GLASGOW WEST END OPTION TESTING

GLASGOW WEST END TRANSPORT MODEL

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IDENTIFICATION TABLE	
Client/Project owner	Glasgow City Council
Project	Glasgow West End Transport Model
Study	Glasgow West End Option Testing
Type of document	Testing Note
Date	15/02/2019
Reference number	GB01T16D96_WestEndOptionTesting_Report
Number of pages	22

APPROVAL

Version	Name		Position	Date	Modifications
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	Approved by	Chris Shaw	Associate	04/01/2019	
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	Checked by	Graham Smith	Senior Consultant	06/02/2019	
	Approved by	Chris Shaw	Associate	06/02/2019	
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	Checked by	Graham Smith	Senior Consultant	15/02/2019	
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1. INTRODUCTION

1.1 Purpose of Report

1.1.1 SYSTRA Ltd was commissioned by Glasgow City Council (GCC) to undertake the development of a Paramics Discovery model of the West End of Glasgow and the subsequent option testing.

1.1.2 The calibration and validation of the Base model is described in detail in the Model Development Report *SYSTRA, "Glasgow West End Transport Model, Model Development Report", June 2017* and the development of the Do-Minimum and Do-Something models is described in detail in SYSTRA, *"Glasgow West End Transport Model, Forecasting Report", October 2017*.

1.1.3 Five scenario models were developed and tested against the Do-Something model and the results of these tests were presented in the Scenario Testing Report (SYSTRA, "Glasgow West End Testing Report", December 2017). Subsequently an additional option was tested and the results presented in SYSTRA, "Glasgow West End Transport Model, Scenario 6 Testing Report", June 2018.

1.1.4 In September 2018 SYSTRA was commissioned by GCC to carry out six additional option tests using the Glasgow West End model. This report will discuss the modelling and outputs from the option tests.

2. OPTION MODEL DEVELOPMENT

2.1.1 Each option model has been tested using the Base demands and network (the 'a' models), and using the Base plus Development demands and network (the 'b' models).

2.1.2 The Base plus Development demands and network include the traffic associated with the proposed developments at the Glasgow University – Western Infirmary Site, Glasgow Harbour, Pump House Hotel and at Yorkhill Hospital.

2.2 Option 1a and Option 1b

2.2.1 The Option 1 model networks are based on the Scenario 6 test as detailed in SYSTRA, "Glasgow West End Transport Model, Scenario 6 Testing Report", June 2018.

2.2.2 The measures included in Scenario 6 are:

- Byres Road one-way Northbound between Dumbarton Road and White Street
- Church Street one-way Southbound between White Street and Dumbarton Street
- Dumbarton Road/Church Street/Thurso Street signalised
- Right turn movement reinstated from Dumbarton Road to Byres Road
- Dedicated cycle stage at Byres Road/Dumbarton Road

2.2.3 In addition the following changes were made to create the Option 1 model.

- Byres Road made one lane each way with short two lane section on North approach to University Avenue/Highburgh Road junction
- Dedicated left turn from Byres Road to Great Western Road removed
- Three second green head start for cycles added to the Byres Road movements at junctions with Great Western Road and University Avenue/Highburgh Road

2.2.4 In addition, signal optimisation was carried out at:

- Byres Road/University Avenue/Highburgh Road
- Byres Road/Great Western Road/Queen Margaret Drive
- Byres Road/Dumbarton Road

2.3 Option 2a and Option 2b

2.3.1 The Option 2 model networks are based on the Option 1 model networks with the following additional measures.

- Northbound bus gate on Byres Road immediately north of Highburgh Road/University Avenue junction
- Southbound bus gate on Byres Road immediately south of Highburgh Road/University Avenue junction
- All bus gates operate 7am to 7pm.

2.3.2 In addition, further signal optimisation was carried out at:

- Byres Road/University Avenue/Highburgh Road
- Byres Road/Great Western Road/Queen Margaret Drive
- Byres Road/Dumbarton Road
- Sauchiehall Street/Kelvin Way

2.3.3 In order to take account of rerouting that is likely to take place due to the introduction of the bus gates, changes have been made to the demands. The external trips that use Byres road northbound are likely to reroute outside the model. To account for this, the trips from Express way, Dumbarton Road, Hyndland Road and intermediate roads to Great Western Road, Queen Margret Drive and Hamilton Drive have been rerouted outside the model and re-join the model at Great Western Road.

2.4 Option 3a and Option 3b

2.4.1 The Option 3 model networks are based on the Option 1 model networks with the following additional measures.

- Southbound bus gate on Byres Road immediately south of Grosvenor Lane
- Northbound bus gate on Byres Road immediately north of Highburgh Road/University Avenue junction
- Southbound bus gate on Byres Road immediately south of Highburgh Road/University Avenue junction
- Northbound bus gate on Byres Road immediately north of Dumbarton Road.
- All bus gates in this test operate in the Inter Peak only.

2.4.2 In addition, further signal optimisation was carried out at:

- Byres Road/Great Western Road/Queen Margaret Drive

2.4.3 In order to take account of rerouting that is likely to take place due to the introduction of the Inter Peak bus gates, changes have been made to the Inter Peak demands. The external trips that use Byres road southbound are likely to reroute outside the model. To account for this, the trips from Great Western Road, Queen Margret Drive and Hamilton Drive to Express way, Dumbarton Road, Hyndland Road and intermediate roads have been rerouted outside the model re-join the model at Great Western Road.

2.5 Option 4a and Option 4b

2.5.1 The Option 4 model networks are based on the Option 1 model networks with the following additional measures:

- Eastbound bus gates on University Avenue immediately east of Ashton Road junction
- Eastbound bus gate on University Avenue immediately east of University Gardens junction
- Westbound bus gate on University Avenue immediately west of University main gate, gate to become exit only
- Westbound bus gate on University Avenue immediately west of the University gate situated west of Kelvin Way, gate to become entry only
- Oakfield Avenue made one way southbound
- Left turn only from Oakfield Avenue to University Avenue
- Left turn only from Southpark Avenue to University Avenue
- All bus gates operate 7am to 7pm.

2.5.2 In addition, signal optimisation was carried out at:

- Byres Road/University Avenue/Highburgh Road
- Byres Road/Great Western Road/Queen Margaret Drive
- Byres Road/Dumbarton Road
- Great Western Road/Park Road

2.5.3 For these options there are no clear effects on routing of external trips so no changes to the demands were required.

2.6 Option 5a and 5b

2.6.1 The Option 5 model networks are based on the Base and Do-Minimum model networks with the following additional measures:

- Byres Road one way southbound between Great Western Road and Dumbarton Road
- Church Street one way northbound between Dumbarton Road and Byres Road

2.6.2 In addition, signal optimisation was carried out at:

- Byres Road/University Avenue/Highburgh Road

- Byres Road/Great Western Road/Queen Margaret Drive
- Byres Road/Dumbarton Road
- Great Western Road/Bank Street

2.6.3 In order to take account of rerouting that is likely to take place due to the one way layout on Byres Road, changes have been made to the demands. The external trips that use Byres road northbound are likely to reroute outside the model. To account for this, the trips from Express way, Dumbarton Road, Hyndland Road and intermediate roads to Great Western Road, Queen Margret Drive and Hamilton Drive have been rerouted outside the model and join the model at Great Western Road.

2.7 Option 6a and 6b

2.7.1 The Option 6 model networks are based on the Base and Do-Minimum model networks with the following additional measures:

- Byres Road one way northbound between Dumbarton Road and Great Western Road
- Church Street one way southbound between Byres Road and Dumbarton Road
- Right turn from Dumbarton Road to Byres Road reopened

2.7.2 In addition, signal optimisation was carried out at:

- Byres Road/Great Western Road/Queen Margaret Drive
- Byres Road/Dumbarton Road
- University Avenue/Gibson Street/Bank Street
- Sauchiehall Street/Kelvin Way
- Great Western Road/Park Road

2.7.3 In order to take account of rerouting that is likely to take place due to the one way layout on Byres Road, changes have been made to the Inter Peak demands. The external trips that use Byres road southbound are likely to reroute outside the model. To account for this, the trips from Great Western Road, Queen Margret Drive and Hamilton Drive to Express way, Dumbarton Road, Hyndland Road and intermediate roads have been rerouted outside the model.

3. TESTING RESULTS

3.1.1 Each of the options being tested were modelled under the Base demand (a) and with the Base plus Development demands (b), incorporating demand from committed developments. These options were run 5 times each for the AM, IP and PM and average results across each of the 5 runs compared with the average results of 5 runs of the Base model.

3.2 Option a General Network Observations

3.2.1 Option 1a shows generally similar operation to the Base with some small increases in congestion on Byres Road in the AM and PM, most notably northbound and southbound between University Avenue and Great Western Road due to the removal of the left lane from Byres Road to Great Western Road and reduction in green time for traffic at the

Byres Road/University Avenue/Highburgh Road signals. There is also some increased queueing eastbound on Great Western Road on approach to the junction with Byres Road in the AM.

3.2.2 In Option 2a there is an increase in queueing on Hyndland Street southbound coming from the junction with Dumbarton Road. In the AM period, this queueing frequently extends back as far as Hyndland Road. This is caused by vehicles rerouting to avoid the southbound bus gate on Byres Road. The traffic levels on Byres Road are reduced compared to Option 1a and the Base model due to the bus gates on Byres Road.

3.2.3 Option 3a has IP only bus gates and as a result the operation of the model in the AM and PM is consistent with the operation of the Option 1a model. The Option 3a IP model operates without significant increases in congestion.

3.2.4 The Option 4a model shows increases in congestion on Byres Road compared to the other option models in all periods due to traffic being forced to reroute to avoid the bus gates on University Avenue. The largest increase is in the PM where this queueing can reach back from Great Western Road through the University Avenue junction to the Dumbarton Road junction. This is due to the inclusion of bus gates on University Avenue. University Avenue has a significant reduction in traffic.

3.2.5 The Option 5a model, with Byres Road operating as southbound only, has increased queueing elsewhere on the network most notably on Bank Street in the AM and PM. The queueing on Bank Street often extends back from Great Western Road to Kelvin Way and also through the Hillhead area.

3.2.6 The Option 6a model, with Byres Road northbound only shows increased queueing on alternative southbound routes in the AM and PM models, most notably on Otago Street and Kelvin Way. In the PM the queueing on Kelvin Way can extend back as far as University Avenue.

3.3 Option a Queue Length Comparisons

3.3.1 Figure 1 shows the queue length comparisons for the a options on the Byres Road approach to the junction with Great Western Road for the AM period.

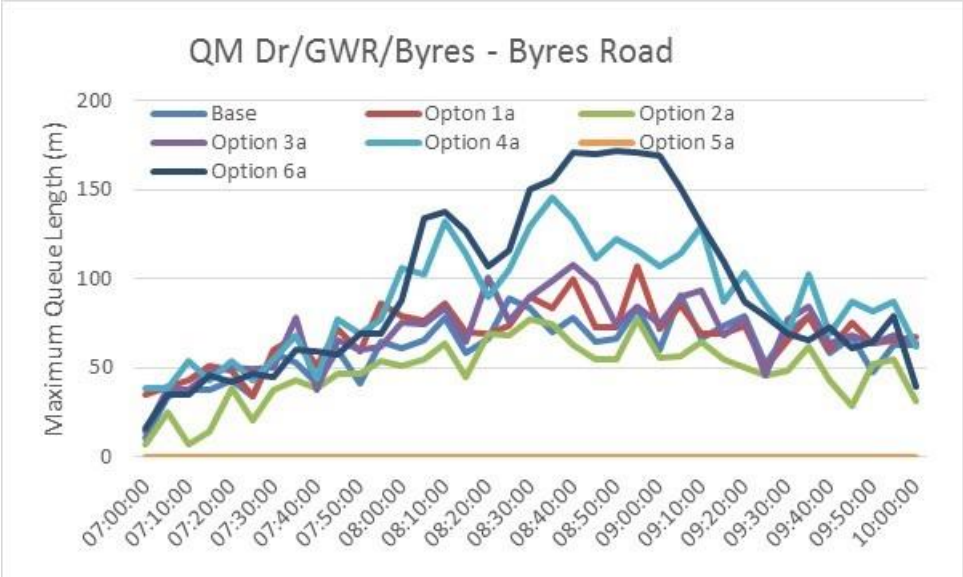

Figure 1. 'a' Option Queue Length Comparison AM – Byres Road at GWR

3.3.2 Figure 1 shows that the queueing on Byres Road on approach to Great Western Road is noticeably higher than the Base in Option 4a and Option 6a, this is due to vehicles rerouting to use Byres Road in these options. The queue length in Option 1a, 2a and 3a is similar to the Base at this location. There is no queueing in Option 5a on Byres Road on approach to Great Western Road as Byres Road is one way southbound in this test.

3.3.3 The queueing patterns at this location are similar in the IP and PM periods.

3.3.4 Figure 2 shows the queue length comparison for Bank Street on approach to the junction with Great Western Road.

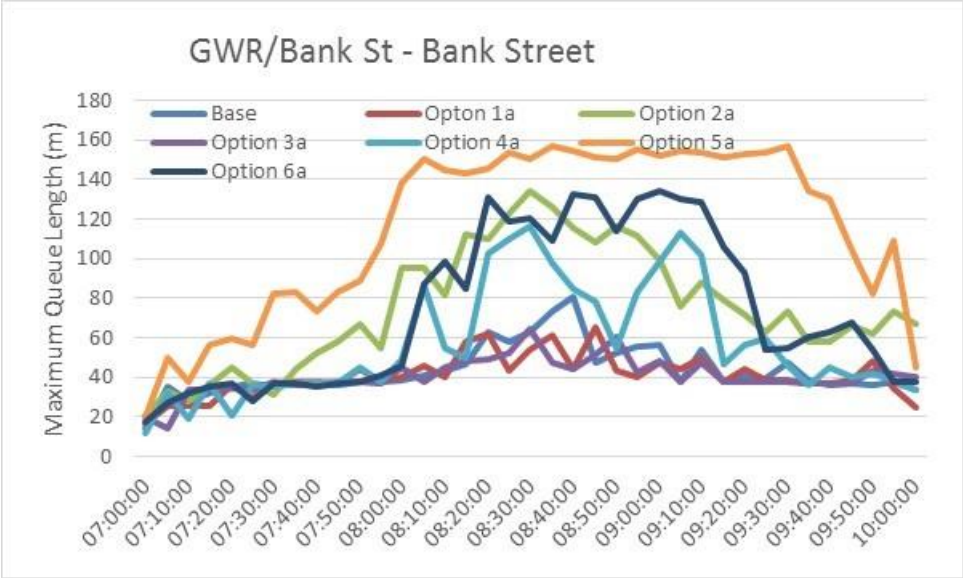

Figure 2. 'a' Option Queue Length Comparison AM – Bank Street at GWR

3.3.5 Figure 2 shows that there is an increase in queueing on Bank Street in Options 2a, 4a, 5a and 6a when compared to the Base model. This is due to northbound vehicles rerouting in these tests due to reductions in capacity elsewhere on the network, specifically on Byres Road in Options 2a, 5a and 6a and on University Avenue in Option 4a.

3.3.6 The queueing on Bank Street in Options 1a and 3a is similar to the Base.

3.3.7 The queueing patterns at this location are similar in the IP and PM periods.

3.3.8 Figure 3 shows the queue length comparison for Hyndland Street on approach to the junction with Dumbarton Road.

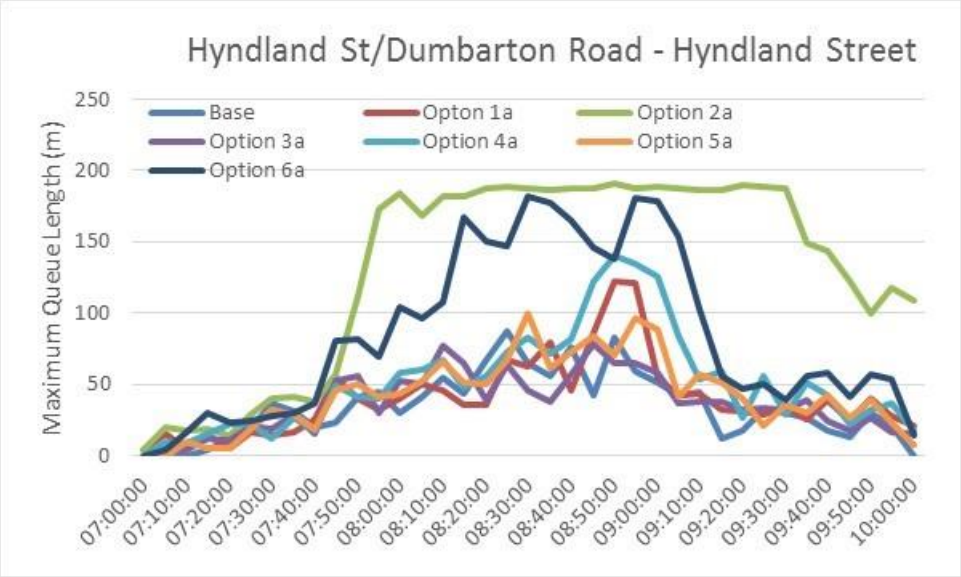

Figure 3. 'a' Option Queue Length Comparison AM – Hyndland Street

3.3.9 Figure 3 shows that there is an increase in queue lengths on Hyndland Street in Option 2a and Option 6a when compared to the Base. This is due to southbound vehicles rerouting as an alternative to using Byres Road.

3.3.10 The queueing in Options 1a, 3a, 4a and 5a is similar to the queueing in the Base.

3.3.11 The queueing patterns at this location are similar in the IP and PM periods.

3.3.12 Further queue length comparisons can be found in the accompanying spreadsheet.

3.4 Option a Link Count Comparisons

3.4.1 Table 1, Table 2 and Table 3 show the link count comparisons for selected links in the models.

Table 1. 'a' Option Link Count Comparisons 08:00-09:00

Location	Direction	Base	Option 1a	Option 2a	Option 3a	Option 4a	Option 5a	Option 6a
Byres Road South of University Avenue	Northbound	240	212	167	226	190	0	286
	Southbound	501	455	10	467	517	476	0
Byres Road North of University Avenue	Northbound	375	379	6	379	503	0	545
	Southbound	390	382	344	395	409	477	0
University Avenue East of Byres Road	Eastbound	440	447	762	461	56	653	365
	Westbound	272	265	151	285	127	243	430
Highburgh Road West of Byres Road	Eastbound	571	563	359	561	482	578	433
	Westbound	158	141	244	160	131	168	240
Hyndland Street South of Highburgh Road	Northbound	296	311	221	300	297	368	293
	Southbound	362	379	424	383	405	419	587
Kelvin Way North of Sauchiehall Street	Northbound	223	260	282	251	330	408	247
	Southbound	198	233	494	216	207	259	477
Bank Street South of GWR	Northbound	242	249	304	243	228	324	197
Otago St South of GWR	Southbound	195	201	197	191	231	172	417
Byres Road North of Dumbarton Road	Northbound	265	420	534	430	402	0	483
	Southbound	189	0	0	0	0	372	0
Byres Road South of GWR	Northbound	381	375	222	387	562	0	735
	Southbound	460	453	457	458	511	550	0
Church Street North of Dumbarton Road	Northbound	172	0	0	0	0	153	0
	Southbound	254	417	176	421	484	0	97

Table 2. 'a' Option Link Count Comparisons 13:00-14:00

Location	Direction	Base	Option 1a	Option 2a	Option 3a	Option 4a	Option 5a	Option 6a
Byres Road South of University Avenue	Northbound	221	170	113	37	100	0	228
	Southbound	356	306	7	7	168	365	0
Byres Road North of University Avenue	Northbound	355	387	6	6	217	0	469
	Southbound	312	274	275	173	180	368	0
University Avenue East of Byres Road	Eastbound	263	278	482	390	29	422	172
	Westbound	319	408	199	203	82	266	471
Highburgh Road West of Byres Road	Eastbound	324	322	206	240	132	327	246
	Westbound	203	204	297	249	80	175	304
Hyndland Street South of Highburgh Road	Northbound	249	277	240	266	130	325	265
	Southbound	184	217	374	292	100	212	385
Kelvin Way North of Sauchiehall Street	Northbound	221	251	281	322	129	378	251
	Southbound	162	190	287	289	100	221	338
Bank Street South of GWR	Northbound	196	177	263	236	98	427	165
Otago St South of GWR	Southbound	146	218	142	263	75	137	354
Byres Road North of Dumbarton Road	Northbound	189	331	371	7	187	0	342
	Southbound	221	0	0	0	0	385	0
Byres Road South of GWR	Northbound	356	378	247	215	228	0	527
	Southbound	389	328	418	52	225	508	0
Church Street North of Dumbarton Road	Northbound	162	0	0	0	0	111	0
	Southbound	178	355	162	164	199	0	93

Table 3. 'a' Option Link Count Comparisons 17:00-18:00

Location	Direction	Base	Option 1a	Option 2a	Option 3a	Option 4a	Option 5a	Option 6a
Byres Road South of University Avenue	Northbound	385	351	178	350	199	0	412
	Southbound	361	331	9	337	336	392	0
Byres Road North of University Avenue	Northbound	403	435	6	424	494	0	587
	Southbound	352	366	384	373	353	530	0
University Avenue East of Byres Road	Eastbound	324	303	512	302	30	546	240
	Westbound	403	392	270	386	193	360	574
Highburgh Road West of Byres Road	Eastbound	279	249	190	245	343	378	309
	Westbound	330	292	498	297	226	331	474
Hyndland Street South of Highburgh Road	Northbound	375	406	387	396	494	492	452
	Southbound	244	285	513	288	251	279	490
Kelvin Way North of Sauchiehall Street	Northbound	321	359	306	344	344	412	283
	Southbound	210	250	227	220	261	204	316
Bank Street South of GWR	Northbound	349	337	305	344	302	431	233
Otago St South of GWR	Southbound	210	248	191	221	181	173	390
Byres Road North of Dumbarton Road	Northbound	268	473	388	479	268	0	440
	Southbound	237	0	0	0	0	458	0
Byres Road South of GWR	Northbound	448	507	363	506	585	0	795
	Southbound	427	410	463	428	535	570	0
Church Street North of Dumbarton Road	Northbound	198	0	0	0	0	103	0
	Southbound	213	430	216	436	393	0	82

3.4.2 These show decreases around the proposed bus gate locations and the increased flows along Hyndland Street, Kelvin Way, and Bank Street as the traffic reroutes throughout the model.

3.4.3 As with the queue length comparisons, the impact of Option 3 is only in the Interpeak period as shown in Table 2.

3.5 Option b General Network Comparisons

3.5.1 Option 1b shows increased congestion on Byres Road northbound and southbound in the AM and PM, in the AM the queueing extends back to Dumbarton Road, less so in the PM than the AM. There is also queueing eastbound on Great Western Road on approach to the junction with Byres Road in the AM.

3.5.2 In Option 2b there is an increase in queueing on Hyndland Street southbound coming from the junction with Dumbarton Road. In the AM period, this queueing frequently extends back as far as Hyndland Road. In the PM there is an increase in queueing on Bank Street, which can extend back to Kelvin Way. This is caused by vehicles rerouting to avoid the bus gates on Byres Road. The traffic levels on Byres Road are reduced compared to Option 1b and the Base model.

3.5.3 Option 3b has IP only bus gates and as a result the operation of the model in the AM and PM is consistent with the operation of the Option 1b model. The Option 3b IP model operates without significant increases in congestion.

3.5.4 The Option 4b model shows increases in traffic levels on Byres Road compared to the other option models in all periods. The largest increase is in the PM where this queueing can reach back from Great Western Road through the University Avenue junction to the Dumbarton Road junction. There is also an increase in traffic on Dumbarton Road,

particularly westbound. These changes are due to the inclusion of bus gates on University Avenue. University Avenue has a significant reduction in traffic volumes.

3.5.5 The Option 5b model, with Byres Road southbound only, has increased queueing elsewhere on the network most notably on Bank Street in the AM and PM. The queueing on Bank Street often extends back from Great Western Road to Kelvin Way and also through the Hillhead area. This is particularly significant in the AM when the queueing can extend back from Great Western Road to Sauchiehall Street via Kelvin Way and to Byres Road via Hillhead. This can lead to model gridlock. Any gridlocked runs have been removed from the comparisons presented below.

3.5.6 The Option 6b model, with Byres Road northbound only shows increased queueing on alternative southbound routes in the AM and PM models, most notably on Otago Street and Kelvin Way. There is also increased queueing on Byres Road northbound. In the AM model there is increased congestion on Dumbarton Road on approach to the junction with Byres Road. In the PM the queueing on Kelvin Way can extend back as far as University Avenue.

3.6 Option 'b' Queue Length Comparisons

3.6.1 Figure 4 shows the queue length comparisons for the b options on the Byres Road approach to the junction with Great Western Road for the PM period.

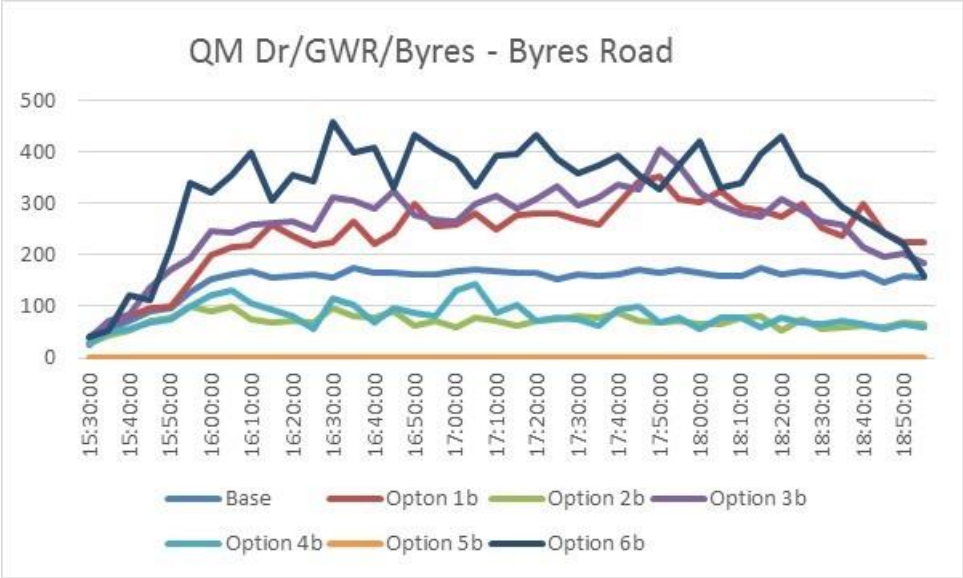

Figure 4. 'b' Option Queue Length Comparison PM – Byres Road South

3.6.2 Figure 4 shows that the queueing on Byres Road on approach to Great Western Road is highest in Option 6b with Byres Road Northbound only. There are also increases in queueing when compared to the Base in Options 1b and 3b. There are decreases in queueing in options 2b and 4b due to the bus gates on Byres Road. There is no queueing in Option 5b on Byres road on approach to Great Western Road as Byres Road is one way southbound in this test.

3.6.3 Figure 5 shows the queue length comparison for Bank Street on approach to the junction with Great Western Road.

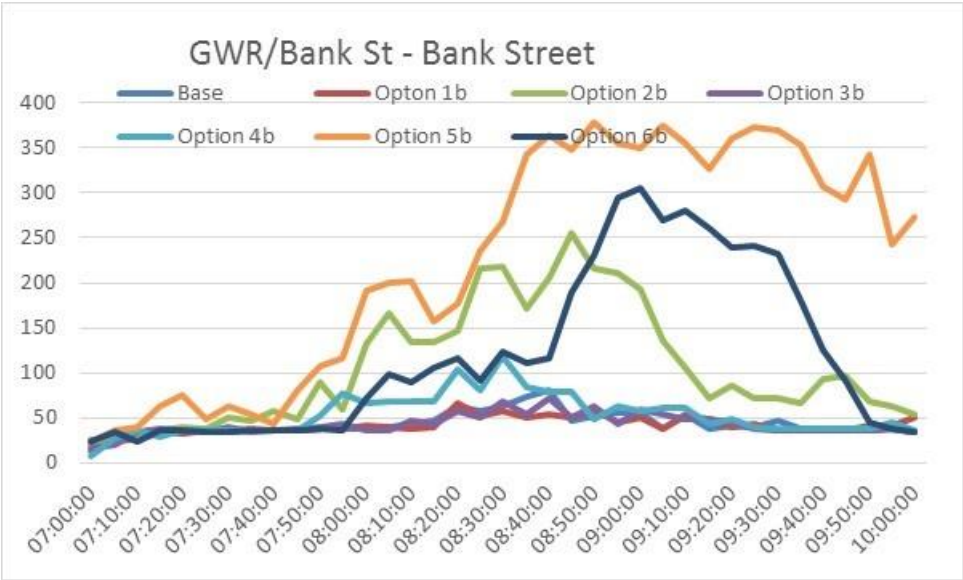

Figure 5. 'b' Option Queue Length Comparison AM – Bank Street

3.6.4 Figure 5 shows that there is an increase in queueing on Bank Street in Options 2b, 4b, 5b and 6b when compared to the Base model. This is due to northbound vehicles rerouting in these tests due to reductions in capacity elsewhere on the network, specifically on Byres Road in Options 2b, 5b and 6b and on University Avenue in Option 4b.

3.6.5 The queueing on Bank Street in Options 1b and 3b is similar to the Base.

3.6.6 The queueing patterns at this location are similar in the IP and PM periods.

3.6.7 Figure 6 shows the queue length comparison for Hyndland Street on approach to the junction with Dumbarton Road.

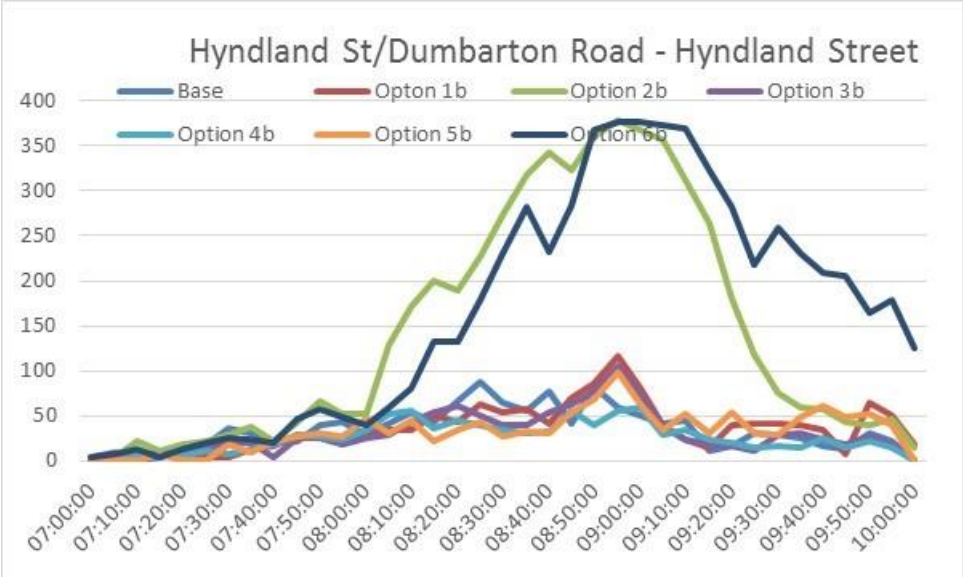

Figure 6. 'b' Option Queue Length Comparison AM – Great Western Road West

3.6.8 Figure 6 shows that there is an increase in queue lengths on Hyndland Street in Option 2b, 4b and Option 6b when compared to the Base. This is due to southbound vehicles rerouting as an alternative to using Byres Road.

3.6.9 The queueing in Options 1b, 3b and 5b is either similar to the queueing in the Base.

3.6.10 The queueing patterns at this location are similar in the IP and PM periods.

3.6.11 Further queue length comparisons can be found in the accompanying spreadsheet.

3.7 Option b Link Count Comparisons

3.7.1 Table 4, Table 5 and Table 6 show the link count comparisons for selected links in the models.

Table 4. 'b' Option Link Count Comparisons 08:00-09:00

Location	Direction	Base	Option 1b	Option 2b	Option 3b	Option 4b	Option 5b	Option 6b
Byres Road South of University Avenue	Northbound	240	187	175	188	154	0	305
	Southbound	501	465	10	462	487	433	0
Byres Road North of University Avenue	Northbound	375	449	6	452	488	0	579
	Southbound	390	359	319	365	361	434	0
University Avenue East of Byres Road	Eastbound	440	400	831	397	63	688	412
	Westbound	272	280	146	286	84	221	389
Highburgh Road West of Byres Road	Eastbound	571	627	459	627	533	647	542
	Westbound	158	140	252	155	95	180	244
Hyndland Street South of Highburgh Road	Northbound	296	294	272	294	276	397	217
	Southbound	362	427	581	445	420	479	538
Kelvin Way North of Sauchiehall Street	Northbound	223	329	327	335	337	409	263
	Southbound	198	215	443	209	224	255	466
Bank Street South of GWR	Northbound	242	250	302	254	226	360	222
Otago St South of GWR	Southbound	195	183	187	184	232	141	459
Byres Road North of Dumbarton Road	Northbound	265	403	559	405	372	0	458
	Southbound	189	0	0	0	0	340	0
Byres Road South of GWR	Northbound	381	365	215	365	388	0	597
	Southbound	460	469	462	467	376	479	0
Church Street North of Dumbarton Road	Northbound	172	0	0	0	0	152	0
	Southbound	254	415	182	406	450	0	36

Table 5. 'b' Option Link Count Comparisons 13:00-14:00

Location	Direction	Base	Option 1b	Option 2b	Option 3b	Option 4b	Option 5b	Option 6b
Byres Road South of University Avenue	Northbound	221	176	127	39	161	0	257
	Southbound	356	305	7	7	295	317	0
Byres Road North of University Avenue	Northbound	355	413	7	7	346	0	503
	Southbound	312	282	254	147	302	340	0
University Avenue East of Byres Road	Eastbound	263	250	502	370	55	399	190
	Westbound	319	334	188	185	109	236	399
Highburgh Road West of Byres Road	Eastbound	324	373	237	240	246	335	304
	Westbound	203	196	289	228	121	193	267
Hyndland Street South of Highburgh Road	Northbound	249	281	256	269	254	0	235
	Southbound	184	260	415	325	229	290	364
Kelvin Way North of Sauchiehall Street	Northbound	221	270	295	343	268	414	252
	Southbound	162	175	281	303	195	227	350
Bank Street South of GWR	Northbound	196	181	278	232	180	428	167
Otago St South of GWR	Southbound	146	156	141	299	149	149	348
Byres Road North of Dumbarton Road	Northbound	189	338	394	7	343	0	367
	Southbound	221	0	0	0	0	325	0
Byres Road South of GWR	Northbound	356	369	224	216	304	0	515
	Southbound	389	381	404	53	319	499	0
Church Street North of Dumbarton Road	Northbound	162	0	0	0	0	122	0
	Southbound	178	366	173	173	375	0	88

Table 6. 'b' Option Link Count Comparisons 17:00-18:00

Location	Direction	Base	Option 1b	Option 2b	Option 3b	Option 4b	Option 5b	Option 6b
Byres Road South of University Avenue	Northbound	385	348	205	351	180	0	411
	Southbound	361	324	9	321	304	363	0
Byres Road North of University Avenue	Northbound	403	513	6	512	376	0	601
	Southbound	352	355	329	349	372	507	0
University Avenue East of Byres Road	Eastbound	324	246	579	259	37	515	295
	Westbound	403	346	215	349	144	308	557
Highburgh Road West of Byres Road	Eastbound	279	317	242	324	253	340	371
	Westbound	330	285	399	285	234	282	456
Hyndland Street South of Highburgh Road	Northbound	375	395	395	390	419	0	364
	Southbound	244	309	417	304	259	259	439
Kelvin Way North of Sauchiehall Street	Northbound	321	414	370	419	328	485	479
	Southbound	210	223	339	242	228	262	492
Bank Street South of GWR	Northbound	349	316	328	312	225	498	271
Otago St South of GWR	Southbound	210	185	193	167	207	194	363
Byres Road North of Dumbarton Road	Northbound	268	478	419	476	318	0	407
	Southbound	237	0	0	0	0	443	0
Byres Road South of GWR	Northbound	448	516	340	522	430	0	665
	Southbound	427	426	446	416	295	554	0
Church Street North of Dumbarton Road	Northbound	198	0	0	0	0	105	0
	Southbound	213	415	216	414	418	0	65

3.7.2 These show decreases around the proposed bus gate locations and the increased counts along Hyndland Street, Kelvin Way, and Bank Street as the traffic is redirected throughout the model.

3.7.3 As with the queue length comparisons, the impact of Option 3 is only in the Interpeak period as shown in Table 2.

4. VEHICLE EMISSONS ANALYSIS

4.1.1 Using the outputs from Paramics Discovery and the AIRE (Analysis of Instantaneous Road Emissions) tool it is possible to generate vehicle emissions outputs from the models. Results are generated for 3 different pollutants, Nitrous Oxides (NOx), Particulate Matter (PM10) and Total Carbon. In the following section the results are presented for each of the pollutants, for four distinct areas of interest in the model. These are:

- Byres Road North (between Great Western Rd and University Ave)
- Byres Road South (between University Ave and Dumbarton Rd) and Church Street
- Dumbarton Road (between Hyndland Street and Argyle Street)
- University Avenue (Between Byres Road and Kelvin Way)

4.2 Option a Comparisons

4.2.1 Vehicle emissions comparisons for the 'a' option models for the AM, IP and PM are presented in Table 7, Table 8 and Table 9. These show the percentage change in emission of the three pollutants in each of the 'a' option model when compared to the Base. In general the change in pollutant levels follow the same pattern as the changes to the link flows, showing that a decrease in traffic will generally lead to a decrease in vehicle emissions and vice versa. It should be noted that while Options 5 and 6 show dramatic reductions in emissions on Byres Road and Dumbarton Road, the tables do not capture

the resulting increases in emissions which would take place elsewhere on the network, for example on Hyndland Street, Bank Street, Otago Street and Kelvin Way.

Table 7. 'a' Option Vehicle Emission Comparisons – AM (07:00-10:00)

		Option 1a	Option 2a	Option 3a	Option 4a	Option 5a	Option 6a
Byres Road N	NOx (mg)	-3%	-39%	-2%	3%	-43%	-44%
	PM10 (mg)	-3%	-38%	-1%	8%	-41%	-40%
	Total Carbon (mg)	-1%	-42%	-3%	8%	-41%	-37%
Byres Road S /Church Street	NOx (mg)	-16%	-45%	-19%	-19%	-64%	-65%
	PM10 (mg)	-14%	-45%	-16%	-16%	-60%	-59%
	Total Carbon (mg)	-13%	-46%	-17%	-14%	-59%	-59%
Dumbarton Road	NOx (mg)	-3%	-39%	-2%	3%	-43%	-44%
	PM10 (mg)	-3%	-38%	-1%	8%	-41%	-40%
	Total Carbon (mg)	-1%	-42%	-3%	8%	-41%	-37%
University Avenue	NOx (mg)	7%	16%	5%	-62%	7%	4%
	PM10 (mg)	3%	23%	2%	-72%	18%	7%
	Total Carbon (mg)	10%	30%	8%	-74%	21%	18%

Table 8. 'a' Option Vehicle Emission Comparisons – IP (12:00-14:00)

		Option 1a	Option 2a	Option 3a	Option 4a	Option 5a	Option 6a
Byres Road N	NOx (mg)	-5%	-39%	-62%	3%	-51%	-53%
	PM10 (mg)	-5%	-37%	-65%	7%	-48%	-46%
	Total Carbon (mg)	-3%	-42%	-70%	9%	-49%	-49%
Byres Road S /Church Street	NOx (mg)	-15%	-50%	-64%	-20%	-58%	-64%
	PM10 (mg)	-15%	-49%	-69%	-15%	-56%	-59%
	Total Carbon (mg)	-13%	-52%	-75%	-13%	-55%	-62%
Dumbarton Road	NOx (mg)	-5%	-39%	-62%	3%	-51%	-53%
	PM10 (mg)	-5%	-37%	-65%	7%	-48%	-46%
	Total Carbon (mg)	-3%	-42%	-70%	9%	-49%	-49%
University Avenue	NOx (mg)	-3%	17%	2%	-61%	16%	8%
	PM10 (mg)	-2%	18%	7%	-71%	20%	9%
	Total Carbon (mg)	-2%	21%	5%	-73%	18%	7%

Table 9. 'a' Option Vehicle Emission Comparisons – PM (16:00-19:00)

		Option 1a	Option 2a	Option 3a	Option 4a	Option 5a	Option 6a
Byres Road N	NOx (mg)	-4%	-48%	-7%	5%	-53%	-45%
	PM10 (mg)	-1%	-42%	-3%	9%	-47%	-38%
	Total Carbon (mg)	-4%	-51%	-6%	9%	-52%	-40%
Byres Road S /Church Street	NOx (mg)	-16%	-54%	-16%	-12%	-57%	-61%
	PM10 (mg)	-11%	-52%	-12%	-12%	-55%	-56%
	Total Carbon (mg)	-10%	-56%	-10%	-3%	-56%	-56%
Dumbarton Road	NOx (mg)	-4%	-48%	-7%	5%	-53%	-45%
	PM10 (mg)	-1%	-42%	-3%	9%	-47%	-38%
	Total Carbon (mg)	-4%	-51%	-6%	9%	-52%	-40%
University Avenue	NOx (mg)	11%	21%	6%	-65%	27%	28%
	PM10 (mg)	6%	23%	4%	-75%	36%	23%
	Total Carbon (mg)	11%	15%	7%	-78%	25%	38%

4.3 Option b Comparisons

4.3.1 Vehicle emissions comparisons for the 'b' option models for the AM, IP and PM are presented in Table 10, Table 11 and Table 12. These show the percentage change in emission of the three pollutants in each of the 'b' option model when compared to the Base. In general the change in pollutant levels follow the same pattern as the changes to the link flows, showing that a decrease in traffic will generally lead to a decrease in vehicle emissions and vice versa. It should be noted that while Options 5 and 6 show dramatic

reductions in emissions on Byres Road and Dumbarton Road, the tables do not capture the resulting increases in emissions which would take place elsewhere on the network, for example on Hyndland Street, Bank Street, Otago Street and Kelvin Way.

Table 10. 'b' Option Vehicle Emission Comparisons – AM (07:00-10:00)

		Option 1b	Option 2b	Option 3b	Option 4b	Option 5b	Option 6b
Byres Road N	NOx (mg)	-2%	-41%	11%	-25%	-32%	-36%
	PM10 (mg)	-1%	-40%	8%	-20%	-34%	-36%
	Total Carbon (mg)	-1%	-45%	12%	-25%	-28%	-31%
Byres Road S /Church Street	NOx (mg)	10%	-41%	27%	-30%	-19%	-55%
	PM10 (mg)	6%	-39%	20%	-27%	-26%	-52%
	Total Carbon (mg)	14%	-42%	34%	-25%	-5%	-37%
Dumbarton Road	NOx (mg)	-2%	-41%	11%	-25%	-32%	-36%
	PM10 (mg)	-1%	-40%	8%	-20%	-34%	-36%
	Total Carbon (mg)	-1%	-45%	12%	-25%	-28%	-31%
University Avenue	NOx (mg)	4%	16%	40%	-65%	44%	10%
	PM10 (mg)	3%	24%	22%	-75%	34%	12%
	Total Carbon (mg)	14%	27%	53%	-77%	75%	29%

Table 11. 'b' Option Vehicle Emission Comparisons – IP (12:00-14:00)

		Option 1b	Option 2b	Option 3b	Option 4b	Option 5b	Option 6b
Byres Road N	NOx (mg)	-1%	-45%	-62%	-30%	-52%	-55%
	PM10 (mg)	-1%	-44%	-66%	-27%	-49%	-50%
	Total Carbon (mg)	-1%	-47%	-69%	-29%	-51%	-47%
Byres Road S /Church Street	NOx (mg)	-17%	-48%	-63%	-26%	-13%	-63%
	PM10 (mg)	-17%	-48%	-70%	-22%	-21%	-59%
	Total Carbon (mg)	-12%	-48%	-74%	-21%	2%	-55%
Dumbarton Road	NOx (mg)	-1%	-45%	-62%	-30%	-52%	-55%
	PM10 (mg)	-1%	-44%	-66%	-27%	-49%	-50%
	Total Carbon (mg)	-1%	-47%	-69%	-29%	-51%	-47%
University Avenue	NOx (mg)	-1%	15%	-2%	-68%	12%	-1%
	PM10 (mg)	-1%	16%	0%	-80%	13%	0%
	Total Carbon (mg)	1%	16%	0%	-78%	12%	2%

Table 12. 'b' Option Vehicle Emission Comparisons – PM (16:00-19:00)

		Option 1b	Option 2b	Option 3b	Option 4b	Option 5b	Option 6b
Byres Road N	NOx (mg)	-10%	-56%	-13%	-42%	-57%	-38%
	PM10 (mg)	-6%	-50%	-9%	-34%	-51%	-34%
	Total Carbon (mg)	-8%	-60%	-12%	-44%	-58%	-32%
Byres Road S /Church Street	NOx (mg)	-18%	-51%	-17%	-33%	-49%	-46%
	PM10 (mg)	-15%	-50%	-13%	-29%	-48%	-45%
	Total Carbon (mg)	-11%	-54%	-12%	-29%	-45%	-37%
Dumbarton Road	NOx (mg)	-10%	-56%	-13%	-42%	-57%	-38%
	PM10 (mg)	-6%	-50%	-9%	-34%	-51%	-34%
	Total Carbon (mg)	-8%	-60%	-12%	-44%	-58%	-32%
University Avenue	NOx (mg)	-2%	17%	-6%	-69%	10%	49%
	PM10 (mg)	-4%	21%	-8%	-78%	21%	39%
	Total Carbon (mg)	-3%	11%	-7%	-80%	11%	60%

5. SUMMARY

5.1 Summary

5.1.1 SYSTRA Ltd was commissioned by Glasgow City Council (GCC) to undertake the development of a Paramics Discovery model of the West End of Glasgow and the subsequent option testing.

5.1.2 Twelve option models were tested, six using the Base demands and network, the 'a' models, and six using the Base plus Development demands and network, the 'b' models.

5.1.3 The Option 1a model shows generally similar operation to the Base with some small increases in congestion on Byres Road and the Option 1b model shows increased congestion on Byres Road in the AM and PM. There is also queueing eastbound on Great Western Road on approach to the junction with Byres Road in the AM. These changes are as a result of the removal of the left lane from Byres Road to Great Western Road and reduction in green time for traffic at the Byres Road/University Avenue/Highburgh Road signals.

5.1.4 The Option 2a and 2b models show an increase in queueing on Hyndland Street southbound coming from the junction with Dumbarton Road. This is caused by vehicles rerouting to avoid the southbound bus gate on Byres Road. The traffic levels on Byres Road are reduced compared to Option 1a and the Base model.

5.1.5 The Option 3a and 3b models have IP only bus gates and as a result the operation of the model in the AM and PM is consistent with the operation of the Option 1a model. The IP models operate without significant increases in congestion.

5.1.6 The Option 4a and 4b models show increases in traffic levels on Byres Road compared to the other option models in all periods. This is due to the inclusion of bus gates on University Avenue. University Avenue has a significant reduction in traffic.

5.1.7 The Option 5a and 5b models show increased queueing on Bank Street, Kelvin Way and in Hillhead. Due to Byres Road being made one way southbound.

5.1.8 The Option 6a and 6b models, with Byres Road northbound only have increased queueing on alternative southbound routes, most notably on Otago Street and Kelvin Way, there is also increased queueing on Byres Road northbound.

5.1.9 The vehicle emissions outputs generally reflect the link flow changes with reductions in traffic leading to reductions in vehicle emissions.

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