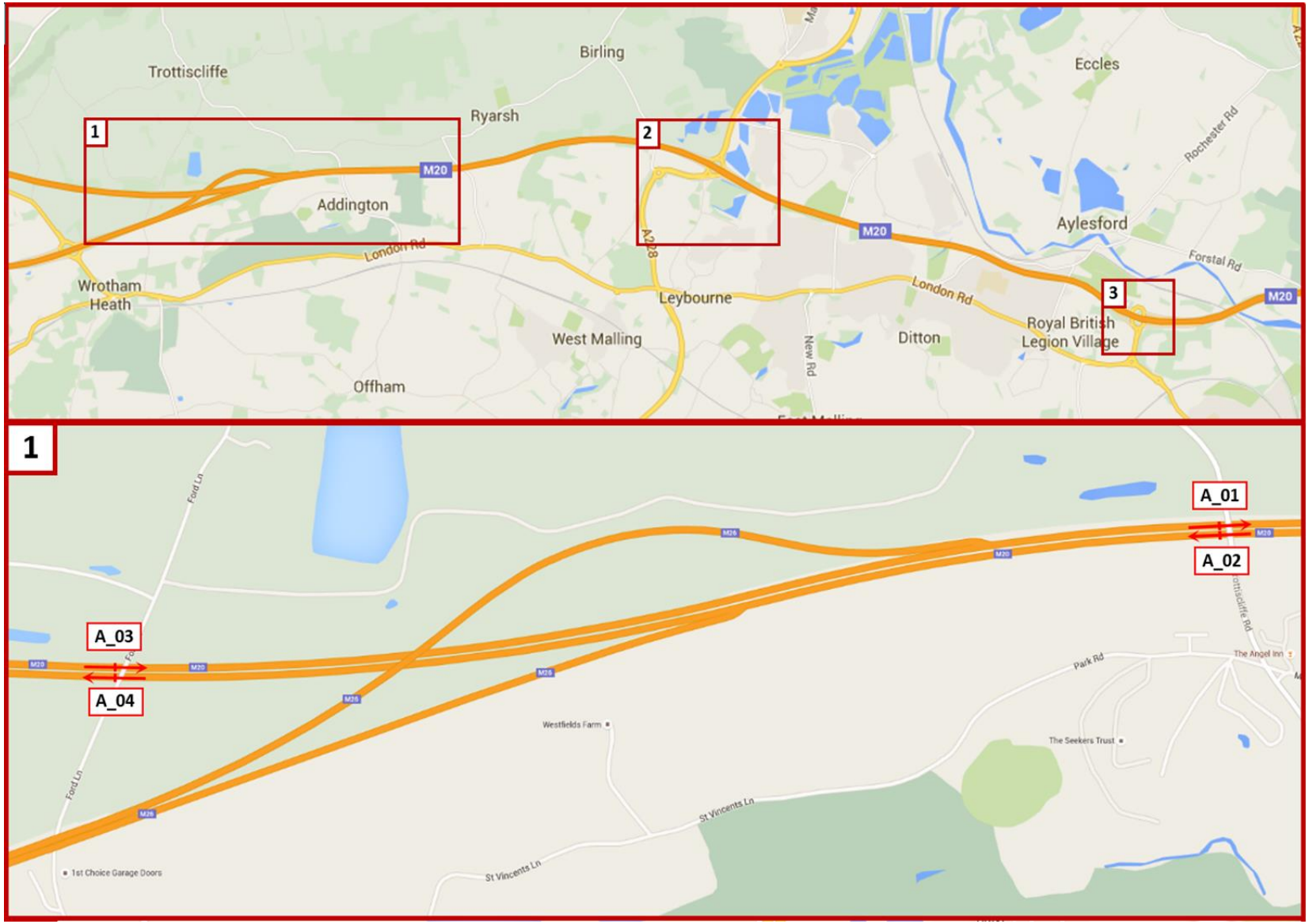
Motorway Test Track Network



Motorway Test Track - Zoning System



ANPR Camera locations



ANPR Camera locations

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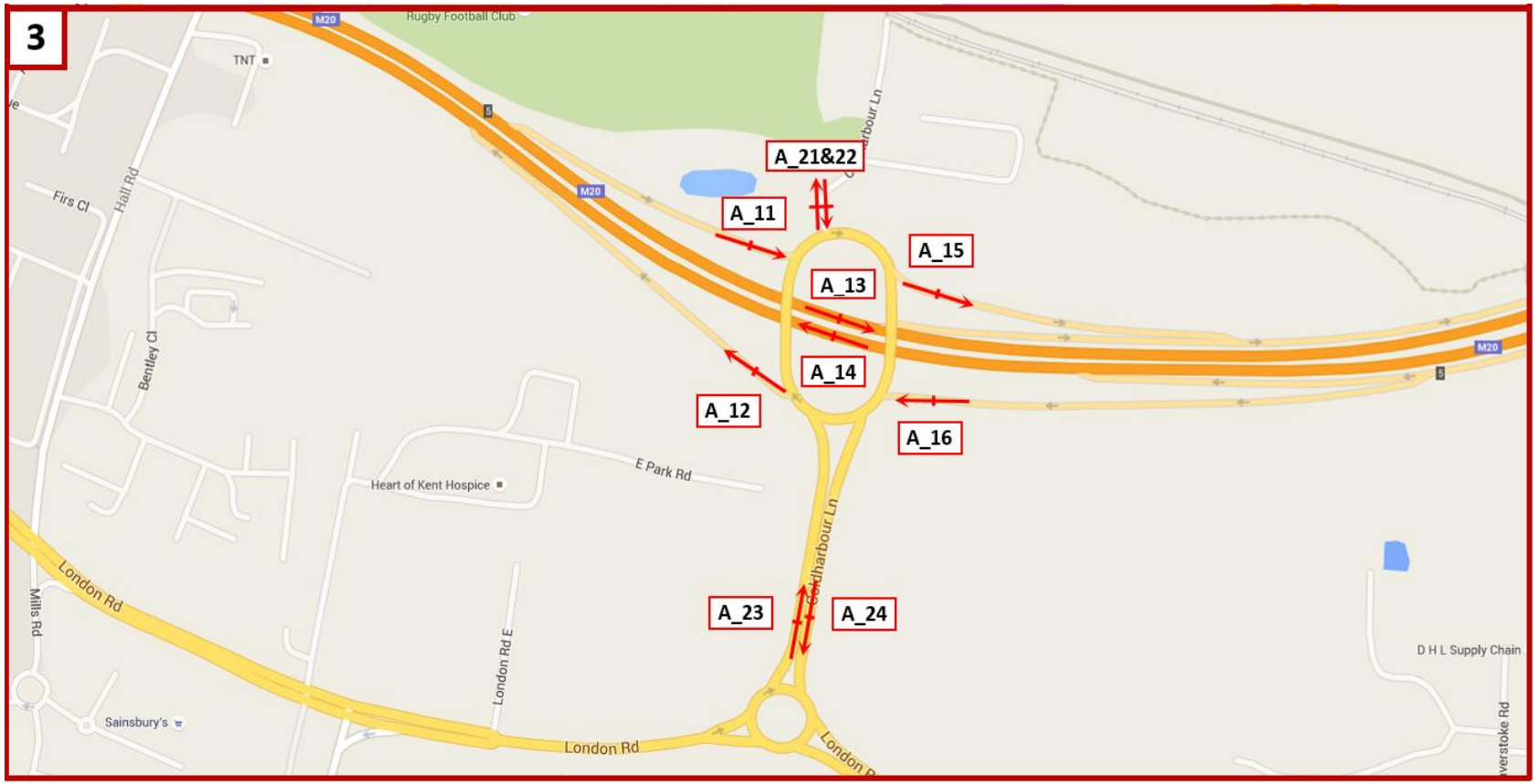
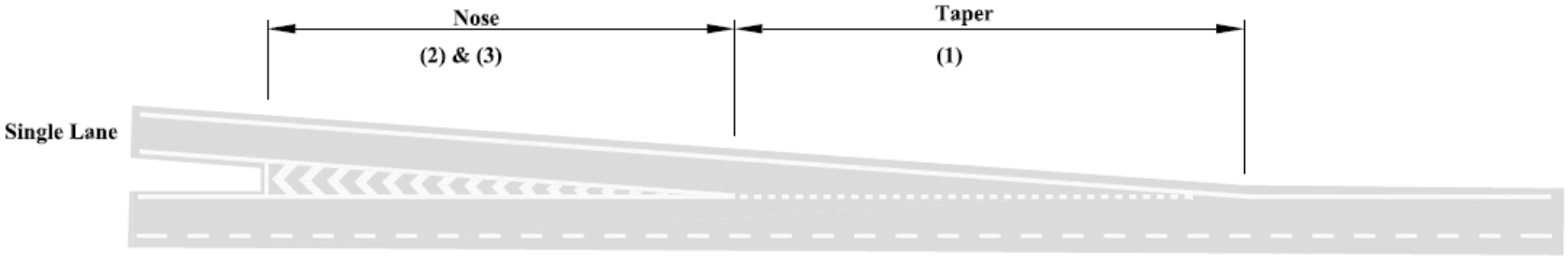
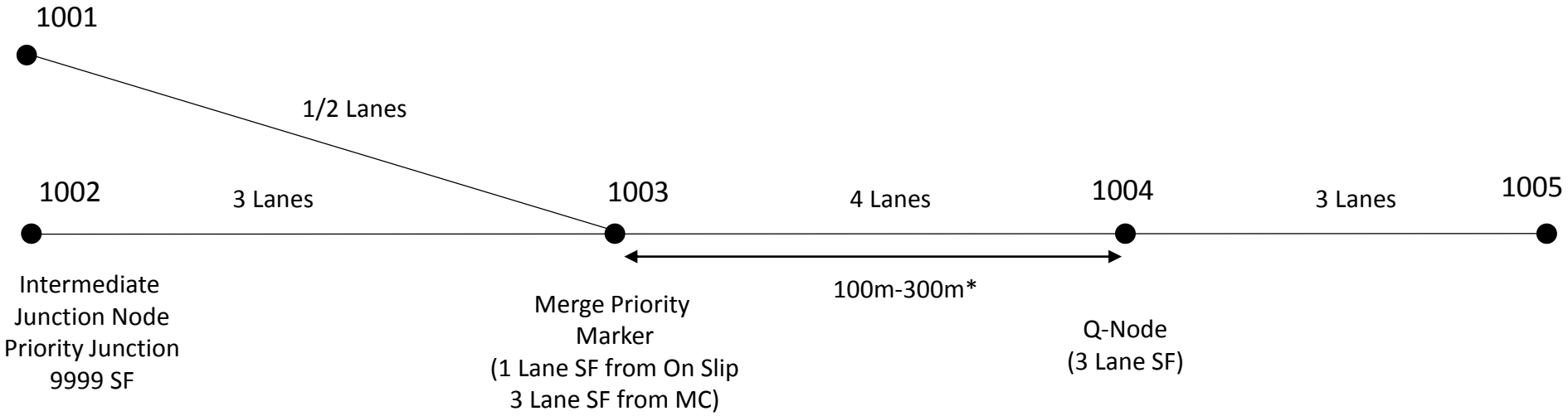


Taper Merge – Schematic Diagrams



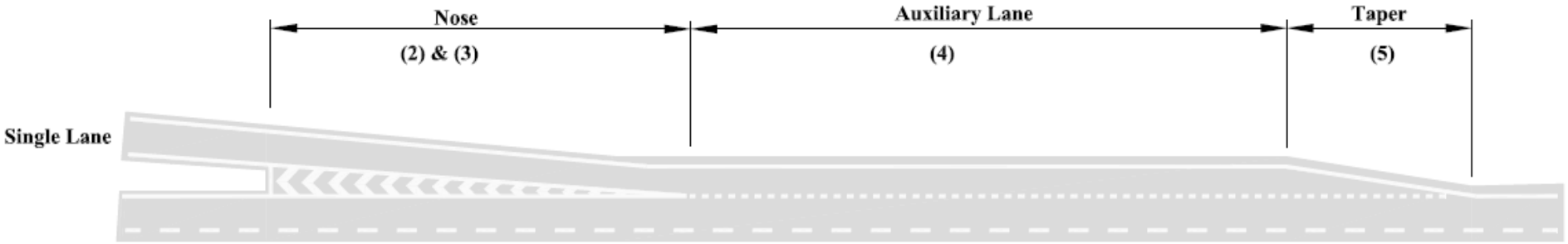
A - Taper Merge



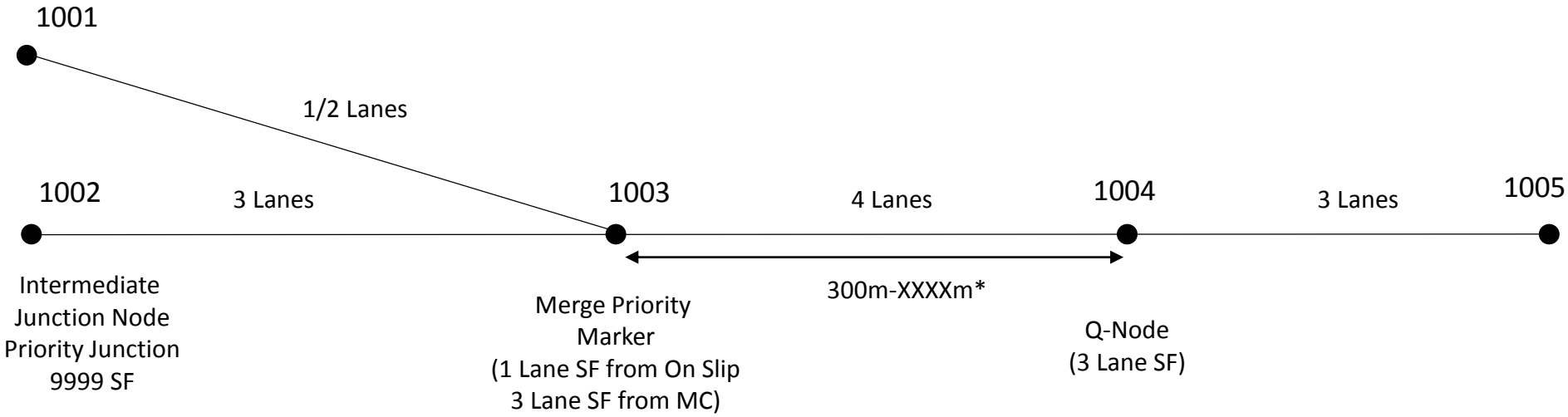
* This distance should be the same for all merges of this type irrespective of the geometry. Let this distance = A

Source DMRB Volume 6 Section 2 Part 1 - TD22/06

Parallel Merge – Schematic Diagrams



B - Parallel Merge



* This distance should be the same for all merges of this type irrespective of the geometry. This distance should be A + Length of Auxiliary Lane

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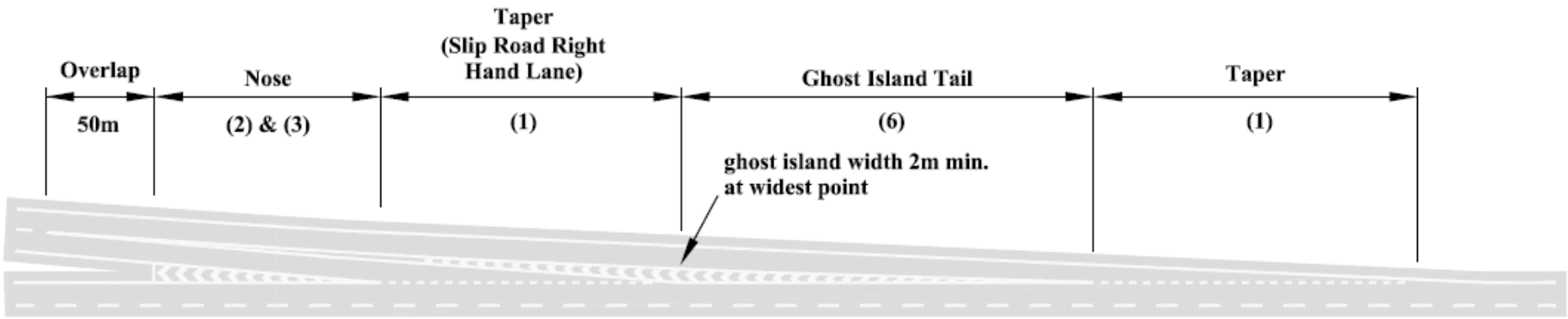
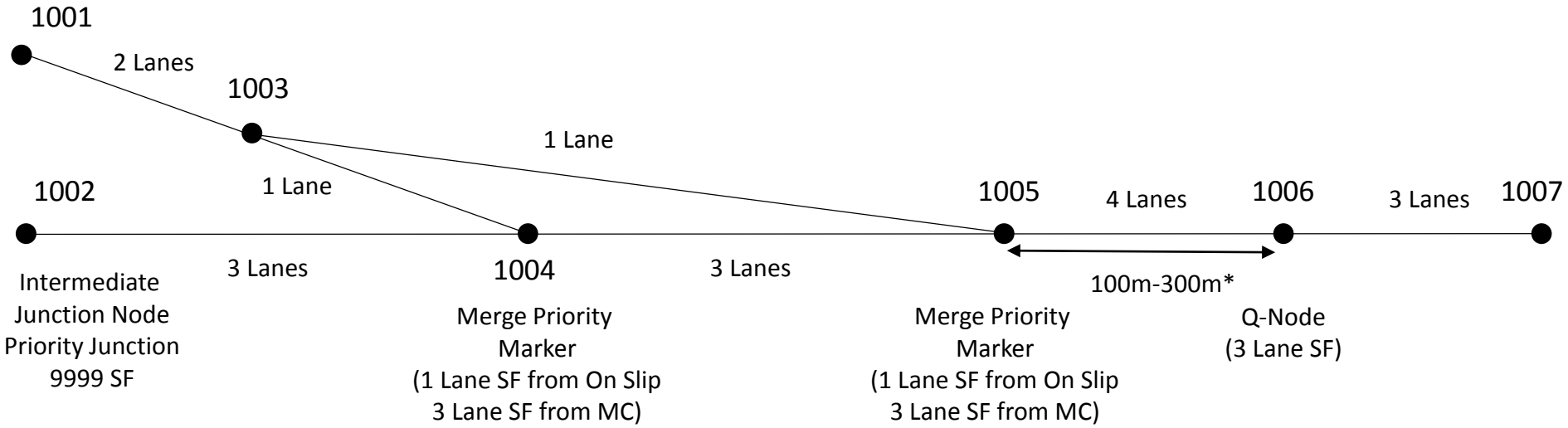
Ghost Island Merge – Schematic Diagrams



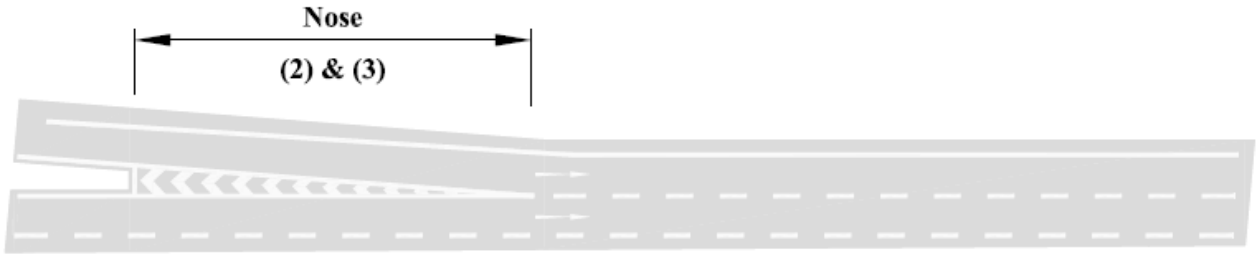
C - Ghost Island Merge



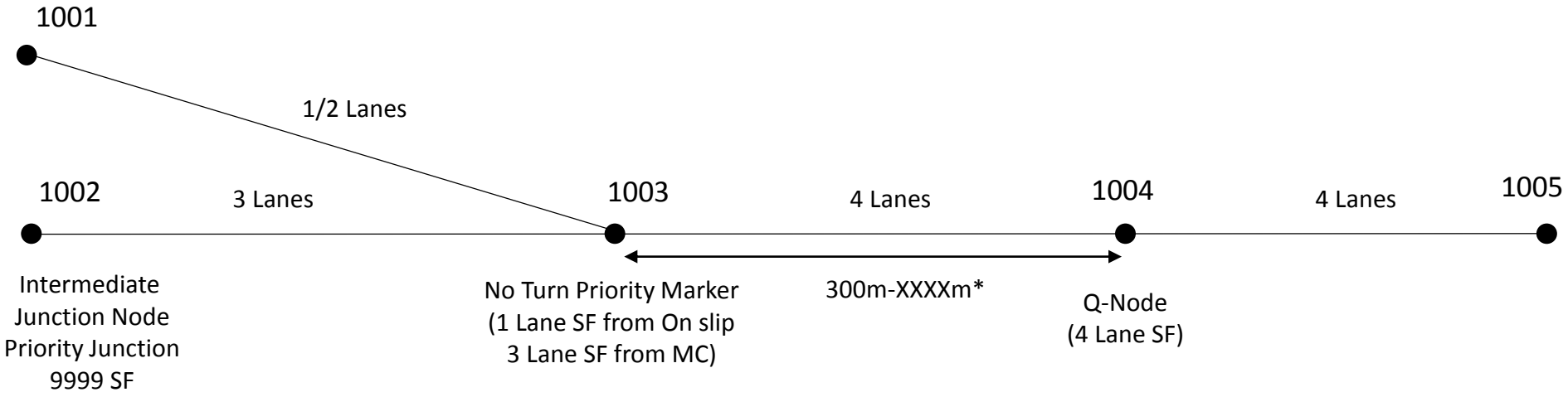
* This distance should be distance A (as per Taper Merge)

Source DMRB Volume 6 Section 2 Part 1 - TD22/06

Lane Gain – Schematic Diagrams



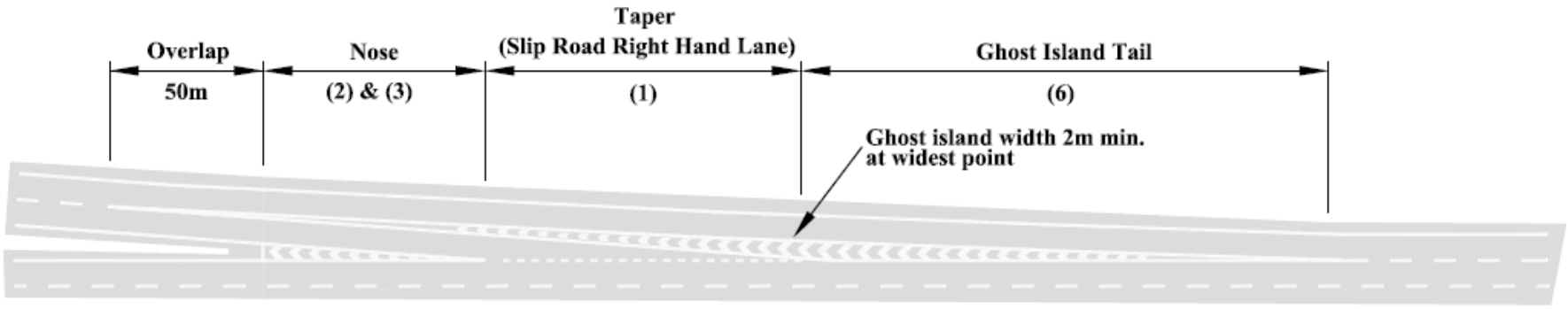
E - Lane Gain



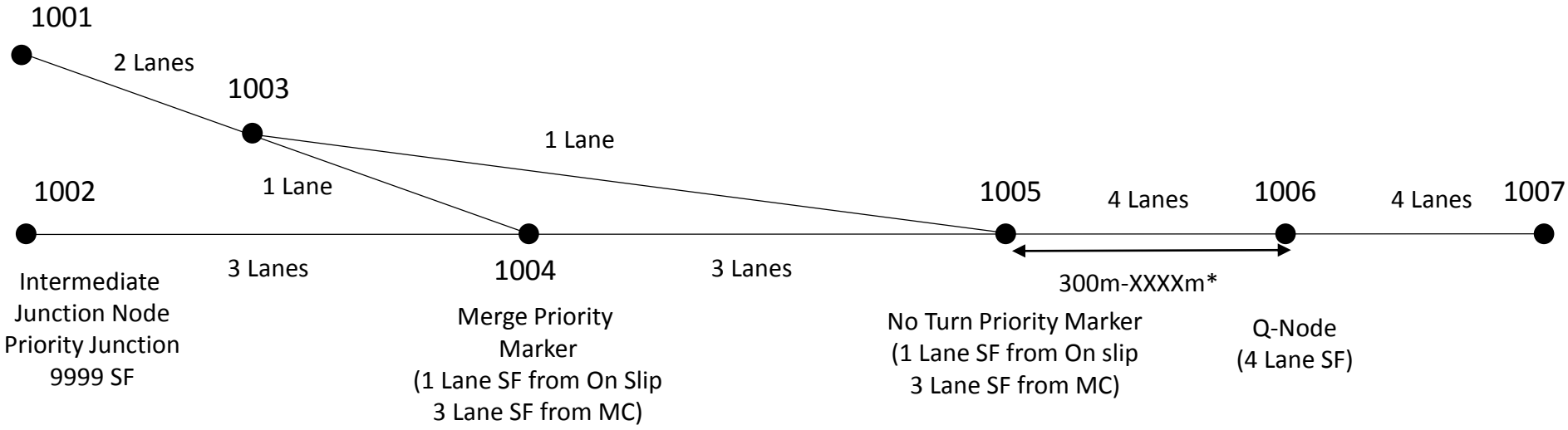
* This distance should be notionally defined but consistent across all junctions of this type

Source DMRB Volume 6 Section 2 Part 1 - TD22/06

Lane Gain with Ghost Island Merge V1 – Schematic Diagrams



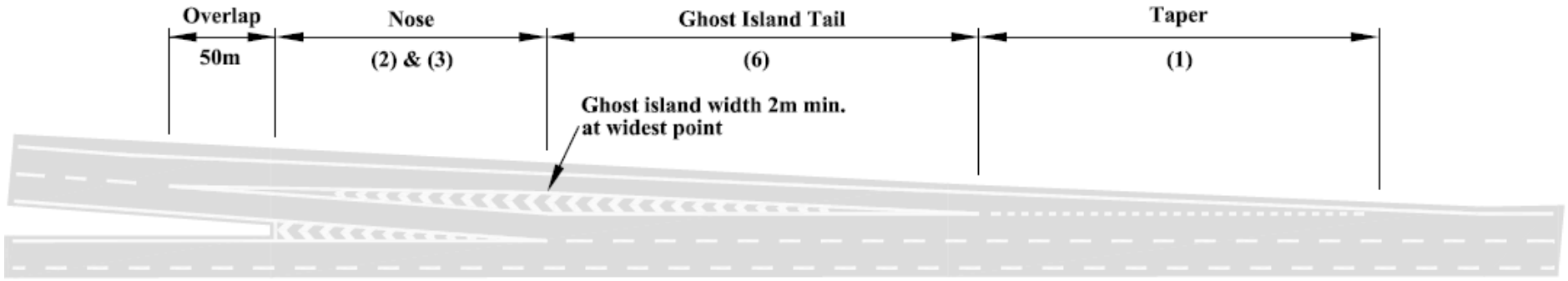
F - Lane Gain with Ghost Island Merge (OPTION 1 - PREFERRED)



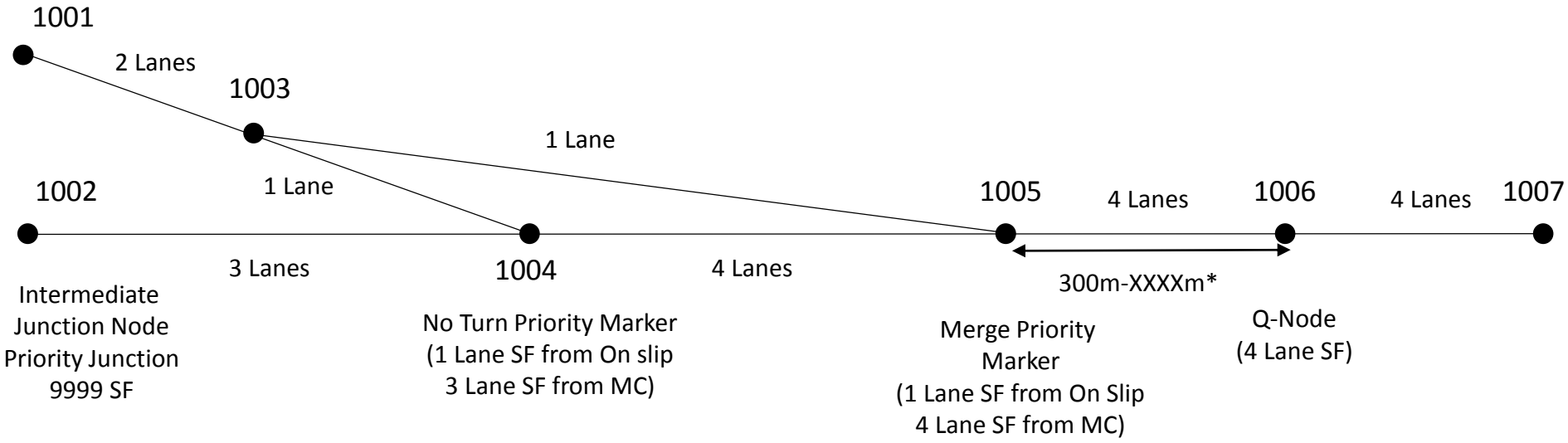
* This distance should be the same as the Lane Gain Distance

Source DMRB Volume 6 Section 2 Part 1 - TD22/06

Lane Gain with Ghost Island Merge V2 – Schematic Diagrams



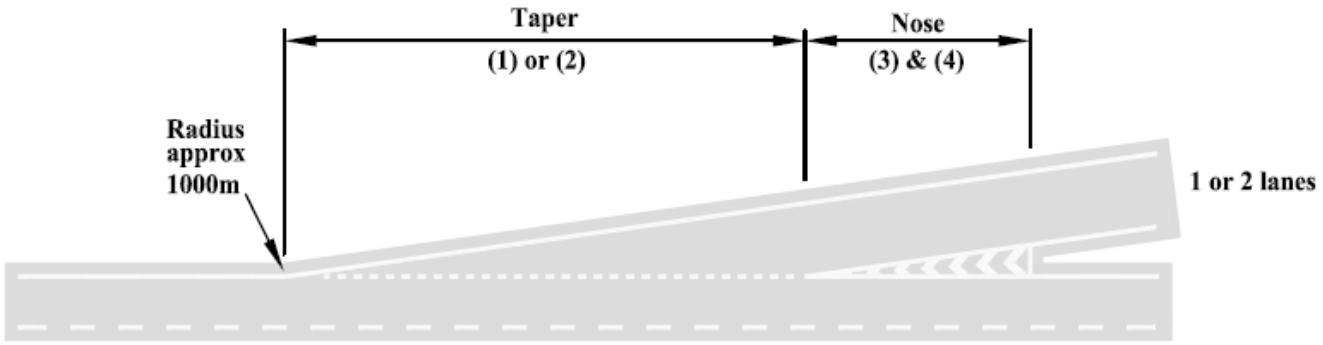
F - Lane Gain with Ghost Island Merge **(OPTION 2 - ALTERNATIVE - See Paragraph 2.30)**



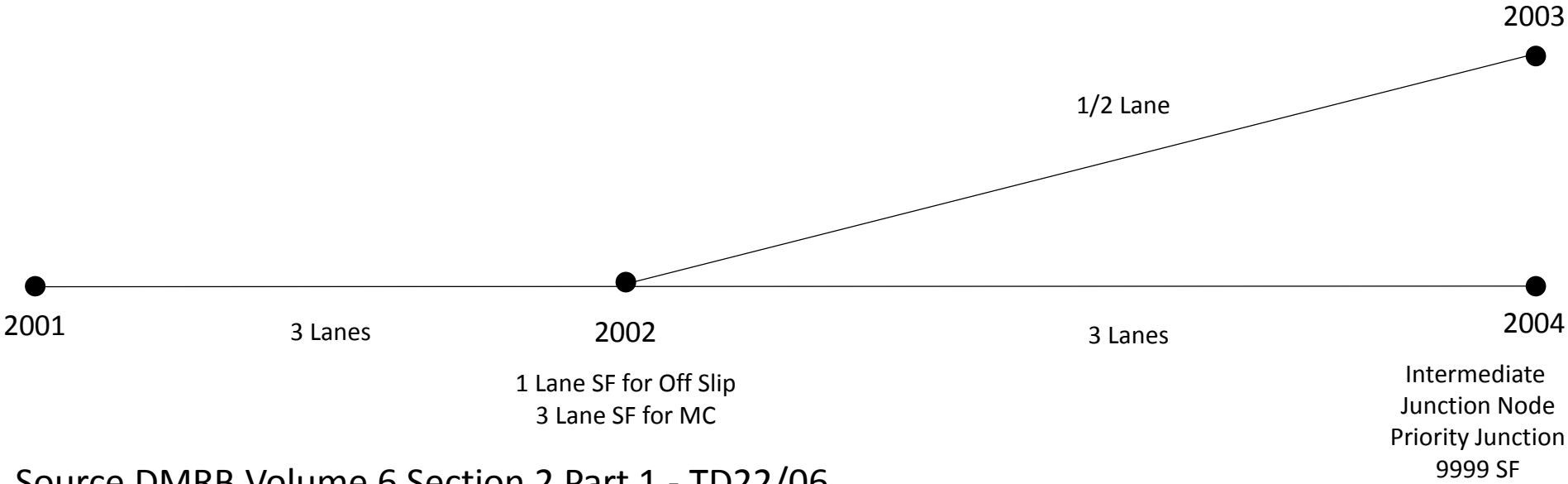
* This distance should be the same as the Lane Gain Distance

Source DMRB Volume 6 Section 2 Part 1 - TD22/06

Taper Diverge – Schematic Diagrams

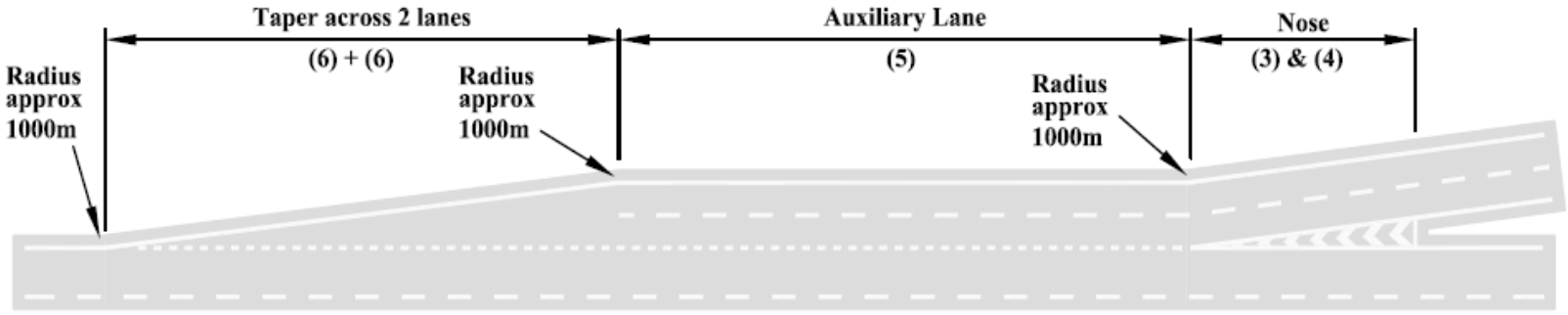


A - Taper Diverge

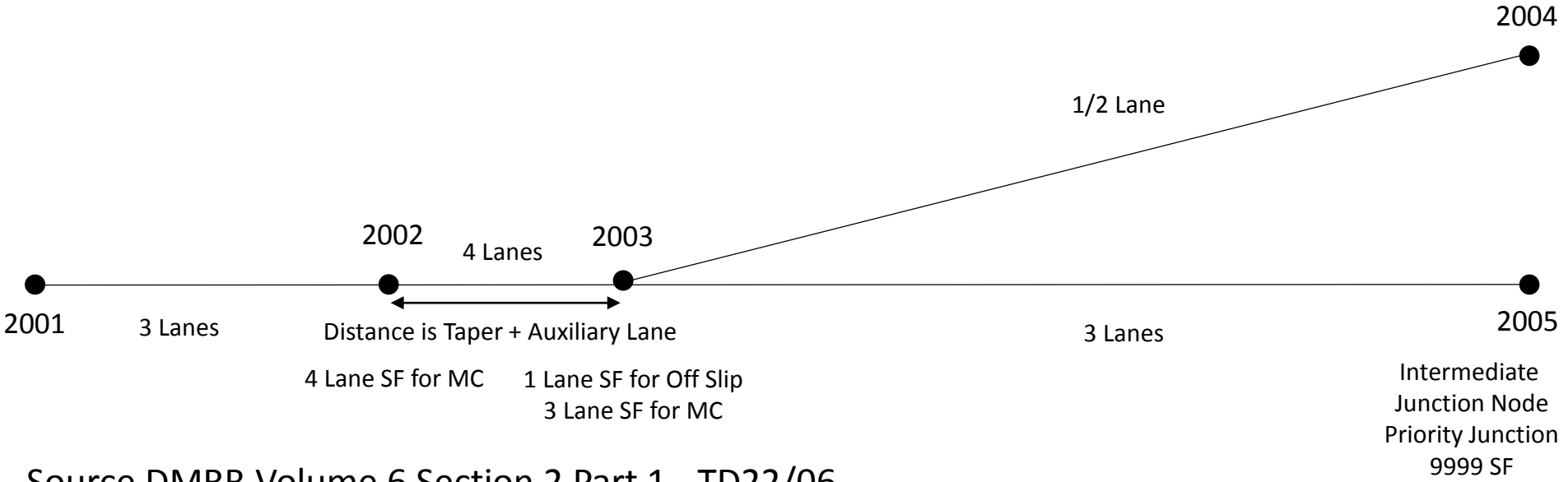


Source DMRB Volume 6 Section 2 Part 1 - TD22/06

Parallel Diverge – Schematic Diagrams

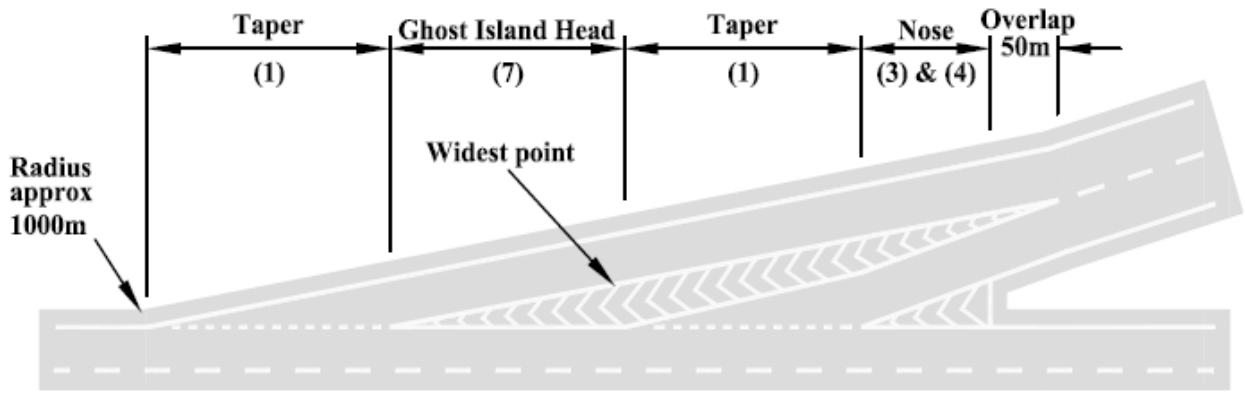


B (Option 2 Not Preferred) - Parallel Diverge

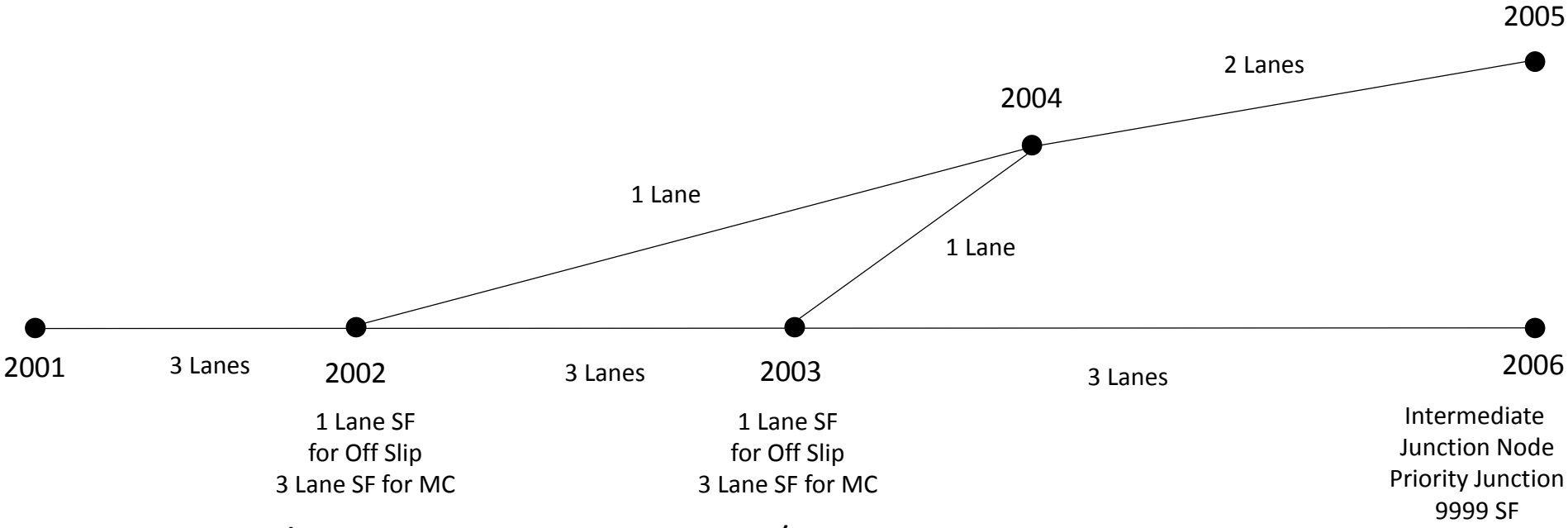


Source DMRB Volume 6 Section 2 Part 1 - TD22/06

Ghost Island Diverge – Schematic Diagrams

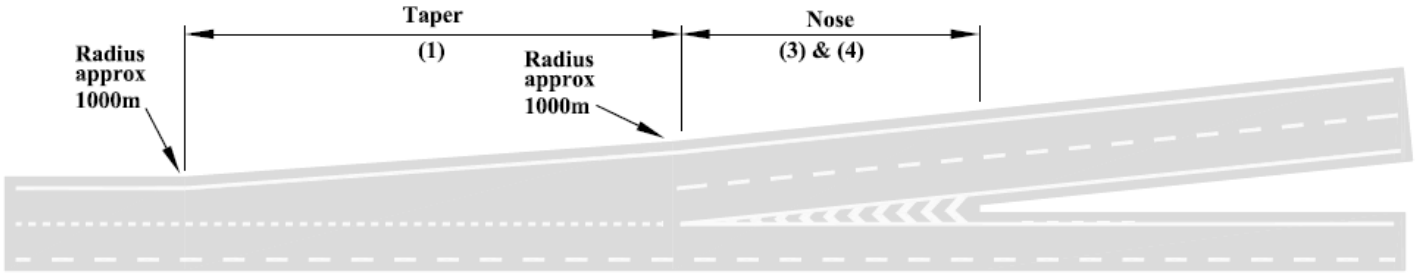


B (Option 1 Preferred) - Ghost Island diverge including for conversion of existing taper diverge



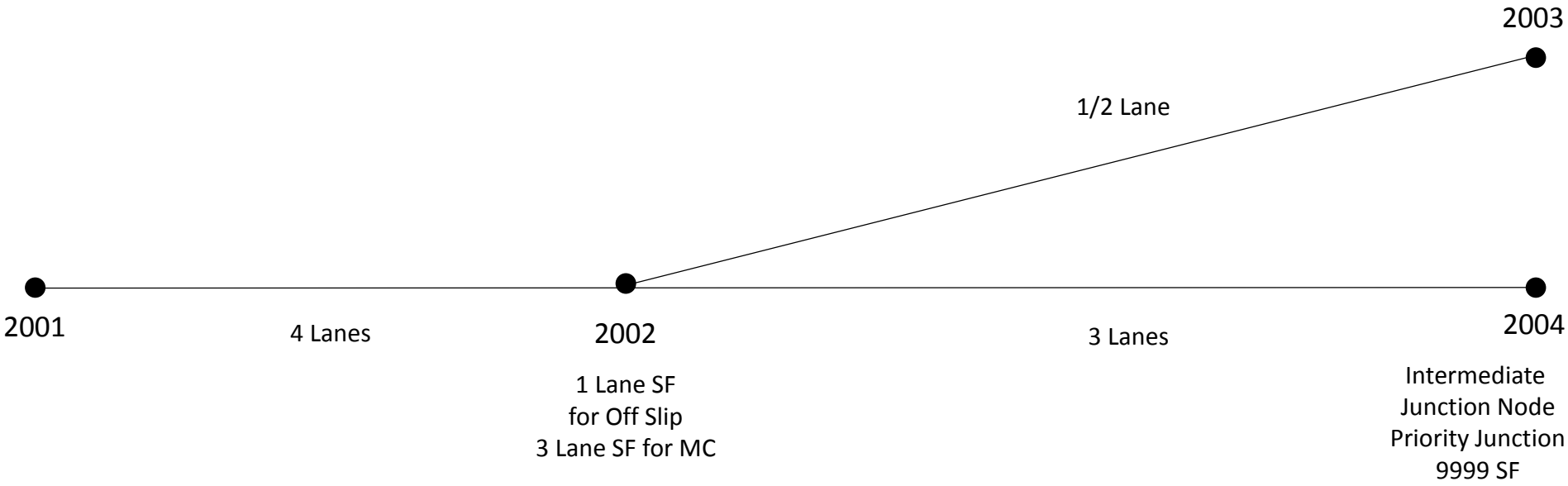
Source DMRB Volume 6 Section 2 Part 1 - TD22/06

Lane Drop at Taper Diverge – Schematic Diagrams



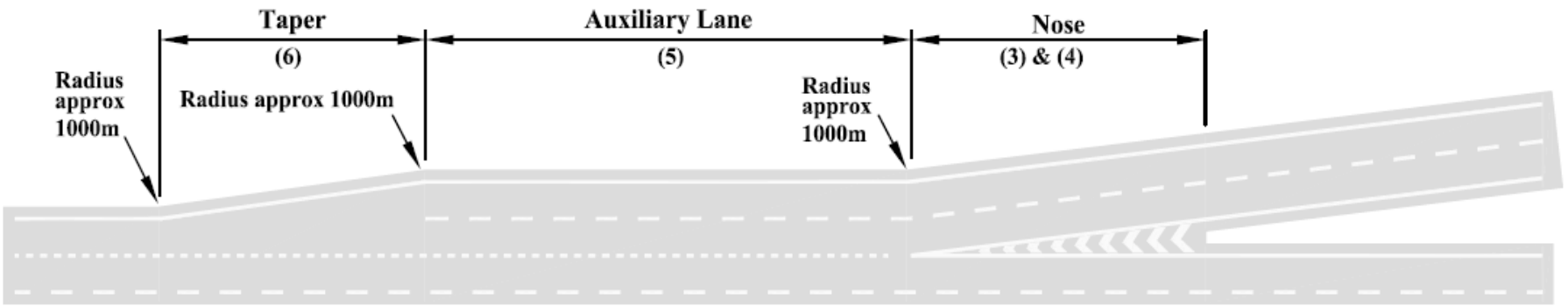
The edge line must be laid to the radii indicated

C - Lane Drop at Taper Diverge

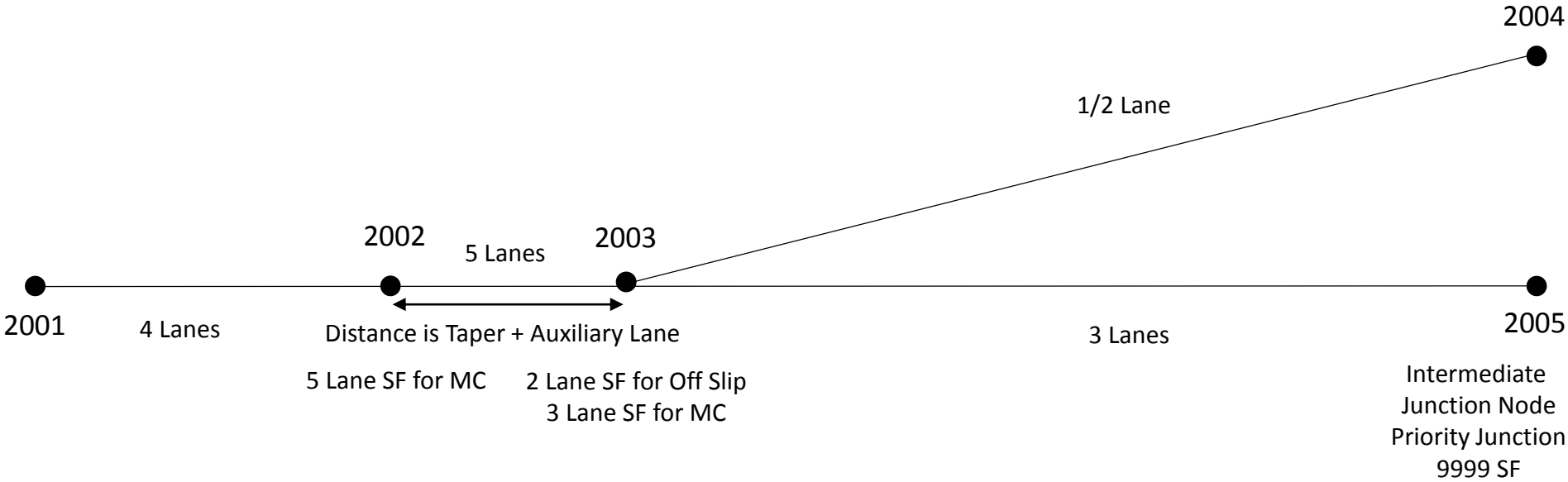


Source DMRB Volume 6 Section 2 Part 1 - TD22/06

Lane Drop at Parallel Diverge – Schematic Diagrams

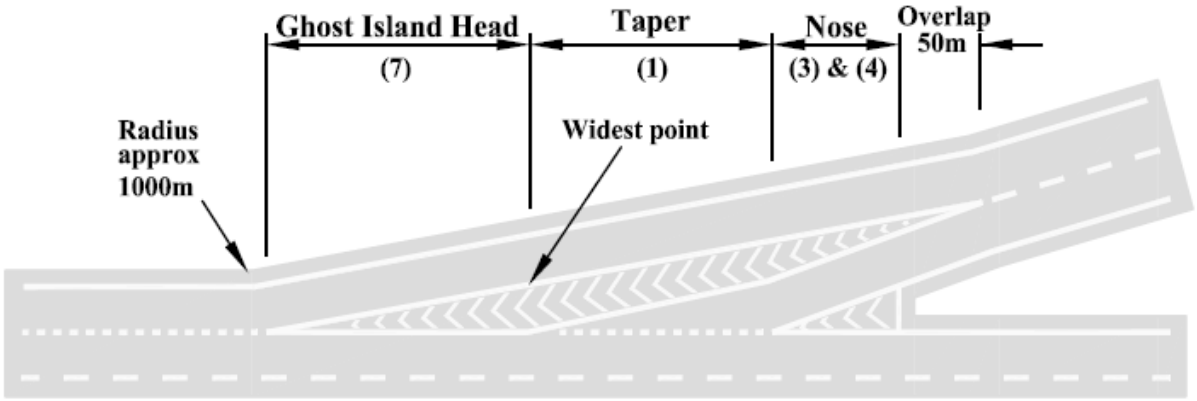


D (Option 2 Not Preferred) - Lane Drop at Parallel Diverge

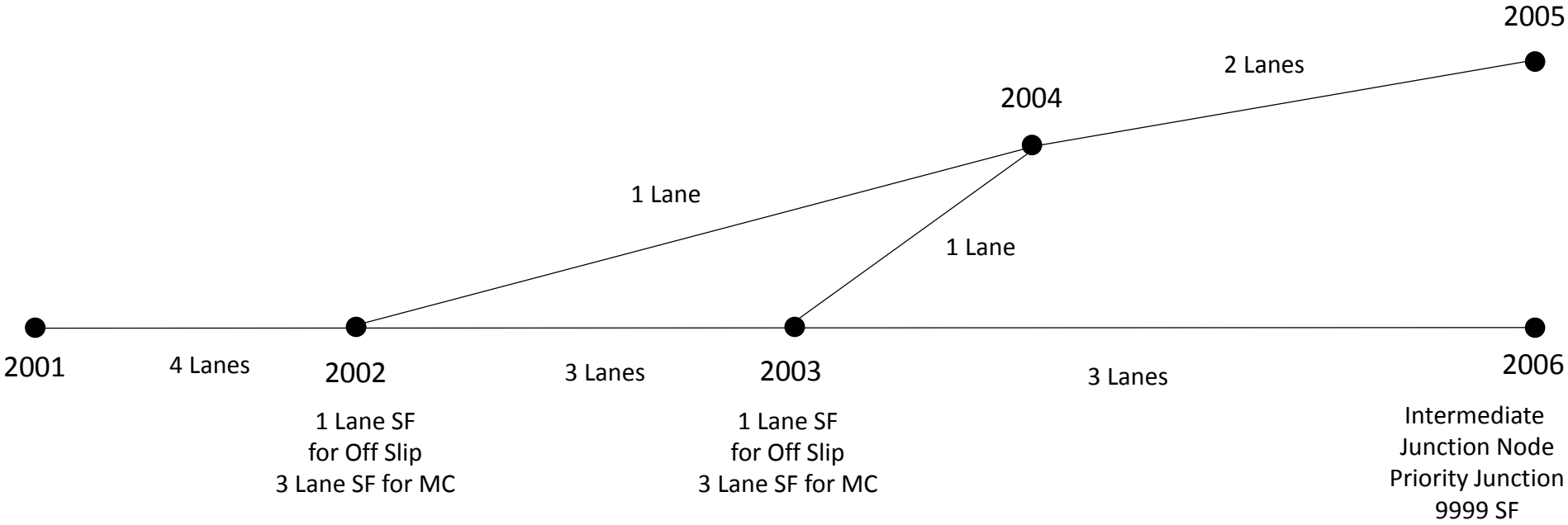


Source DMRB Volume 6 Section 2 Part 1 - TD22/06

Lane Drop at Ghost Island Diverge – Schematic Diagrams



D (Option 1 Preferred) - Ghost Island diverge for Lane Drop including for conversion of existing Lane Drop at Taper Diverge



Source DMRB Volume 6 Section 2 Part 1 - TD22/06

Initial Simulation Network Coding

The existing M20 network was cordoned between Junction 2 and 5, incorporating the M26 west of the M20 Junction 3.

The motorway merges were initially coded as follows:

J5 westbound = Tapered merge with taper 200m
1 lane on-slip with a saturation flow of 1930 pcus.hr merging with 3 lanes with a saturation flow of 6220 pcus.hr
Qnode 200m from merge node

J4 westbound and eastbound = Parallel merges with auxiliary lane and taper 400m
1 lane on-slip with a saturation flow of 1930 pcus.hr merging with 3 lanes with a saturation flow of 6220 pcus.hr
Qnode 400m from merge node

J3 eastbound = Parallel merge with ghost island with auxiliary lane and taper 400m
1 lane on-slip with a saturation flow of 1930 pcus.hr merging with 3 lanes with a saturation flow of 6220 pcus.hr
Qnode 400m from merge node

Initial Simulation Network Coding

The motorway diverges were initially coded as follows:

J5 eastbound = parallel diverge with taper and auxiliary lane 400m
1 lane off-slip with a saturation flow of 1930 pcus.hr (movement lane 1 to 1)
Main carriageway 3 lanes with a saturation flow of 6360 pcus.hr (movement lanes 2 to 4)

J4 westbound = Tapered diverge with ghost island taper 150,
1 lane off-slip with a saturation flow of 1930 pcus.hr (movement lane 1 to 1)
Main carriageway 3 lanes with a saturation flow of 6220 pcus.hr (movement lanes 1 to 3)

J4 eastbound = Tapered diverge with ghost island with taper 150m
1 lane off-slip with a saturation flow of 1930 pcus.hr (movement lane 1 to 1)
Main carriageway 3 lanes with a saturation flow of 6220 pcus.hr (movement lanes 1 to 3)

J3 eastbound = Tapered diverge with ghost island with taper 150m
1 lane off-slip with a saturation flow of 1930 pcus.hr (movement lane 1 to 1)
Main carriageway 3 lanes with a saturation flow of 6220 pcus.hr (movement lanes 1 to 3)

Network Development

The key parameters that will effect the test track network were initially set as follows:

ApresV was set at the SATURN default of 1

Funnel is set to F

Clicks = 90kph (maximum HGV speed)

GAPM = 1 second (for merges)

GAP = 2 seconds (priority junctions)

A negative stacking capacity was coded at the Qnode to break the chain of links.

Initial Speed-flow Curves

The speed-flow curves between Junction 2 and 5 allocated according to the Network Coding Manual. This assumes a capacity of 2229 pcus per lane as shown below. These were extracted from the original M25AM.

Description	S0	S1	Capacity (PCU/Hr)	Power Term (N value)
D6M Rural/Suburban	111	79	13374	2.9
D5M Rural/Suburban	111	79	11145	2.9
D4M Rural/Suburban	111	79	8916	2.9
D3M Rural/Suburban	111	79	6687	2.9
D2M Rural/Suburban	104	77	4660	3.0

June 16th 2015 ATC counts

		AM peak (7-9 av Hr)		Interpeak (9 to 16 av hr)		PM peak (16-18 av hr)	
Main Carriageways	**Direction**	**Total pcus**	**% hgv**	**Total pcus**	**% hgv**	**Total pcus**	**% hgv**
M26 Jct 3 and 2a	WB	3173	16%	2314	22%	2239	14%
M26 Jct 2a and J3	EB	2624	22%	2836	30%	3968	20%
M20 J3 and J2	WB	2975	14%	1637	24%	1615	14%
M20 J2 and J3	EB	2004	16%	1706	22%	2838	12%
M20 J4 and J3	WB	6147	15%	3951	23%	3854	14%
M20 J3 and J4	EB	4628	19%	4542	27%	6806	16%
M20 J5 and J4	WB	6662	13%	4440	20%	4784	12%
M20 J4 and J5	EB	5017	11%	4505	18%	6619	9%
M20 J6 and J5	WB	5744	14%	3916	21%	4091	14%
M20 J5 and J6	EB	4092	12%	3882	18%	5893	10%

Initial Network Calibration

The speed-flow curves were also revised to a maximum of 6850 pcus per hour for a D3 lane motorway, representing an increase from 2229 to 2283 pcus per hour for D3 to D6 motorways. It is proposed that D2 motorway will remain unchanged.

Description	S0	S1	Capacity (PCU/Hr)	Power Term (N value)
D6M Rural/Suburban	111	79	13700	2.9
D5M Rural/Suburban	111	79	11417	2.9
D4M Rural/Suburban	111	79	9133	2.9
D3M Rural/Suburban	111	79	6850	2.9
D2M Rural/Suburban	104	77	4660	3.0

	2 Lanes		3 Lanes		4 Lanes		5 Lanes		6 Lanes	
	Inc Ns	Exc Ns	Inc Ns	Exc Ns	Inc Ns	Exc Ns	Inc Ns	Exc Ns	Inc Ns	Exc Ns
Min Value	3680	3820	5590	5730	7500	7640	9410	9550	11320	NA
Median Value	4100	4240	6220	6360	8340	8480	10460	10600	12580	NA
Max Value	4520	4660	6850	6990	9180	9320	11510	11650	13840	NA

Initial Flow Calibration (Post ME)

		AM peak (7-9 av Hr)		Interpeak (9 to 16 av hr)		PM peak (16-18 av hr	
Main Carriageways	**Direction**	**Total pcus**	**% diff from Obs**	**Total pcus**	**% diff from Obs**	**Total pcus**	**% diff from Obs**
M26 Jct 3 and 2a	WB	3173	0%	2342	1%	2240	0%
M26 Jct 2a and J3	EB	2681	2%	2336	-18%	3691	-7%
M20 J3 and J2	WB	2976	0%	1641	0%	1638	1%
M20 J2 and J3	EB	2012	0%	1711	0%	2839	0%
M20 J4 and J3	WB	6149	0%	3983	1%	3878	1%
M20 J3 and J4	EB	4692	1%	4047	-11%	6514	-4%
M20 J5 and J4	WB	6660	0%	4426	0%	4740	-1%
M20 J4 and J5	EB	5011	0%	4497	0%	6488	-2%
M20 J6 and J5	WB	5742	0%	3903	0%	4050	-1%
M20 J5 and J6	EB	4087	0%	3875	0%	5754	-2%

Initial AM Peak Journey Time Validation - Light Vehicles

AM Peak	Modelled	Light Vehicles			% Diff	
Time (mins)	Distance (m)	ANPR	Trafficmaster	Initial Run	ANPR	Trafficmaster
M20 J5-J4 WB	4,404	2.7	3.3	4.3	59%	31%
M20 J4-J3 WB	3,712	2.2	2.2	2.9	31%	29%
M20 J3-J2 Bridge WB	1,839	1.0	1.0	1.1	18%	16%
M20 J5 to J2 Bridge WB	**9,955**	**5.9**	**6.5**	**8.3**	**41%**	**28%**
M20 J2 Bridge-J3 EB	1,852	1.0	0.9	1.0	9%	9%
M20 J3-J4 EB	3,702	2.0	2.0	2.1	9%	7%
M20 J4-J5 EB	4,398	2.5	2.5	2.6	5%	5%
M20 J2 Bridge to J5 EB	**9,952**	**5.4**	**5.4**	**5.8**	**7%**	**6%**
M20 J3 to M26 J2a Bridge WB	1,966	NA	1.2	1.5	NA	23%
M26 J2a Bridge to M20 J3 EB	2,044	NA	1.2	1.4	NA	22%

Initial Interpeak Journey Time Validation - Light Vehicles

Interpeak	Modelled	Light Vehicles			% Diff	
Time (mins)	Distance (m)	ANPR	Trafficmaster	Initial Run	ANPR	Trafficmaster
M20 J5-J4 WB	4,404	2.5	2.5	2.5	3%	3%
M20 J4-J3 WB	3,712	2.4	2.1	2.1	-13%	0%
M20 J3-J2 Bridge WB	1,839	1.0	1.0	1.0	5%	5%
M20 J5 to J2 Bridge WB	**9,955**	**5.9**	**5.5**	**5.7**	**-3%**	**2%**
M20 J2 Bridge-J3 EB	1,852	1.0	0.9	1.0	6%	9%
M20 J3-J4 EB	3,702	2.0	2.0	2.1	5%	5%
M20 J4-J5 EB	4,398	2.5	2.5	2.6	2%	3%
M20 J2 Bridge to J5 EB	**9,952**	**5.5**	**5.4**	**5.7**	**4%**	**5%**
M20 J3 to M26 J2a Bridge WB	1,966	NA	1.1	1.2	NA	9%
M26 J2a Bridge to M20 J3 EB	2,044	NA	1.2	1.4	NA	16%

Validation is based on Travel times +-15% of observed value

Initial PM Peak Journey Time Validation - Light Vehicles

PM Peak	Modelled	Light Vehicles			% Diff	
Time (mins)	Distance (m)	ANPR	Trafficmaster	Initial Run	ANPR	Trafficmaster
M20 J5-J4 WB	4,404	2.5	2.5	2.6	4%	4%
M20 J4-J3 WB	3,712	2.1	2.1	2.1	0%	0%
M20 J3-J2 Bridge WB	1,839	1.0	1.0	1.0	7%	6%
M20 J5 to J2 Bridge WB	**9,955**	**5.5**	**5.5**	**5.7**	**3%**	**3%**
M20 J2 Bridge-J3 EB	1,852	1.3	1.1	1.6	23%	44%
M20 J3-J4 EB	3,702	3.0	3.1	3.2	8%	3%
M20 J4-J5 EB	4,398	3.5	3.3	3.8	7%	14%
M20 J2 Bridge to J5 EB	**9,952**	**7.8**	**7.5**	**8.6**	**10%**	**14%**
M20 J3 to M26 J2a Bridge WB	1,966	NA	1.1	1.2	NA	9%
M26 J2a Bridge to M20 J3 EB	2,044	NA	2.0	2.2	NA	14%

Validation is based on Travel times +-15% of observed value

Initial AM Peak Journey Time Validation - Heavy Good vehicles

AM Peak	Modelled	Heavy Good Vehicles			% Diff	
Time (mins)	Distance (m)	ANPR	Trafficmaste	Initial Run	ANPR	Trafficmaster
M20 J5-J4 WB	4,404	3.3	3.7	4.5	36%	23%
M20 J4-J3 WB	3,712	2.6	2.7	3.1	19%	16%
M20 J3-J2 Bridge WB	1,839	1.2	1.3	1.3	6%	5%
M20 J5 to J2 Bridge WB	**9,955**	**7.2**	**7.6**	**9.0**	**25%**	**17%**
M20 J2 Bridge-J3 EB	1,852	1.2	1.3	1.3	5%	-2%
M20 J3-J4 EB	3,702	2.4	2.5	2.5	3%	0%
M20 J4-J5 EB	4,398	3.0	3.0	3.0	0%	1%
M20 J2 Bridge to J5 EB	**9,952**	**6.6**	**6.8**	**6.8**	**2%**	**0%**
M20 J3 to M26 J2a Bridge WB	1,966	NA	1.4	1.5	NA	12%
M26 J2a Bridge to M20 J3 EB	2,044	NA	1.4	1.5	NA	7%

Validation is based on Travel times +-15% of observed value

Initial Interpeak Journey Time Validation - Heavy Good vehicles

Interpeak	Modelled	Heavy Good Vehicles			% Diff	
Time (mins)	Distance (m)	ANPR	Trafficmaste	Initial Run	ANPR	Trafficmaster
M20 J5-J4 WB	4,404	3.0	3.1	3.1	2%	0%
M20 J4-J3 WB	3,712	3.0	2.6	2.6	-13%	-3%
M20 J3-J2 Bridge WB	1,839	1.3	1.3	1.3	0%	0%
M20 J5 to J2 Bridge WB	**9,955**	**7.2**	**7.0**	**6.9**	**-4%**	**-1%**
M20 J2 Bridge-J3 EB	1,852	1.2	1.2	1.3	3%	2%
M20 J3-J4 EB	3,702	2.5	2.5	2.6	3%	1%
M20 J4-J5 EB	4,398	3.0	3.0	3.1	3%	3%
M20 J2 Bridge to J5 EB	**9,952**	**6.7**	**6.8**	**6.9**	**3%**	**2%**
M20 J3 to M26 J2a Bridge WB	1,966	NA	1.4	1.4	NA	3%
M26 J2a Bridge to M20 J3 EB	2,044	NA	0.3	0.3	NA	5%

Validation is based on Travel times +-15% of observed value

Initial PM Peak Journey Time Validation Heavy Good vehicles

PM Peak	Modelled	Heavy Good Vehicles			% Diff	
Time (mins)	Distance (m)	ANPR	Trafficmast	Initial Run	ANPR	Trafficmaster
M20 J5-J4 WB	4,404	3.3	3.0	3.1	-6%	4%
M20 J4-J3 WB	3,712	2.6	2.7	2.6	-2%	-4%
M20 J3-J2 Bridge WB	1,839	1.2	1.3	1.3	1%	0%
M20 J5 to J2 Bridge WB	**9,955**	**7.2**	**6.9**	**6.9**	**-4%**	**0%**
M20 J2 Bridge-J3 EB	1,852	1.2	1.4	1.8	52%	32%
M20 J3-J4 EB	3,702	2.4	3.4	3.7	53%	10%
M20 J4-J5 EB	4,398	3.0	3.5	4.3	43%	22%
M20 J2 Bridge to J5 EB	**9,952**	**6.6**	**8.3**	**9.8**	**48%**	**19%**
M20 J3 to M26 J2a Bridge WB	1,966	NA	1.3	1.4	NA	6%
M26 J2a Bridge to M20 J3 EB	2,044	NA	2.2	2.4	NA	11%

Validation is based on Travel times +-15% of observed value

Saturn Network Parameter Testing

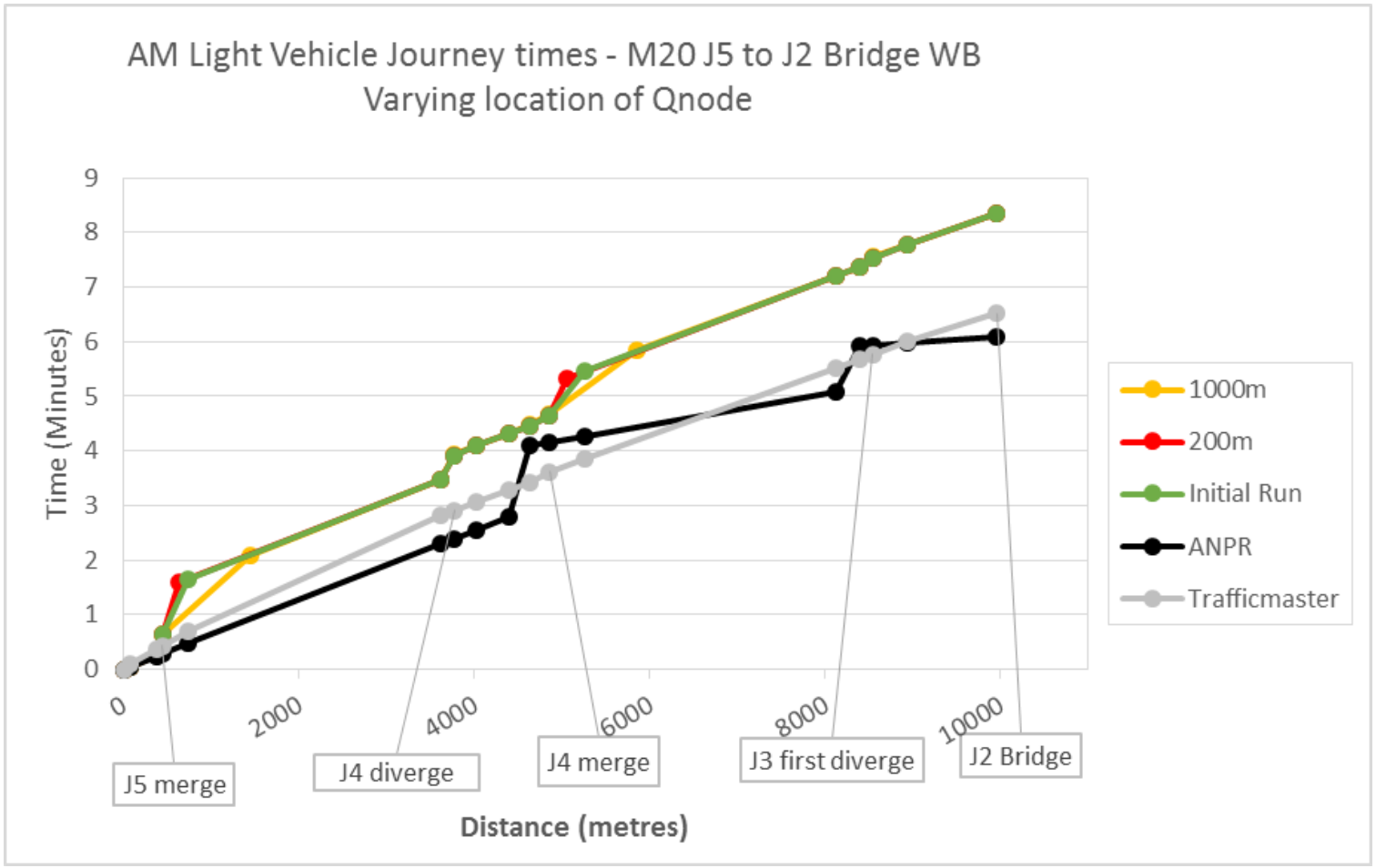
ApresV controls the default “weight” assigned to merging traffic in terms of the lane choice by the “major” traffic for turn priority markers M
SATURN default = 1 which assumes all the delay is on the main carriageway, proposed M20 values =0.5
testing values 0 to 1

GAPM gap for merging turns
SATURN default = 1, testing values 1 to 3

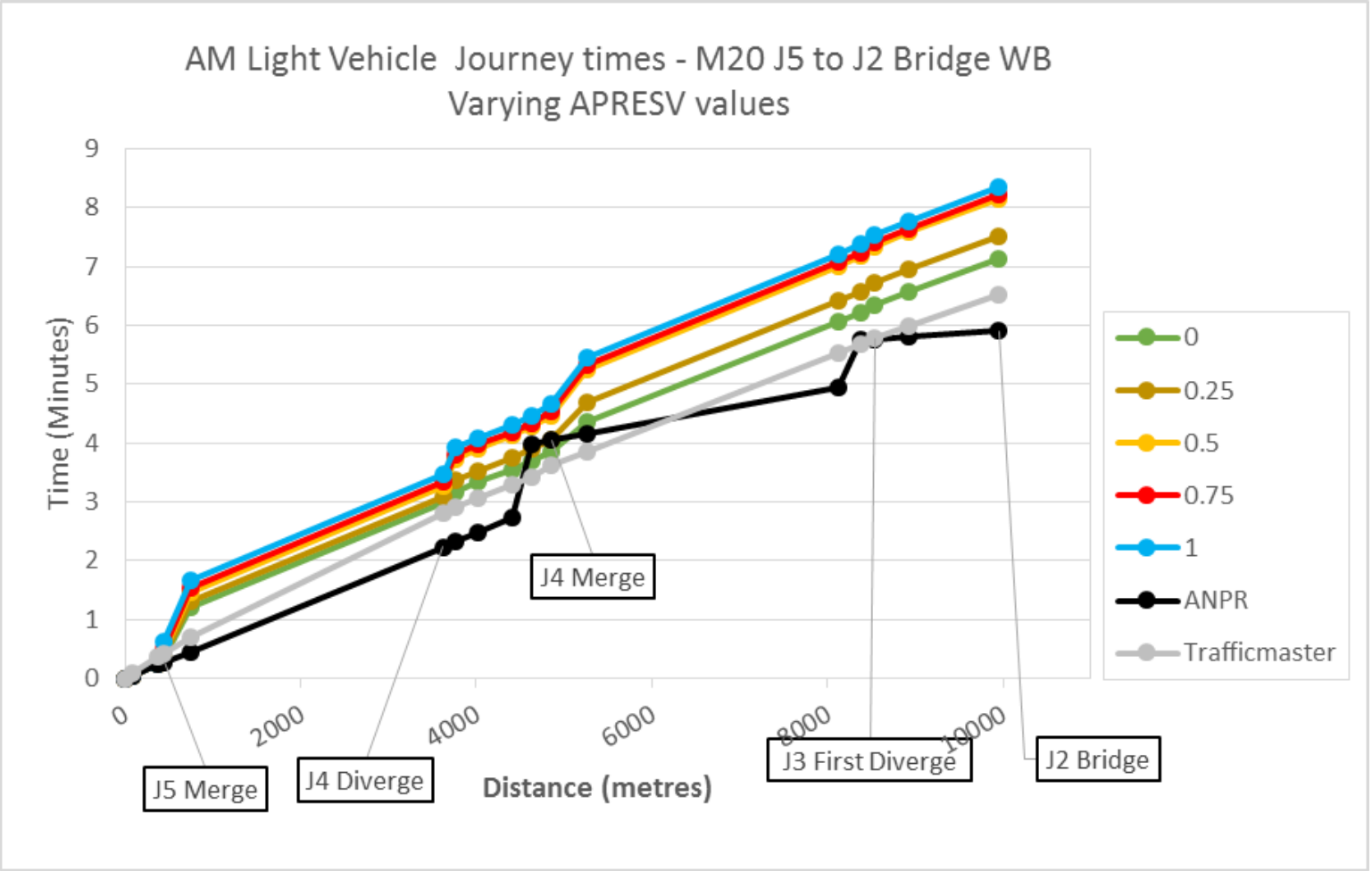
Merge removing Merge marker

Funnel If TRUE turns coded with a single Priority Marker M are assumed to “funnel” into a single exit lane with their “major” turn. Setting this parameter to FALSE (default) is felt to better replicate actual behaviour at merge locations.

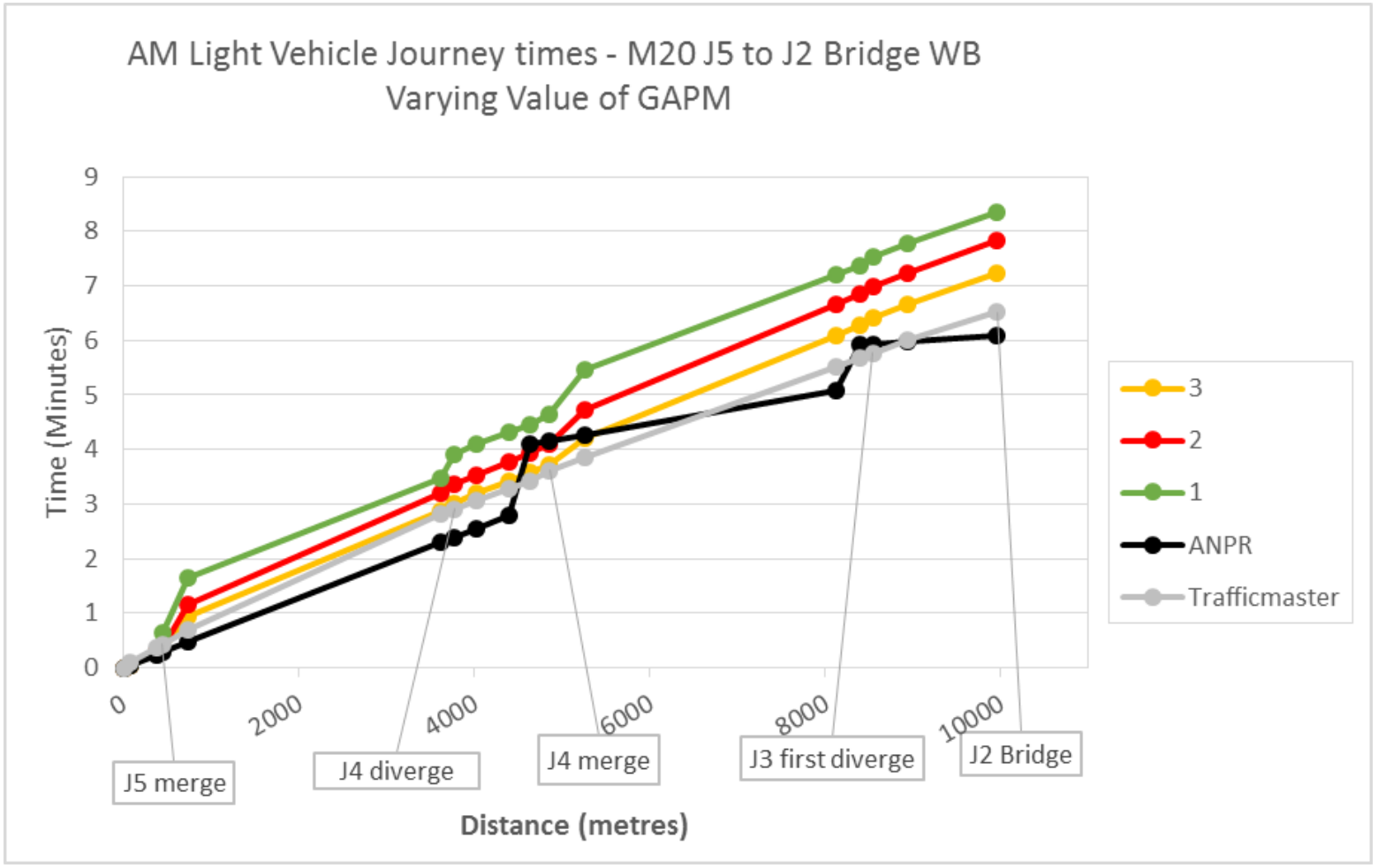
Varying location of Qnode – AM peak



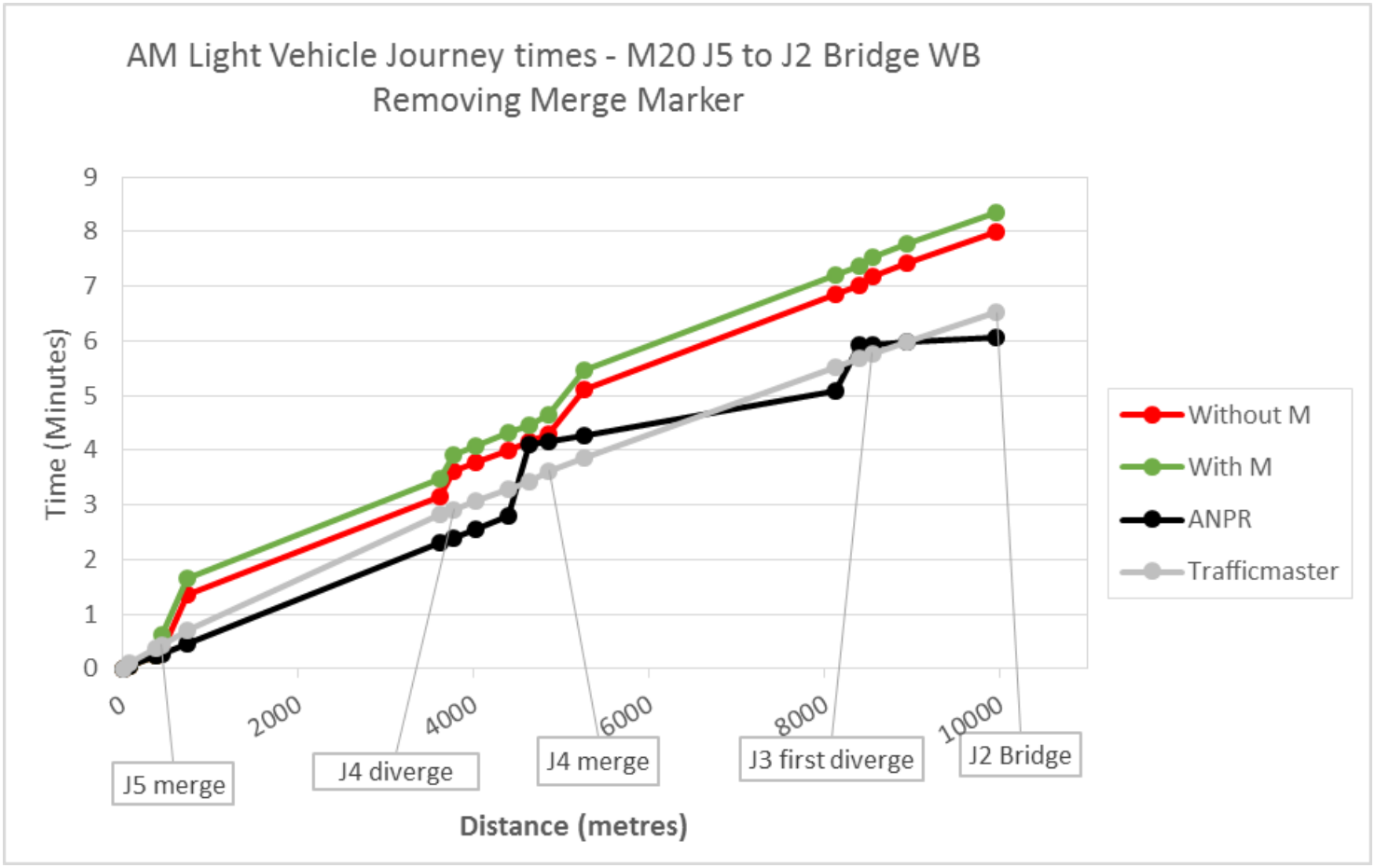
Varying APRESV – AM peak
Impact on M20 Journey Times



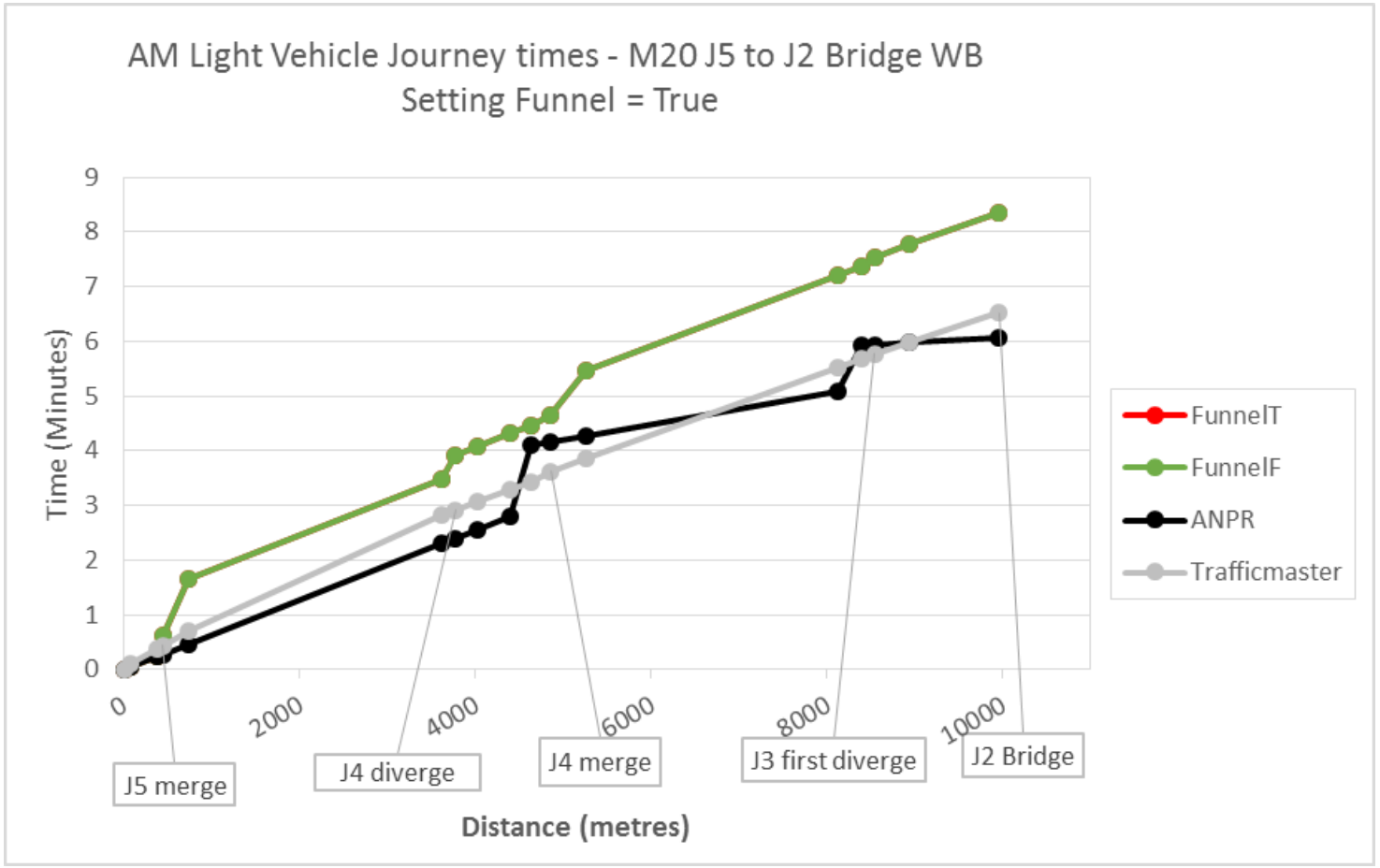
Varying GAPM– AM peak
Impact on M20 Journey Times



Removing Merge Marker– AM peak Impact on M20 Journey Times



Setting Funnel to True – AM peak
Impact on M20 Journey Times



Impact of Parameter Tests

ApresV has some effect on speeds on the main carriageway increasing the westbound speeds by as much as 1.5 mins (11kph) on the M20 between J2 and J5 when set to zero, however reducing it has an adverse impact for the on-slips traffic.

Increasing the GAPM from 1 to 3 reduced the travel times on the M20 in the westbound direction by 2.7 mins (17 kph) but there is a large increase in delays for the on-slips when GAPM is set to 2 and severe delays with GAPM set to 3.

Setting Funnel to T does not impact the journey times

Removing the Merge marker has minimal impact

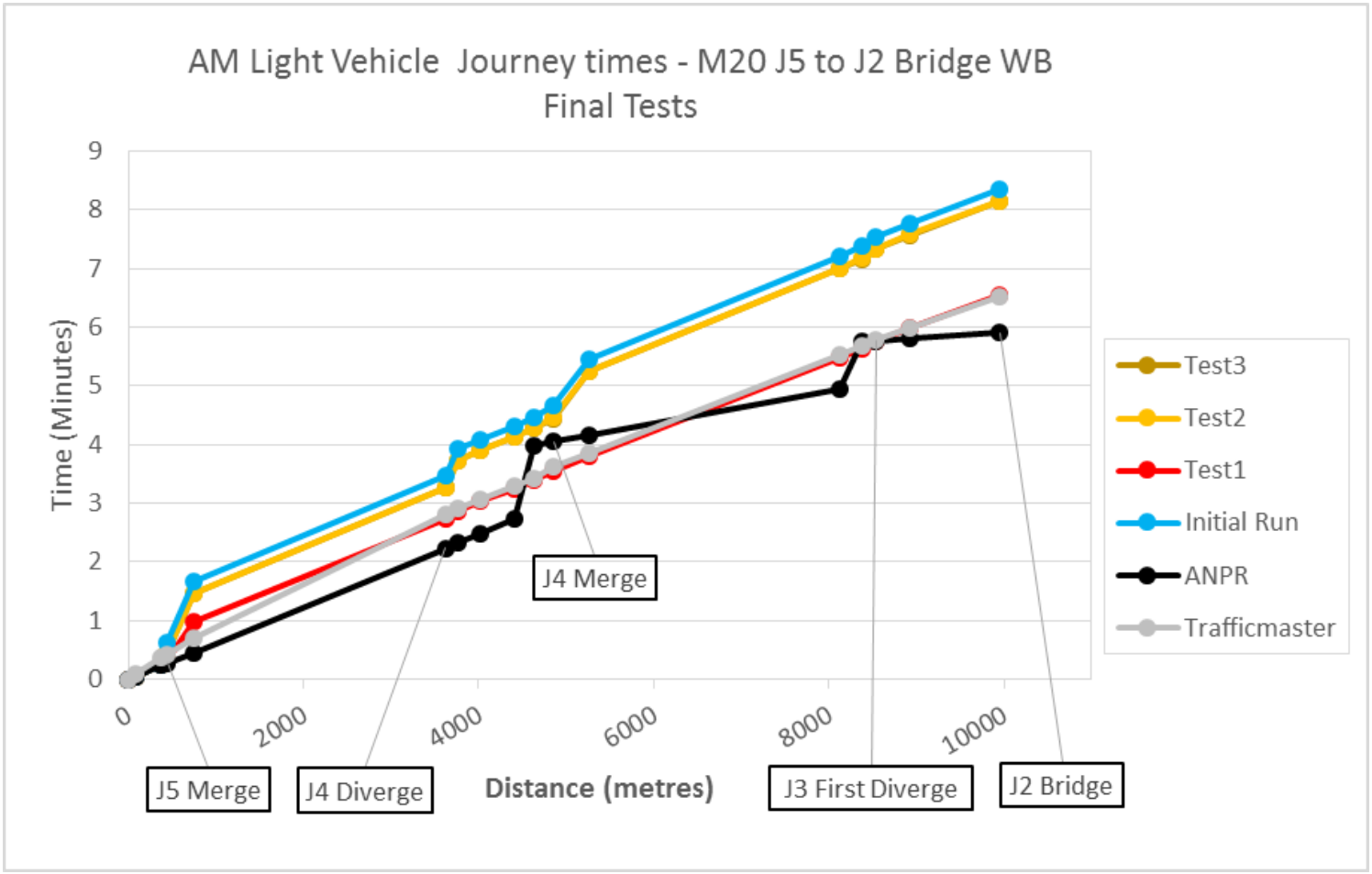
Adjusting the position of the Qnode also has limited impact on the overall travel time along the M20 when increasing or decreasing the stacking capacity.

Testing Combinations of Network Parameters

Initial Run - APRESV=1, GAPM1, With Merge Marker and initial Qnode lengths.

Test 1 - APRESV=0.5, GAPM2
Test 2 - APRESV=0.5, GAPM1
Test 3 - APRESV=0.5, GAPM2, GAPM1 junction J5 WB on-slip

Final Tests
Impact on Journey Time on the M20



Conclusions

There is no 1 size fits all method for coding motorway merges

The existing SATURN parameters enable substantial network calibration to reflect observed speeds and journey times

Combinations of parameters can be used to define the best fit

BE CAREFUL – some of these parameters can have major adverse effects on other locations in the networks in particular on slip roads

Questions?