Doing It Backwards!
An Innovative Signal Control Solution for A Very Small Roundabout in East Kilbride

By

Barbara Chard BSc MSc CEng MICE MIHT
Barbara Chard Consultancy limited

JCT Symposium, September 2005

Barbara Chard Consultancy Limited
2 Byland Close
Lincoln LN2 4GH

Tel/Fax: 01522 548271
Email: bc@bcctraffic.co.uk
Web: www.bcctraffic.co.uk

1.0 BACKGROUND

This paper describes the development of a suitable signal controlled design for a previously un-signalled small (48m) roundabout in East Kilbride.

Mavor roundabout is sited along the East Kilbride corridor midway between two other roundabouts, Nerston, some 100m north, and Whirlies, some 220m south (**Figure 1**). The Barbara Chard Consultancy (BCC), in association with the Ian Routledge Consultancy, was commissioned by South Lanarkshire Council to provide signal controlled designs, drawings and specifications for all three roundabouts and advise whether linking of all three was beneficial. The JCT Consultancy also offered advice and assistance with the Linsig work described herin.

Figures 2A, 2B and 2C show the turning movements (in pcus, year 2004) at all three roundabouts in the weekday AM, Weekday PM and Saturday peak periods.

The author originally investigated a 'traditional design', i.e. three arms signal controlled, with the arm with the lowest traffic demand, i.e. Arm D, left as giveway (**Figure 3**). The numbers in circles on Figure 3 refer to photographs taken of the original un-signalled roundabout (see **Figures 4A, 4B and 4C)**.

The lane/flow diagrams and subsequent Transyt results for this 'original design' are shown in **Figures 5A, 5B and 5C** for the three peak periods.

However aspects of this 'traditional' design that gave concern were:-

- The difficulty in catering for the high right turn movement from Kingsway north. These right-turners would have to wait at the Kingsway South circulatory stop line where the distance available for stacking without blocking the ahead traffic is very small. It is therefore likely that queuing right-turners would affect traffic travelling South on Kingsway in the offside lane.

- In all the peak periods the mean queue on the south gyratory section is predicted at 4 pcus which may block ahead traffic and also cause the first vehicle/s out of the A749 to slow considerably. It would be very difficult for the system to cater for any more than 4 queuing arrivals per cycle.

- The design could lead to a 'see through' problem because the stop lines are very close together.

- Cars leaving Mavor Road (uncontrolled) rely on two upstream intergreen 'gaps' /cycle. During one of the two 'gap' periods, cars would proceed onto a red stopline with a very limited storage area.

Accordingly, a more robust design was sought that directly addressed the above concerns.

2.0 NEW DESIGN APPROACH – DOING IT BACKWARDS!

Figure 6 shows the improved design proposal for this roundabout. **Figures 7A, 7B and 7C** show the peak period laneflow diagrams for this modified design.

2.1 Design Amendments

2.1.1 Approach and Island Geometry

Kingsway North and the Node 2 gyratory arm now accommodate 3 entry lanes, enabling the offside lane to be designated as right turn only. Whilst this will allow southbound traffic to traverse the roundabout unimpeded, it does not of itself resolve the problem of the physical capacity of the storage space and whether this might ultimately lead to the roundabout locking up. However, the latter problem can be addressed using a different signalling technique.

2.1.2 Revision to Signalling Technique

Because the roundabout is so small, and offers little or no scope for in-roundabout storage, a design whereby all entries run separately in an anticlockwise fashion was considered. Such designs offer the following advantages:-

- No traffic should ever have to stop on the circulatory stop lines except 'U' turners.
- As all four arms will need to be signalised, this removes the safety concern regarding traffic exiting during 'gaps' onto the roundabout from Mavor Road.
- The anticlockwise sequential stopline release methodology removes the 'see-through' problem.

A disadvantage of such designs is that they can be significantly less efficient.

However in this case, by altering the roundabout geometry (i.e. increasing the entry capacity) and advancing each entry early(i.e. minimising 'lost time'), timings were found that provided a viable solution and also addressed the hitherto mentioned design concerns.

2.2 The 'Doing it Backwards' Signalling Technique

The proposal involves signalising all four arms of the roundabout and sequencing the signals to ensure that there is no internal queuing except for U turners. The roundabout, in essence, will run as a cross roads with each arm running in turn in an anti-clockwise direction.

To off-set inherent inefficiencies with this technique, it was necessary to:-

- carefully co-ordinate the signals to minimise the lost time at each signalled node; and
- improve capacity on the entries and within the roundabout.

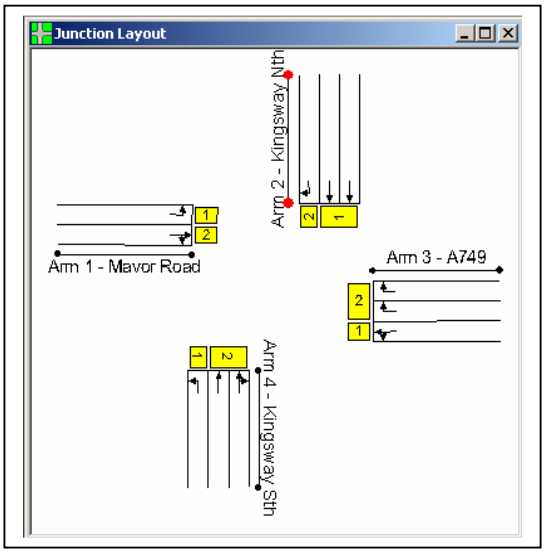
The later necessitated some modest highway alteration both on the approaches and on the roundabout island itself. These amendments are indicated in **Figure 6** and described in section 2.1 above. The works effectively reduced the 48m inscribed diameter roundabout to a 30m inscribed diameter roundabout!

The main alterations involved the conversion of Kingsway both North and South into 3 lane entries. This was possible with minimal carriageway works. Some adjustments were also necessary to the roundabout island geometry for alignment purposes.

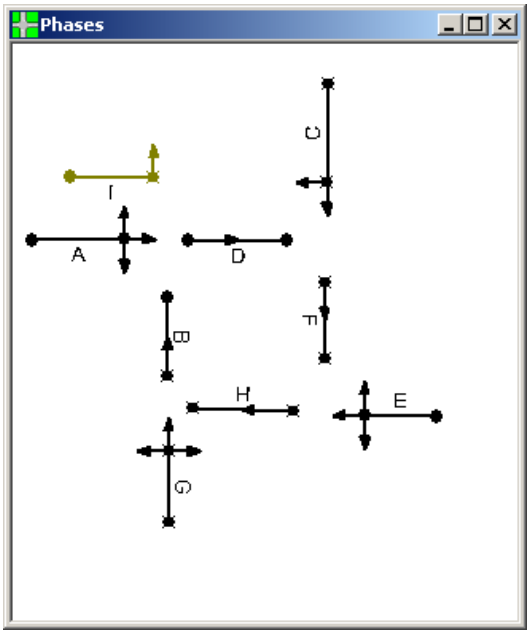
To achieve the proposed signal control methodology, it was necessary to design the roundabout as though one junction in a single stage stream. Unfortunately this reduces control type flexibility. Accordingly, the best way forward was considered to have the junction running only in CLF mode and providing a series of suitable (and as flexible as possible) CLF plans. In the off-peak periods it proved possible to run this roundabout at much lower cycle times.

In association with the JCT Consultancy, a LINSIG model, MAVOR1 was built for the design proposal as follows (see also **Figures 8A, 8B and 8C**):-

LINSIG Junction Layout View



LINSIG Phase View

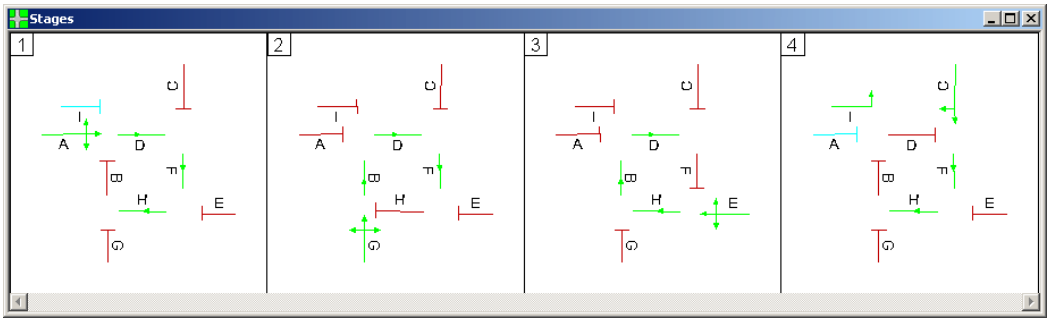


Note that a left-turn filter phase has been added onto Mavor Road. This is very unusual for a roundabout but does offer additional capacity for the Saturday scenario. **It is proposed that this filter stage will only be called, for the weekend peak hour scenarios.**

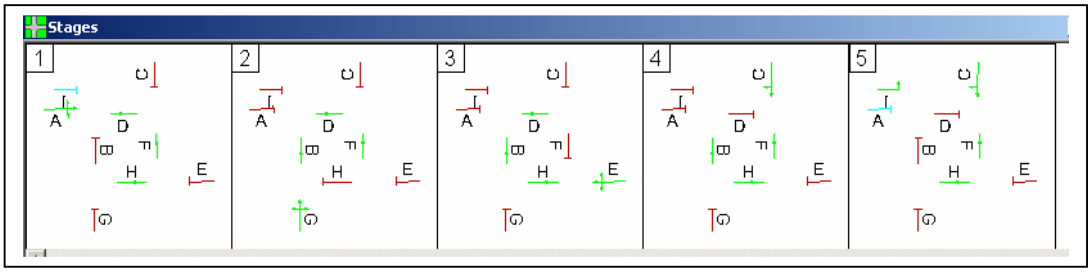
It should be noted that there are no internal links because no traffic will be stopping on the circulatory stop lines. Flares have been ignored in this model because they are long compared with the green time allocated.

The Staging is relatively straight forward with one Stage for each Arm:-

LINSIG Stage View



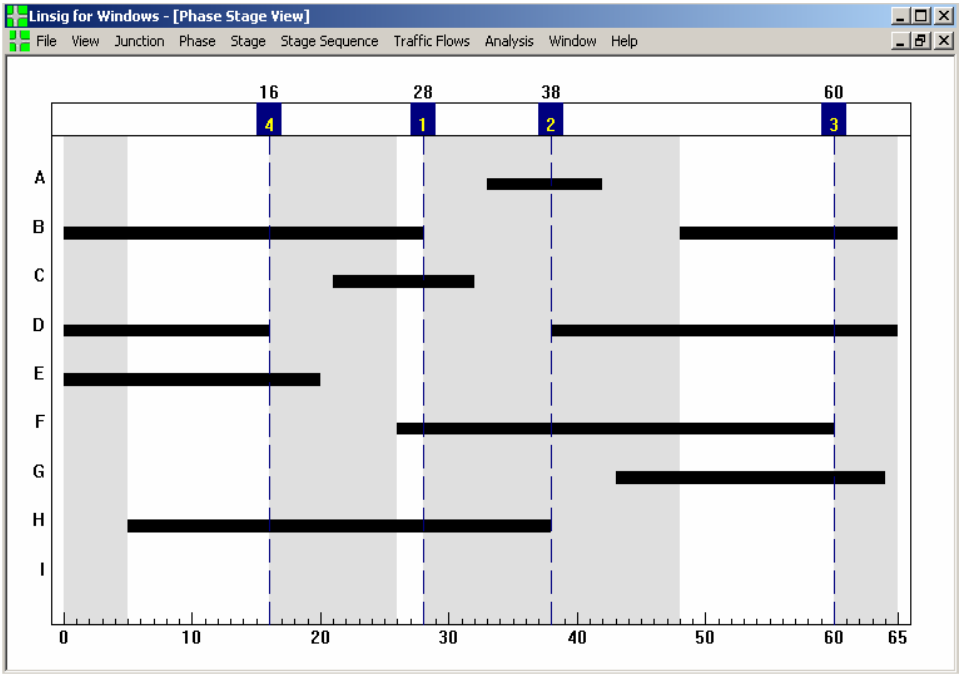
or



The filter stage, stage 5, will only be called in the peak Saturday/Sunday plans.

The figure below shows the Phase Stage Diagram for the morning peak. The coordination will be the same for every plan, only the Stage durations will vary.

LINSIG Phase/ Stage Diagram showing Timings for morning Peak



The co-ordination was derived 'interactively' using the Linsig program by first modelling as normal (i.e. specifying intergreens and stage times), then reducing the sequence to a minimum, and then applying phase delays and gains step by step to achieve the following objectives (see Figure 8C):-

- each entry phase to start up 5" before the next gyratory stopline phase
- the last car through each entry to be able to clear two internal stoplines (minimum of 5", preferably 6" cruise time required)

The results have been summarised in the Tables below and can be seen in more detail in **Figures 9A to 9C.** Overall, the revised design offered higher capacity than the previous 'traditional design' option, although it does include more carriageway works. In addition, the Figure 6 design solution is probably more robust in that an increase in the percentage of turning traffic for any reason will not cause the roundabout to fail.

	Cycle Time	**PRC %**
AM Peak	**65**	**1.4 %**
PM Peak	**54**	**1.4 %**
Saturday	**54 / 60**	**4.2 % / 7.4%**

LINSIG results for AM Peak

Link Results

Arm Num	Lnk Num	Lnk Typ	Ful Phs	Arr Phs	Num Grn	Tot Grn	Arr Grn /cyc	Gaps /cyc	Igrn Flow PCU	MxSat PCU/h	AvSat PCU/h	Cap PCU	Deg Sat	Dly s/pcu	TDly pcuh	Que pcu
1	1	U	A	I	1	9	-		139	1940	1940	298	46.6	31.0	1.2	2.3
1	2	U	A		1	9	-		76	1950	1950	300	25.3	27.0	0.6	1.2
2	1	U	C		1	11	-		627	3890	3890	718	87.3	42.4	7.4	12.1
2	2	U	C		1	11	-		241	1950	1950	360	66.9	35.3	2.4	4.2
3	1	U	E		1	20	-		316	1940	1940	627	50.4	21.3	1.9	4.0
3	2	U	E		1	20	-		1113	3900	3900	1260	88.3	31.7	9.8	16.8
4	1	U	G		1	21	-		48	1940	1940	657	7.3	15.5	0.2	0.6
4	2	U	G		1	21	-		1172	3900	3900	1320	88.8	31.2	10.1	17.3

Cycle Time 65s PRC 1.4 % Total Junction Delay 33.5 PCUh

LINSIG results for PM Peak

Link Results

Arm Num	Lnk Num	Lnk Typ	Ful Phs	Arr Phs	Num Grn	Tot Grn	Arr Grn /cyc	Gaps /cyc	Igrn Flow PCU	MxSat PCU/h	AvSat PCU/h	Cap PCU	Deg Sat	Dly s/pcu	TDly pcuh	Que pcu
1	1	U	A	I	1	9	-		293	1940	1940	359	81.6	42.5	3.5	5.3
1	2	U	A		1	9	-		316	1950	1950	361	87.5	52.7	4.6	6.6
2	1	U	C		1	14	-		949	3890	3890	1081	87.8	30.6	8.1	13.3
2	2	U	C		1	14	-		349	1950	1950	542	64.4	23.7	2.3	4.2
3	1	U	E		1	15	-		296	1940	1940	575	51.5	19.7	1.6	3.2
3	2	U	E		1	15	-		1026	3900	3900	1156	88.8	30.4	8.7	14.2
4	1	U	G		1	12	-		141	1940	1940	467	30.2	19.2	0.8	1.6
4	2	U	G		1	12	-		806	3900	3900	939	85.8	31.3	7.0	11.7

Cycle Time 54s PRC 1.4 % Total Junction Delay 36.5 PCUh

LINSIG results for Saturday

Link Results

Arm Num	Lnk Num	Lnk Typ	Ful Phs	Arr Phs	Num Grn	Tot Grn	Arr Grn /cyc	Gaps /cyc	Igrn Flow PCU	MxSat PCU/h	AvSat PCU/h	Cap PCU	Deg Sat	Dly s/pcu	TDly pcuh	Que pcu
1	1	U	A	I	1	16	-		391	1940	1940	611	64.0	21.7	2.4	4.4
1	2	U	A		1	10	-		343	1950	1950	397	86.3	47.3	4.5	6.6
2	1	U	C		1	15	-		963	3890	3890	1153	83.6	26.1	7.0	12.2
2	2	U	C		1	15	-		330	1950	1950	578	57.1	20.9	1.9	3.7
3	1	U	E		1	11	-		253	1940	1940	431	58.7	25.3	1.8	3.3
3	2	U	E		1	11	-		585	3900	3900	867	67.5	24.1	3.9	7.4
4	1	U	G		1	14	-		257	1940	1940	539	47.7	19.9	1.4	2.9
4	2	U	G		1	14	-		926	3900	3900	1083	85.5	28.5	7.3	12.5

Cycle Time 54s PRC 4.2 % Total Junction Delay 30.2 PCUh

Or

Link Results

Arm Num	Lnk Num	Lnk Typ	Ful Phs	Arr Phs	Num Grn	Tot Grn	Arr Grn /cyc	Gaps /cyc	Igrn Flow PCU	MxSat PCU/h	AvSat PCU/h	Cap PCU	Deg Sat	Dly s/pcu	TDly pcuh	Que pcu
1	1	U	A	I	1	20	-		391	1940	1940	679	57.6	20.1	2.2	4.4
1	2	U	A		1	12	-		343	1950	1950	423	81.2	40.4	3.8	6.1
2	1	U	C		1	17	-		963	3890	3890	1167	82.5	27.2	7.3	13.0
2	2	U	C		1	17	-		330	1950	1950	585	56.4	22.3	2.0	4.0
3	1	U	E		1	11	-		253	1940	1940	388	65.2	31.3	2.2	3.9
3	2	U	E		1	11	-		585	3900	3900	780	75.0	30.0	4.9	8.9
4	1	U	G		1	16	-		257	1940	1940	550	46.8	21.3	1.5	3.1
4	2	U	G		1	16	-		926	3900	3900	1105	83.8	29.0	7.5	13.1

Cycle Time 60s PRC 7.4 % Total Junction Delay 31.4 PCUh

3.0 OPERATIONAL ADJUSTMENTS – CLF DESIGN

Mavor roundabout signals were commissioned on Friday 25th March using CLF plans based on the Linsig File Mavor1 analyses (i.e. see peak hour plans Figures 9A, 9B and 9C). A Peek controller was used.

The CLF Steam, Stage and Phase labelling are shown in Figure 10.

Following a subsequent site visit in June 2005, when it was considered the traffic would have 'settled down', the following adjustments were made:-

- the intergreen time between the approach and the gyratory stoplines was reduced from 6" to 5" at nodes 1 and 2
- the start up of Phase C relative to Phase F was reduced from 5" to 4" for 'safety'
- small adjustments were made to the approach green times to better reflect observed demand requirements.

These adjustments are illustrated in Figures 11 and 12 where:-

- Figures 11A, 11B and 11C provide an operational key to the control methodology and CLF plan layout
- Figure 11D provides the full CLF Timetable by time of day and day of week
- Figures 12A, 12B and 12C show the currently running weekday AM, weekday PM and Saturday peak hour CLF plans; and
- Figure 12D shows a 'manufactured' plan for night-time use.

What about linking the three roundabouts?

The optimum cycle times for the three roundabouts do not 'lend themselves' to running the three roundabouts at a single cycle time or a factor thereof. The June site visit confirmed the author's original advice that the three roundabouts would function best if left to individually run at their own optimum cycle times. No 'approach starvation' was observed in the peak periods.

A Paramics model illustrating current operation together with video footage taken during the June site visit (if time) will be shown at the Symposium presentation.

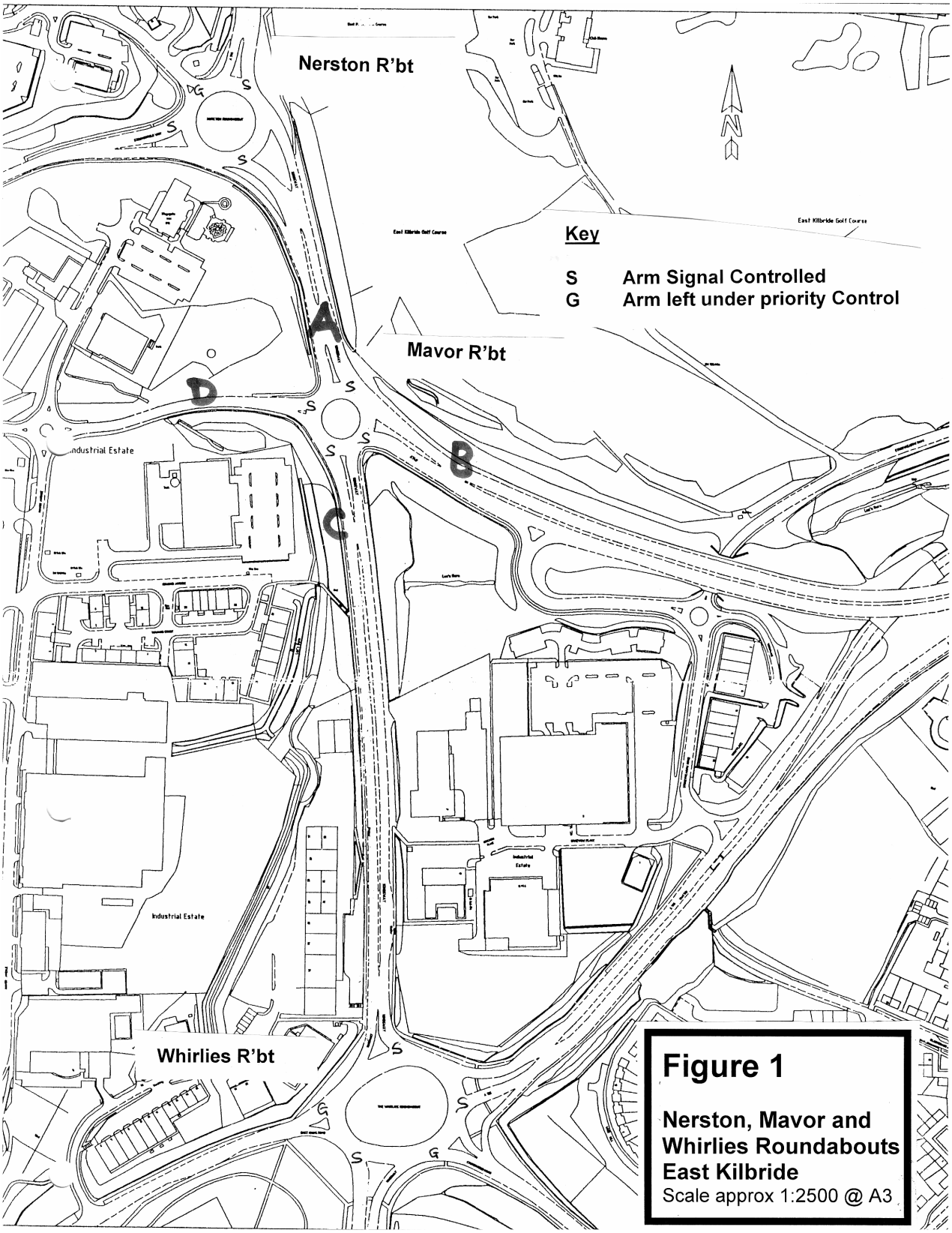
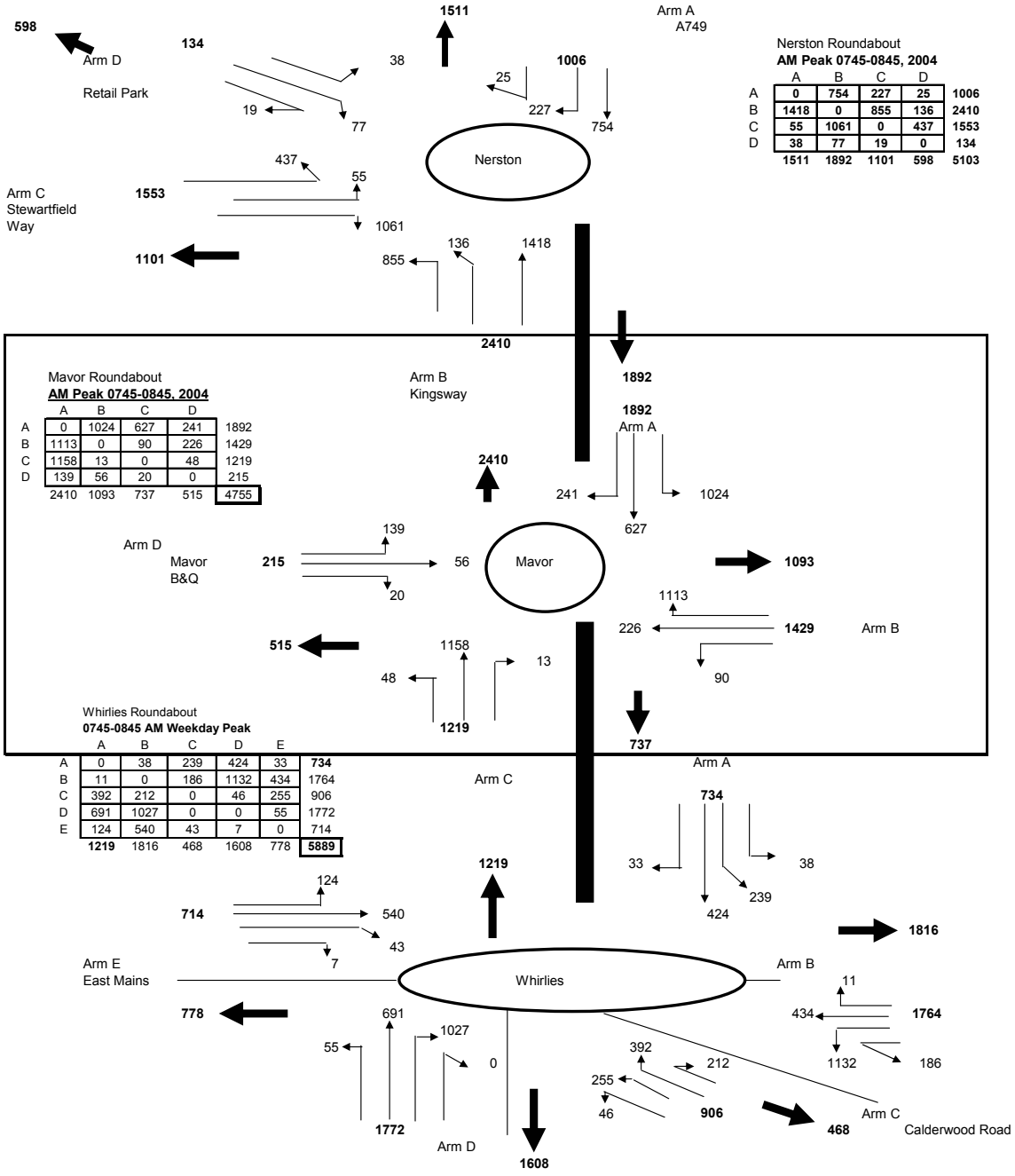


Figure 1

Nerston, Mavor and Whirlies Roundabouts East Kilbride
Scale approx 1:2500 @ A3



Nerston Roundabout
AM Peak 0745-0845, 2004

	A	B	C	D	
A	0	754	227	25	1006
B	1418	0	855	136	2410
C	55	1061	0	437	1553
D	38	77	19	0	134
	1511	1892	1101	598	5103

Mavor Roundabout
AM Peak 0745-0845, 2004

	A	B	C	D	
A	0	1024	627	241	1892
B	1113	0	90	226	1429
C	1158	13	0	48	1219
D	139	56	20	0	215
	2410	1093	737	515	4755

Whirlies Roundabout
0745-0845 AM Weekday Peak

	A	B	C	D	E	
A	0	38	239	424	33	734
B	11	0	186	1132	434	1764
C	392	212	0	46	255	906
D	691	1027	0	0	55	1772
E	124	540	43	7	0	714
	1219	1816	468	1608	778	5889

Figure 2A
Weekday AM Peak (0745 -0845) Flows (Pcus – Year 2004)

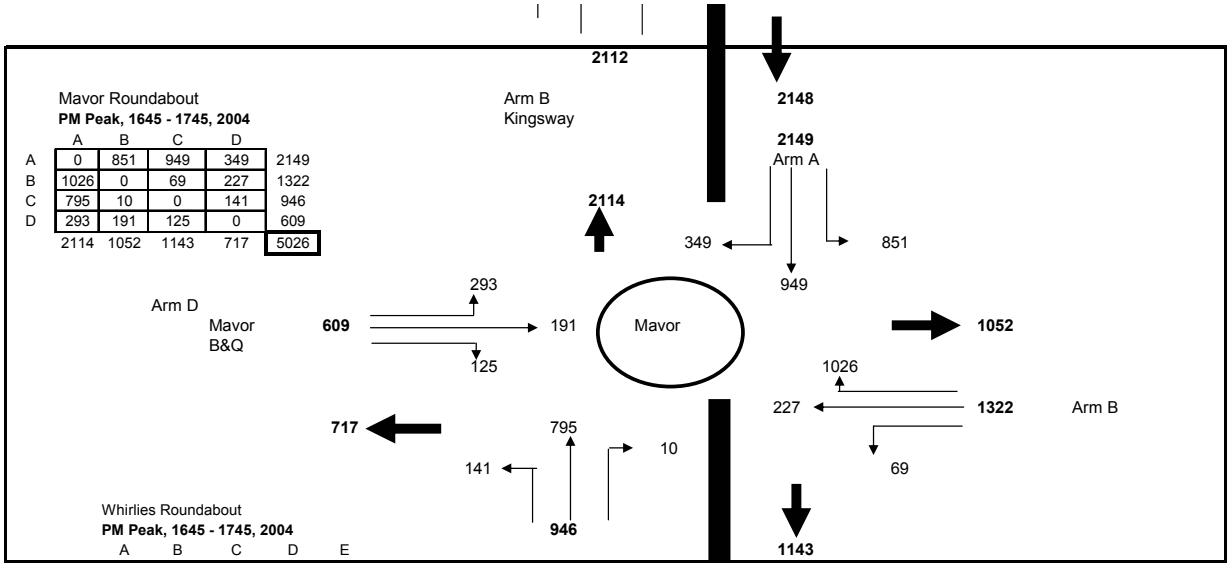


Figure 2B Weekday PM Peak (1645 - 1745) Flows (Pcus – Year 2004)

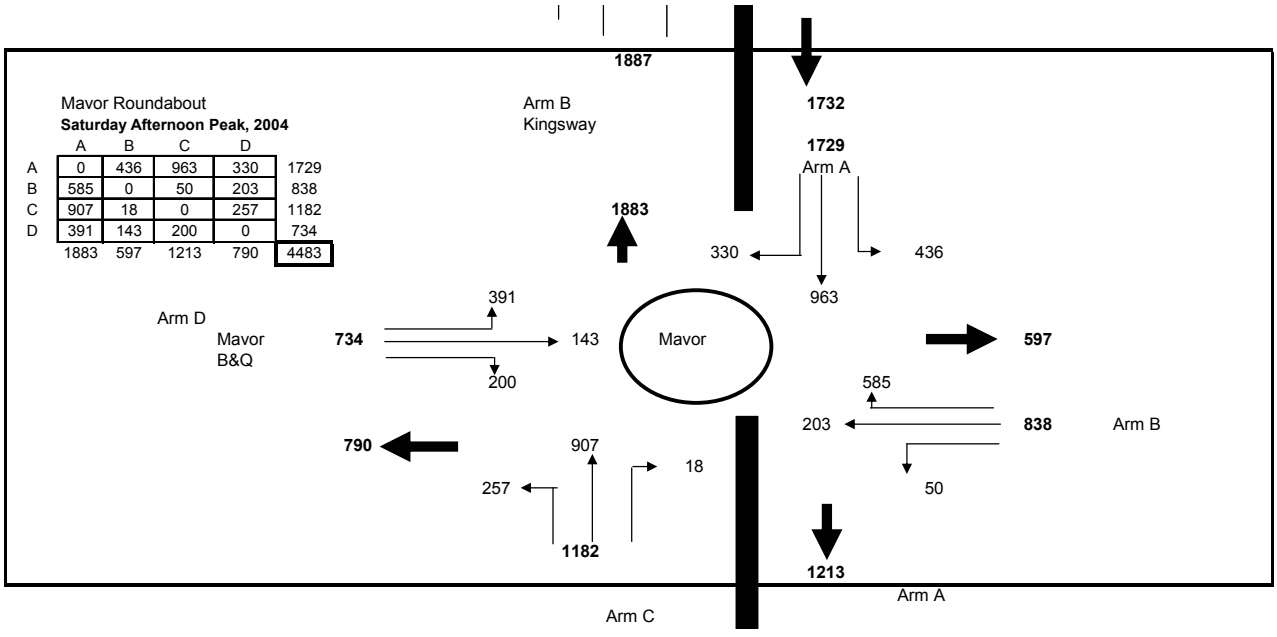
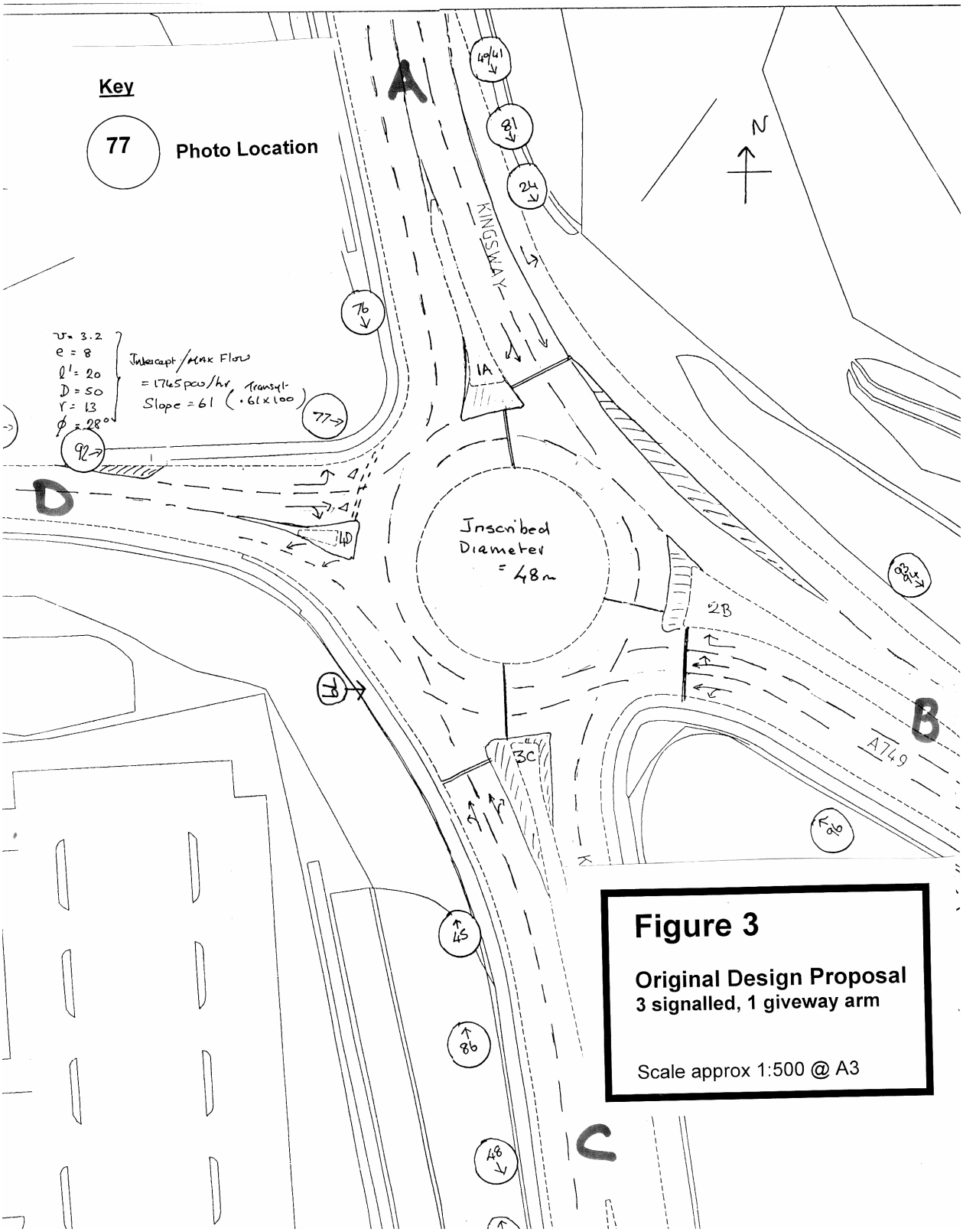


Figure 2C Saturday Peak (1300-1400) Flows (Pcus – Year 2004)



'Traditional Design'

Approaching Mavor R'bt from Arm A

Approaching Mavor R'bt from Arm B

Figure 4A: Views approaching Mavor R'bt on Arms A and B

Approaching Mavor R'bt from Arm C

Approaching Mavor R'bt from Arm D

Figure 4B: Views approaching Mavor R'bt on Arms C and D

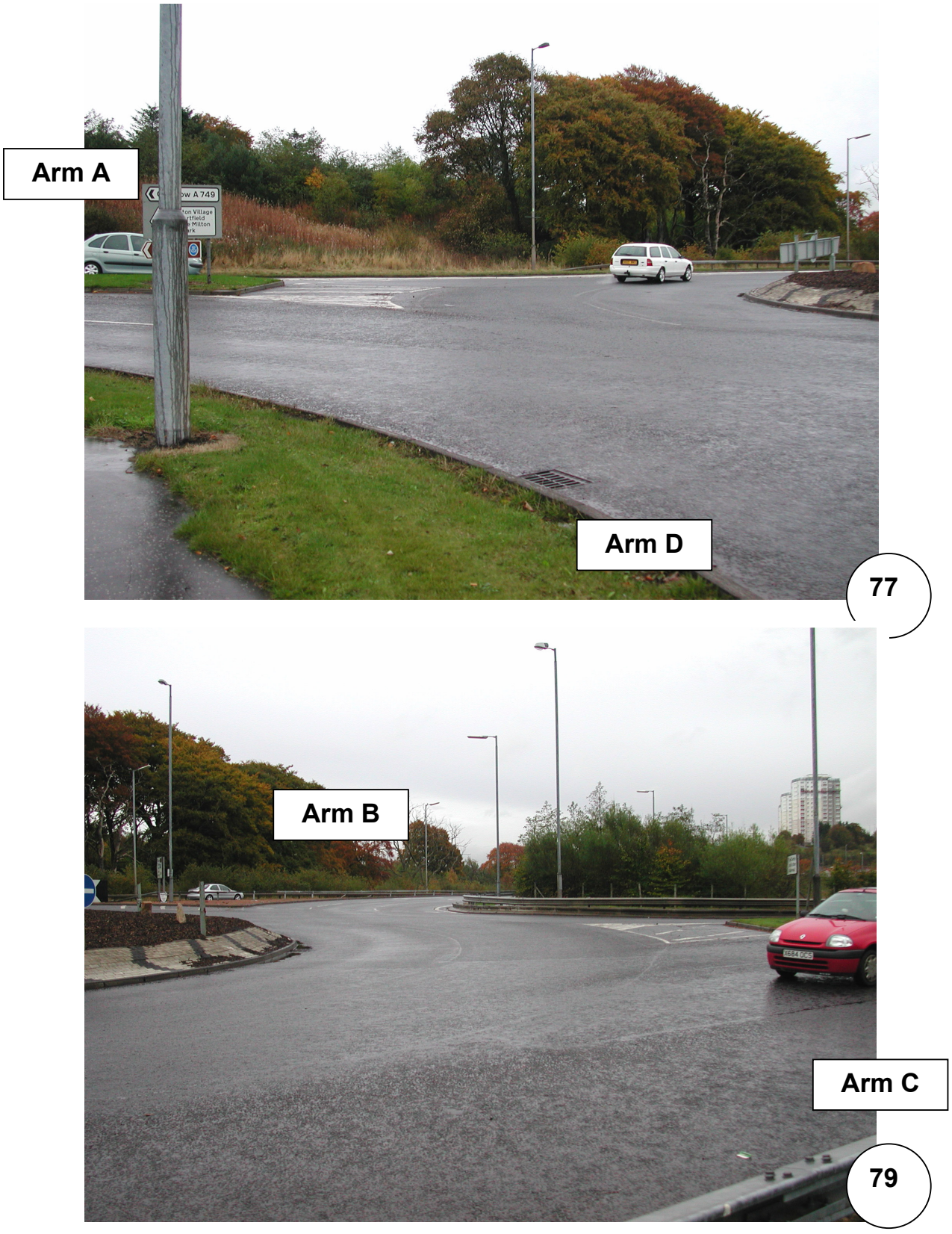


Figure 4C: Views on Mavor R'bt (North and South Gyratory sections)

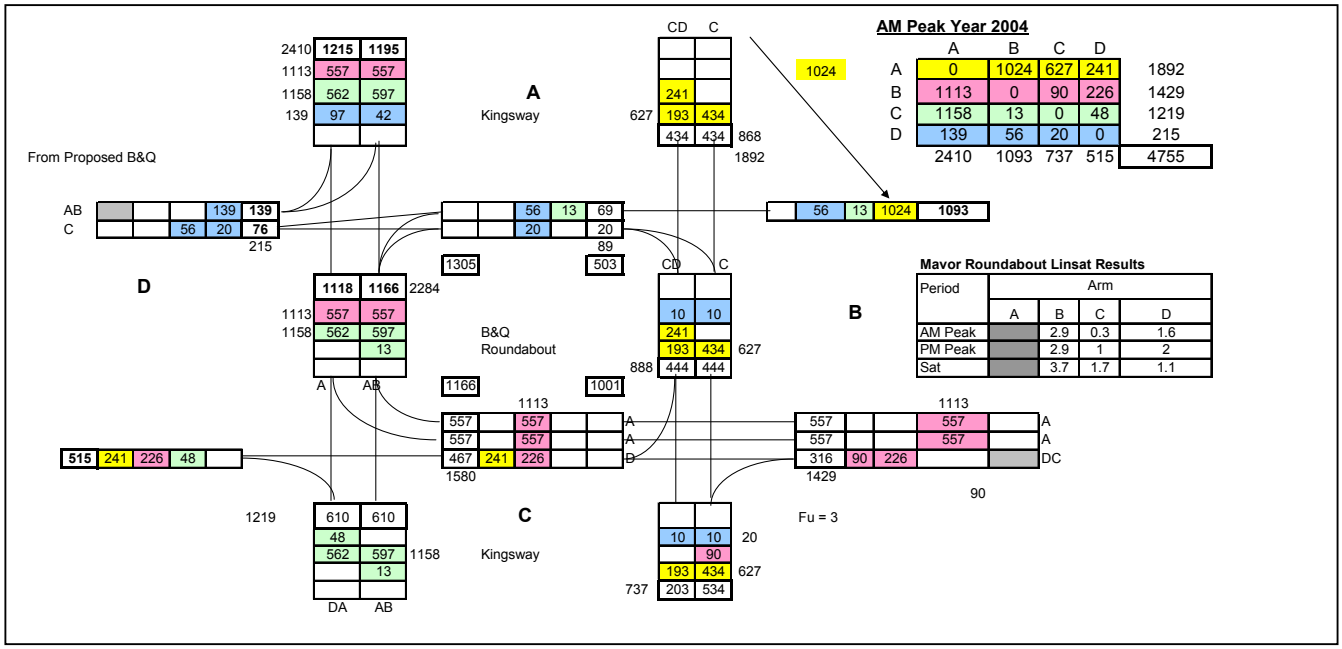
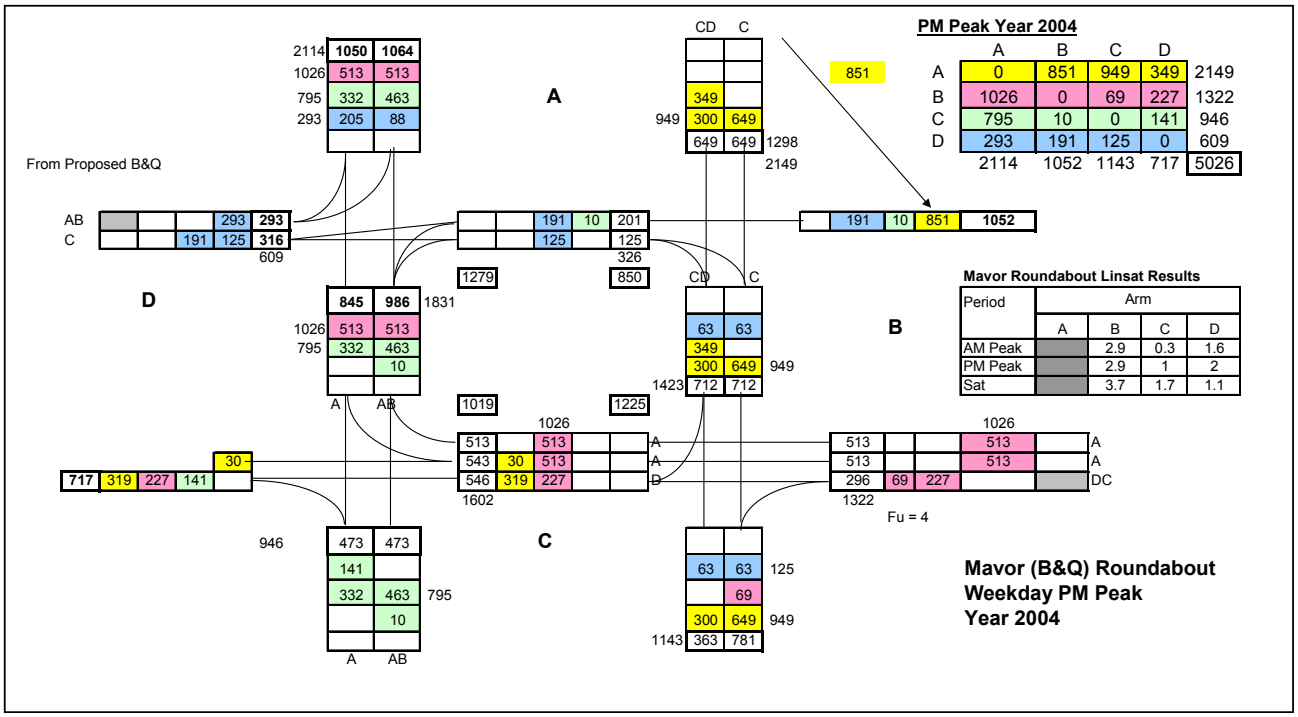
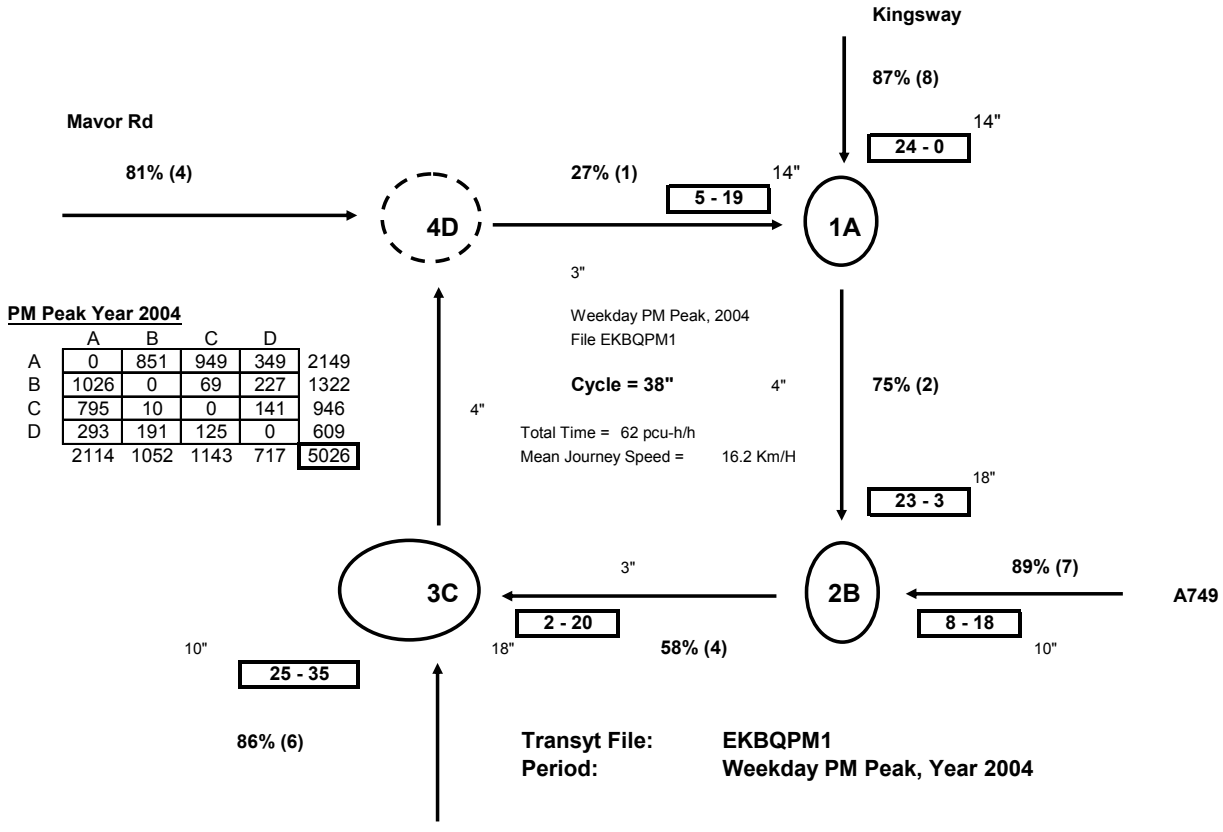


Figure 5A: **Lane Flow Diagram and Results for AM Peak Original Design Proposal (i.e. Arm D as Giveway)**

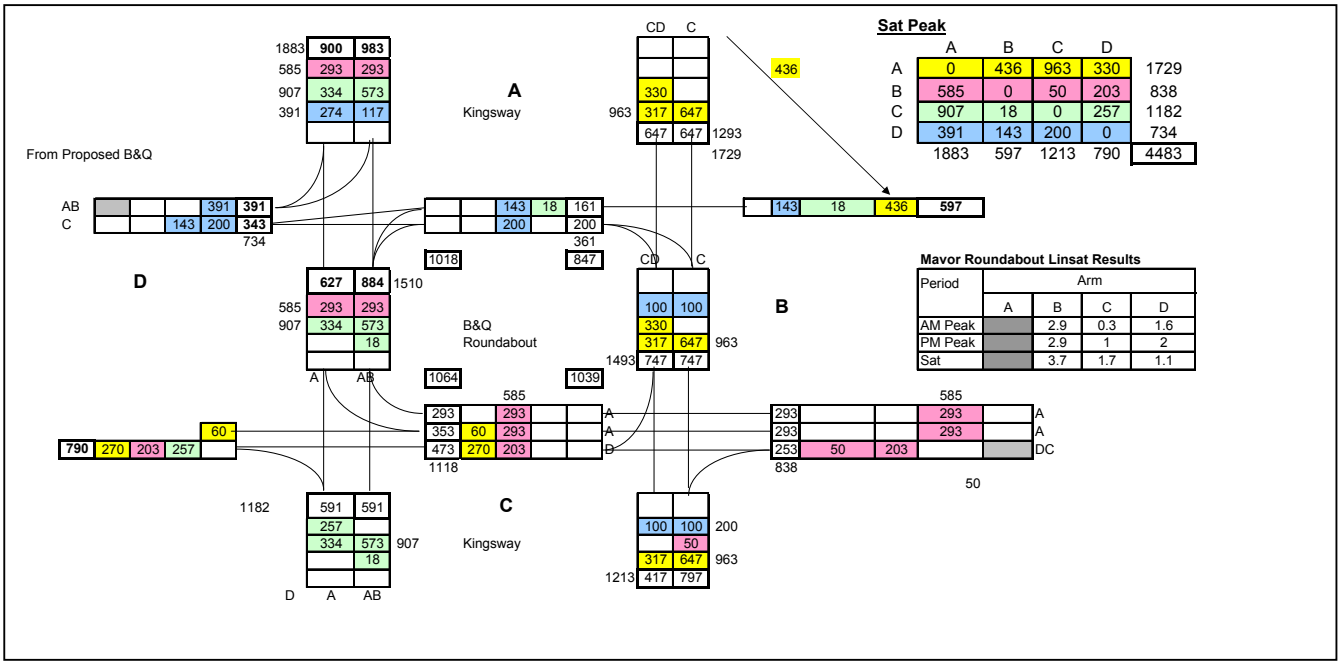




PM Peak Year 2004

	A	B	C	D	
A	0	851	949	349	2149
B	1026	0	69	227	1322
C	795	10	0	141	946
D	293	191	125	0	609
	2114	1052	1143	717	5026

Figure 5B: Lane Flow Diagram and Results for PM Peak Original Design Proposal (i.e. Arm D as Giveway)



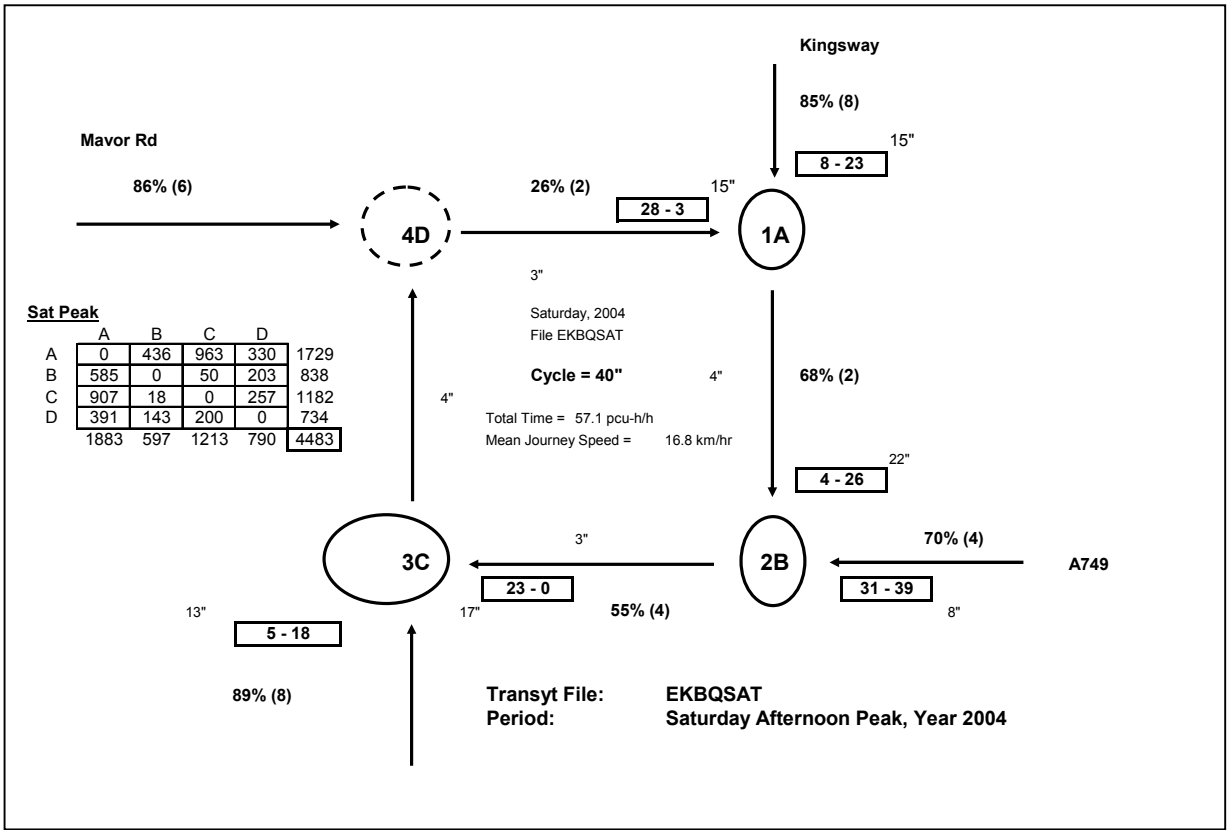


Figure 5C: Lane Flow Diagram and Results for Sat Peak Original Design Proposal (i.e. Arm D as Giveway)

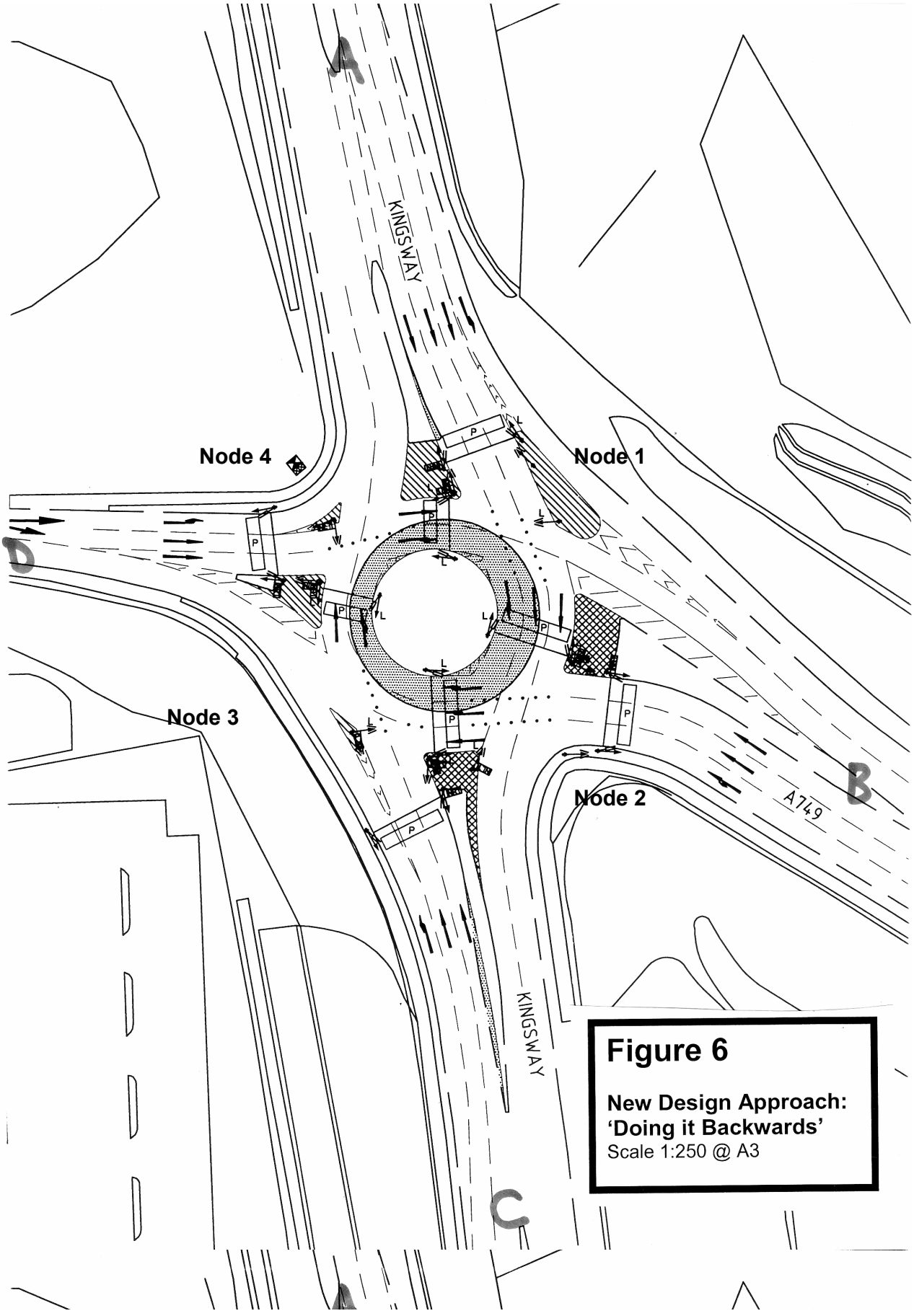


Figure 6

New Design Approach: 'Doing it Backwards'
Scale 1:250 @ A3

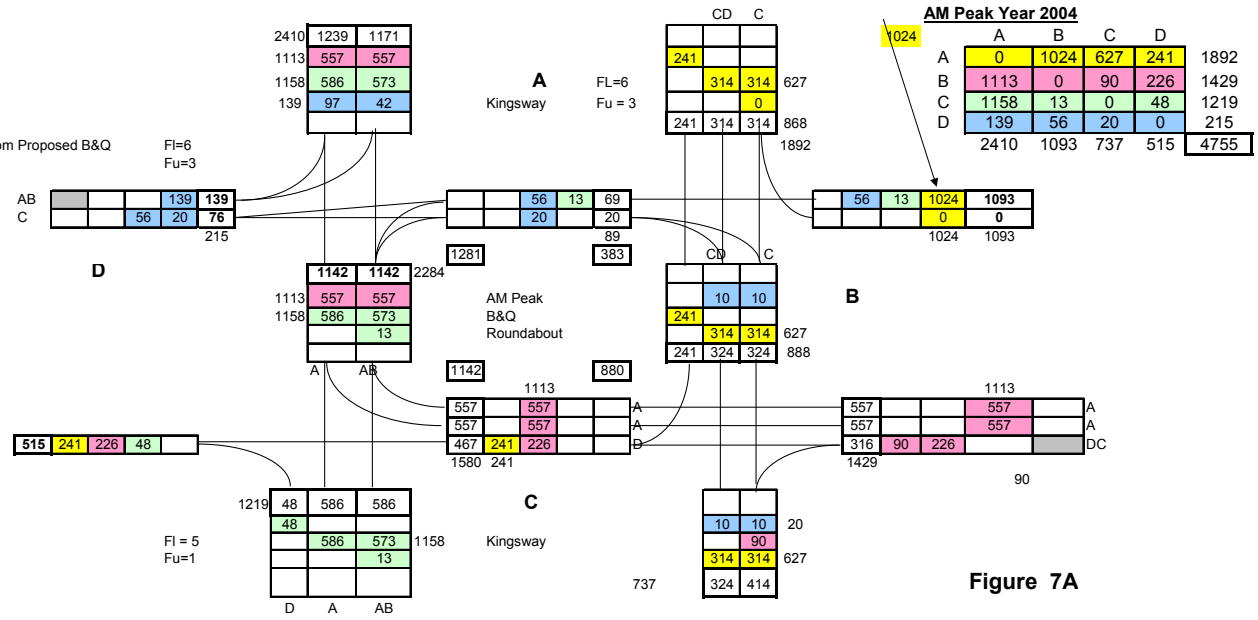


Figure 7A

Mavor Roundabout
Weekday AM Peak
0745 - 0845
Linsig File MAVOR1

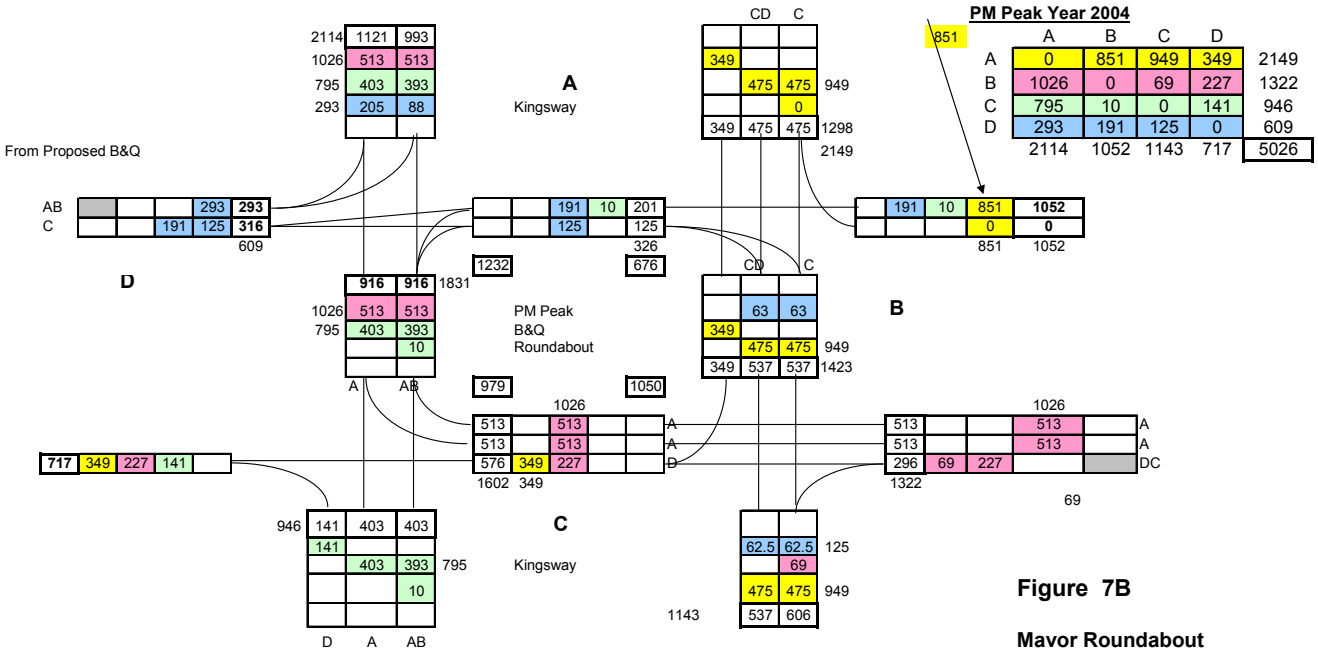


Figure 7B

Mavor Roundabout
Weekday PM Peak
1645 - 1745
Linsig File MAVOR1

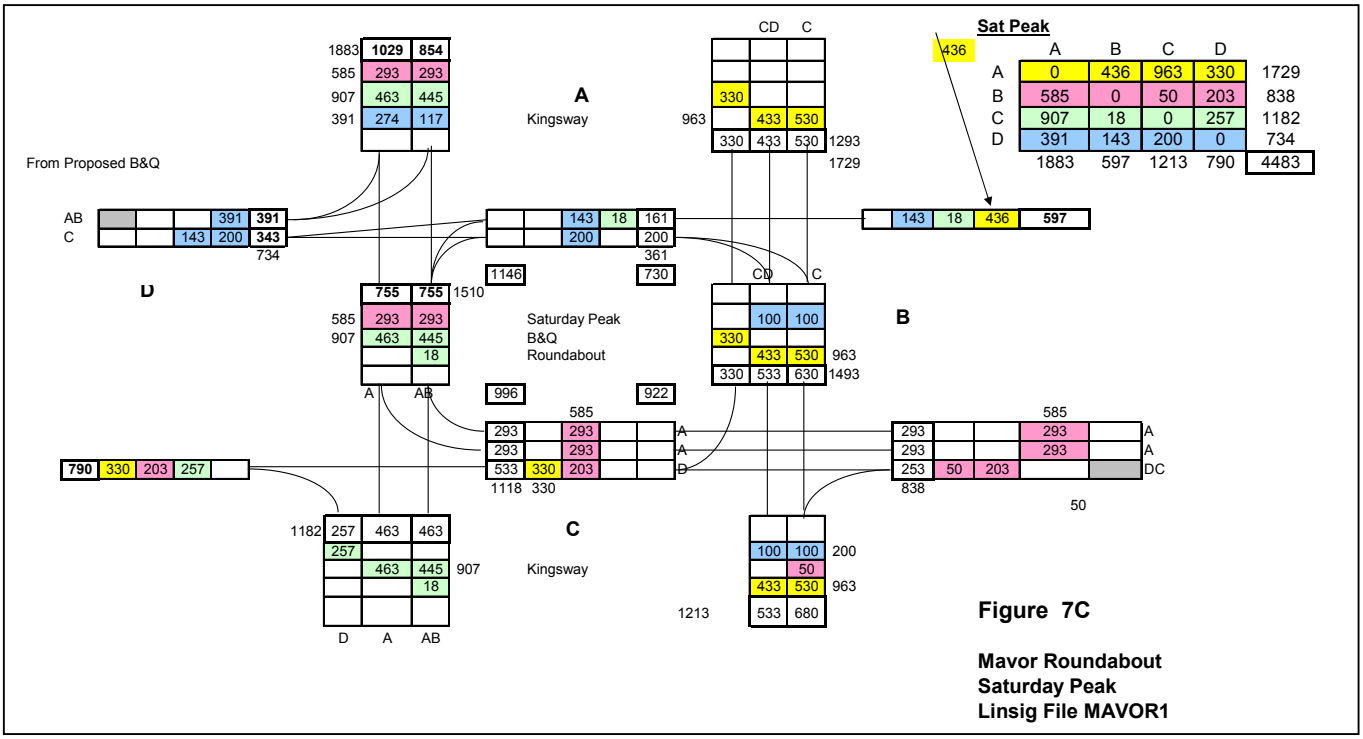


Figure 7C

Mavor Roundabout
Saturday Peak
Linsig File MAVOR1

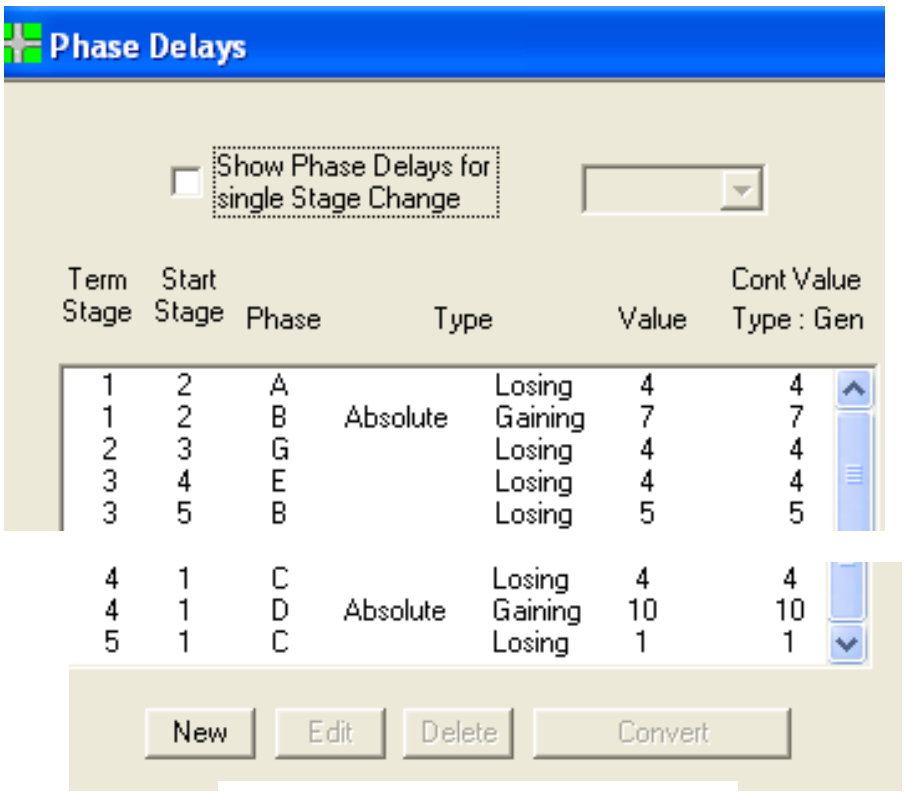
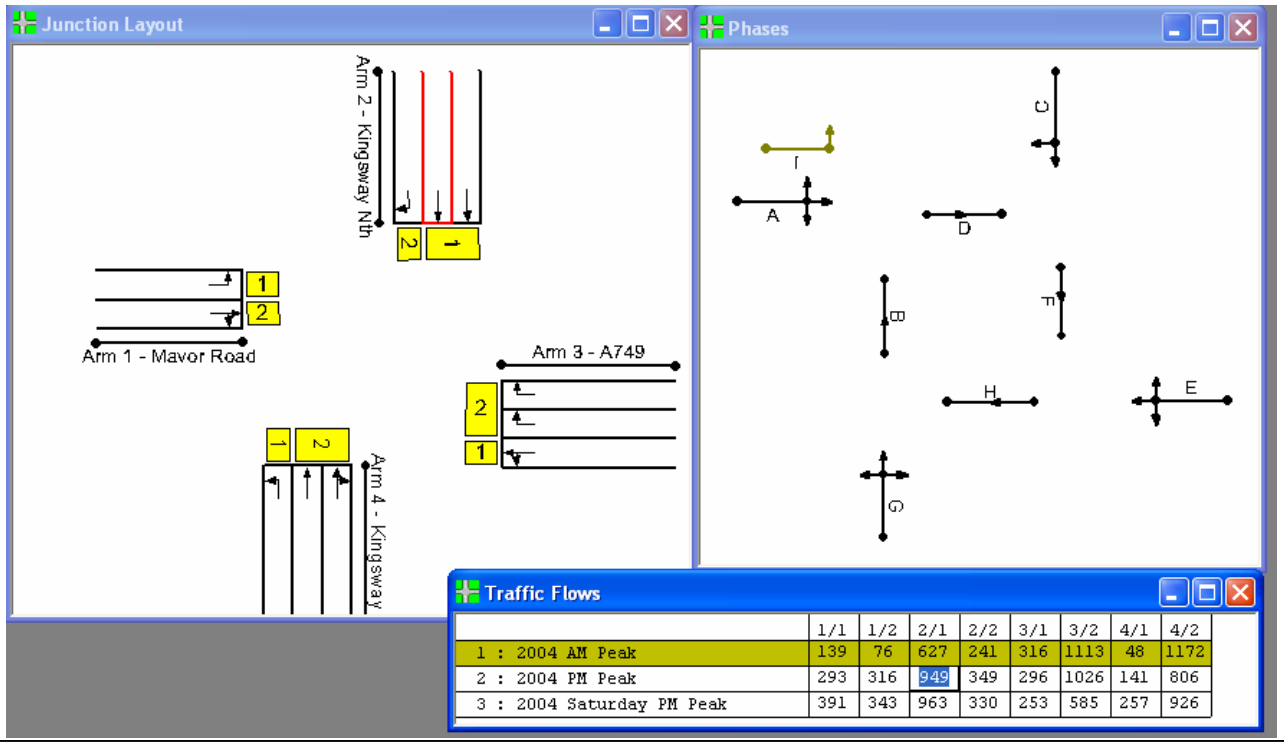
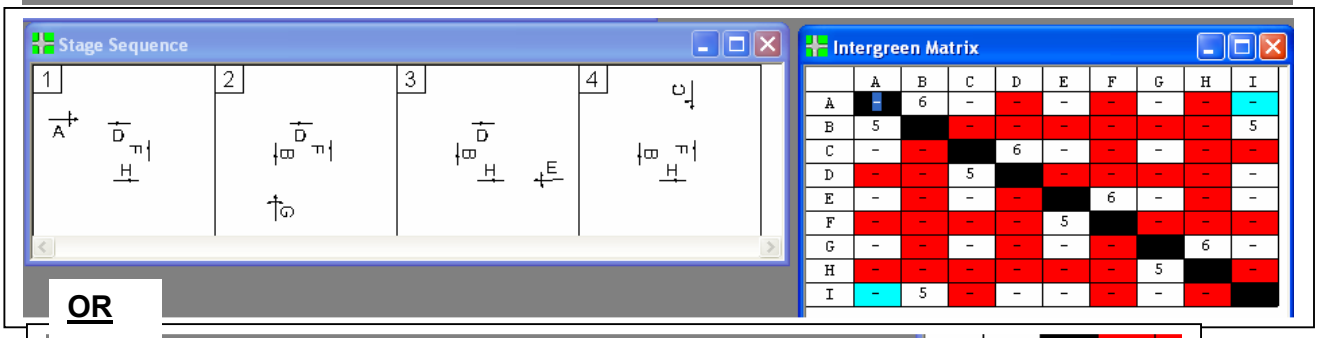


Figure 8A

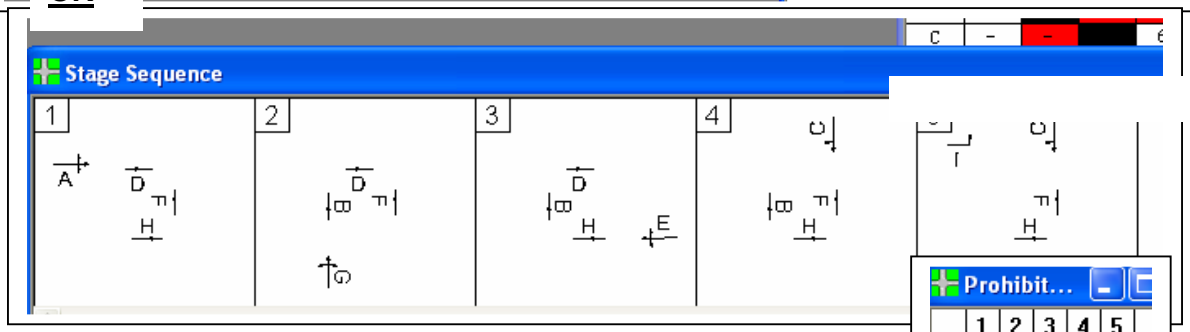
Linsig File General Settings

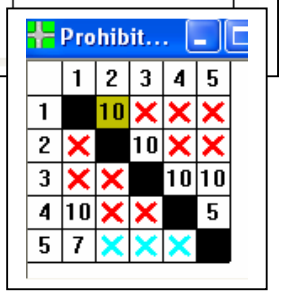
File Mavor1





OR





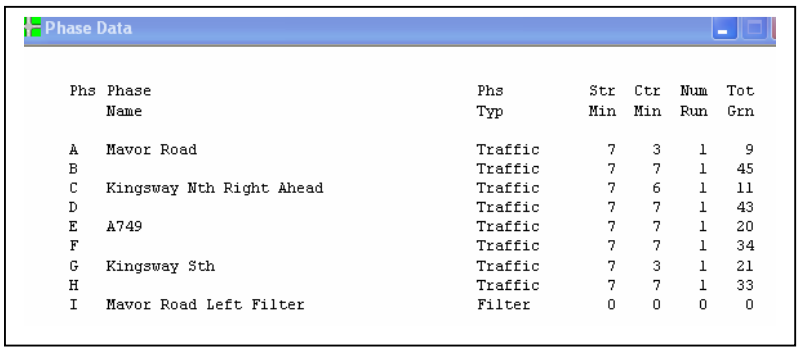
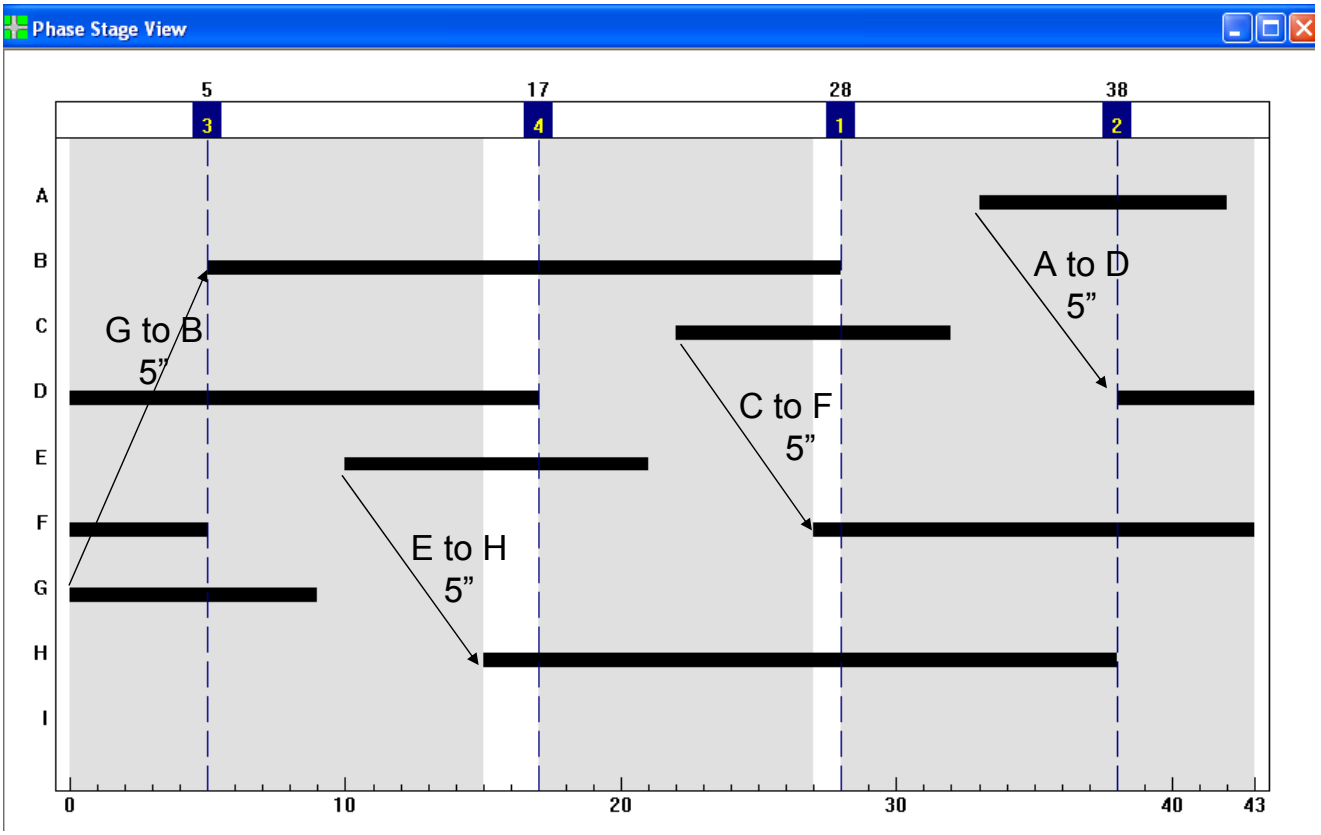


Figure 8B

Linsig File Mavor1 General Settings



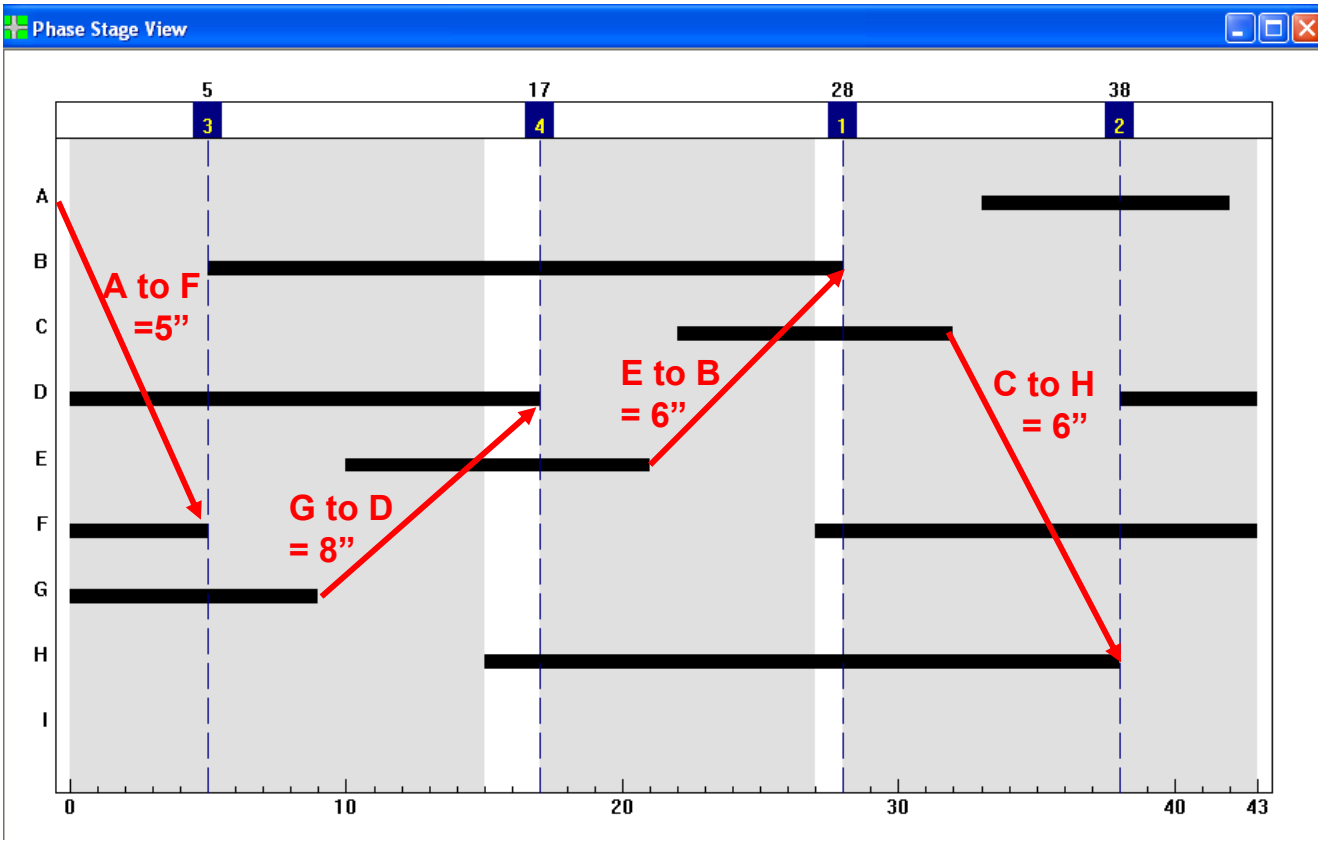


Figure 8C

Minimized Phase-Stage View on Linsig File Mavor1

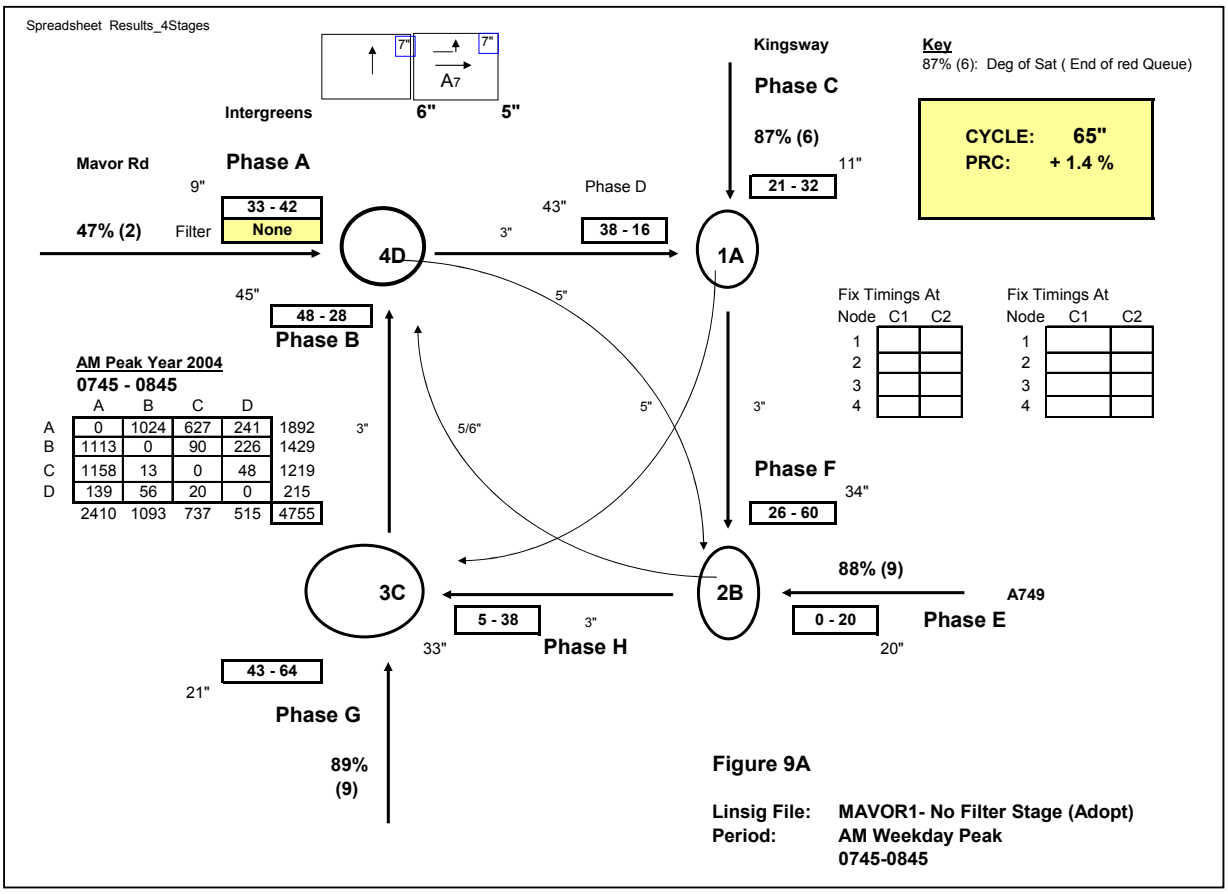


Figure 9A

Linsig File: MAVOR1- No Filter Stage (Adopt)
Period: AM Weekday Peak
0745-0845

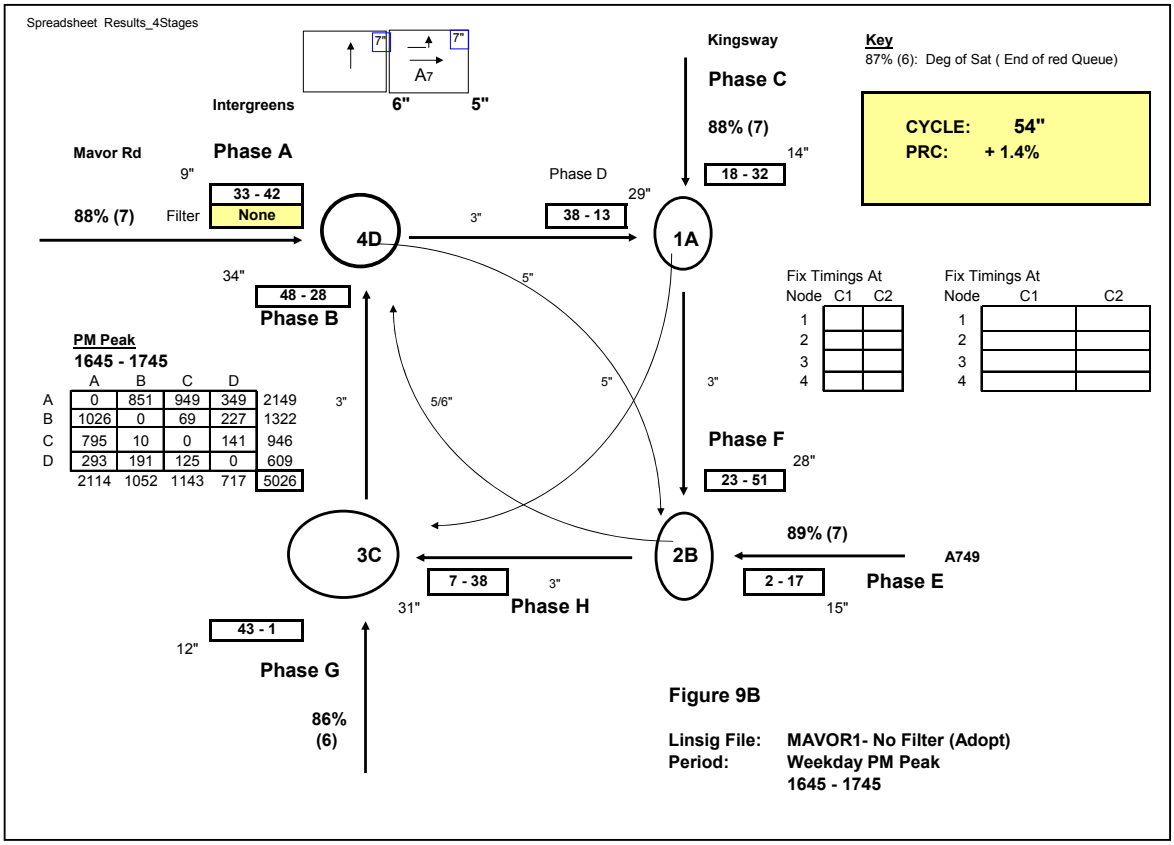


Figure 9B

Linsig File: MAVOR1- No Filter (Adopt)
Period: Weekday PM Peak
1645 - 1745

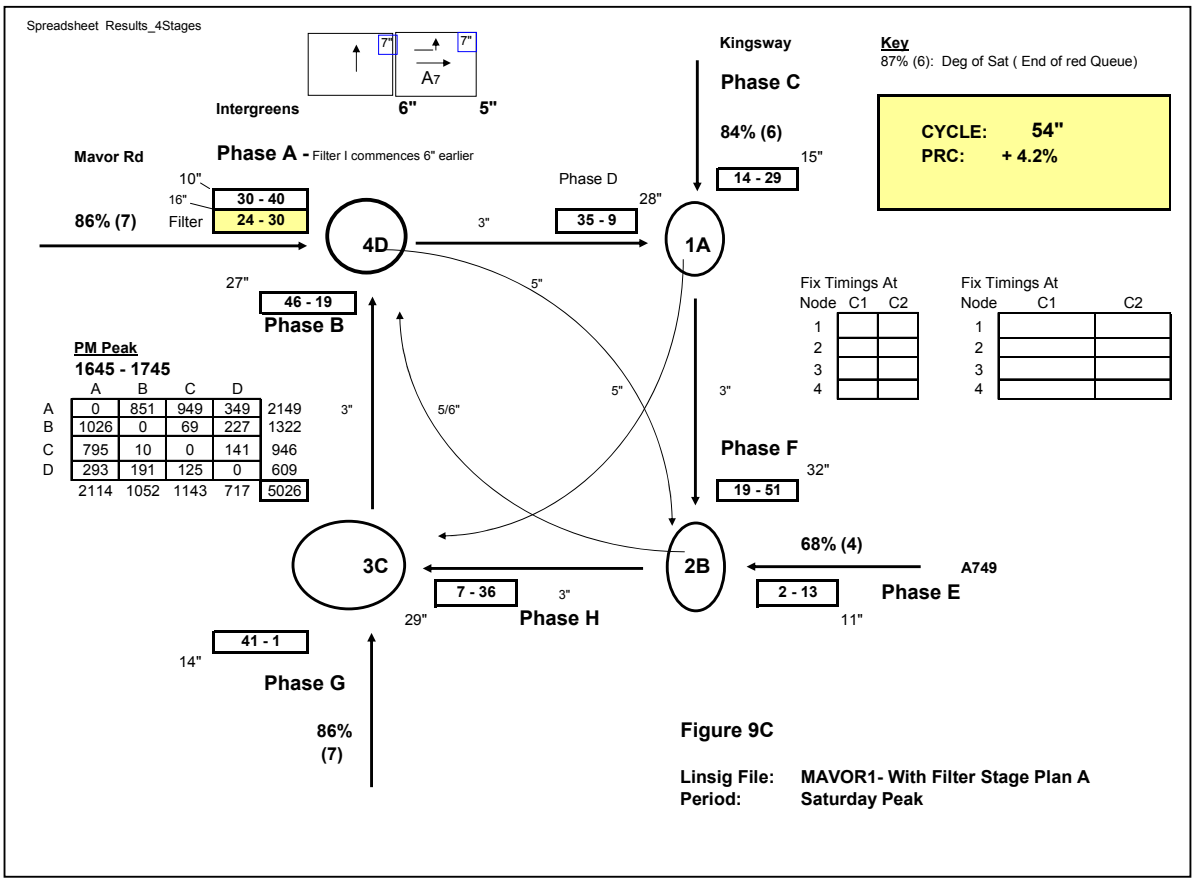


Figure 9C

Linsig File: **MAVOR1- With Filter Stage Plan A**
Period: **Saturday Peak**

Intergreens for Mavor Roundabout

	A	B	C	D	E	F	G	H
A		5						
B	5							
C				6				
D			5					
E						6		
F					5			
G								5
H							5	

Cruise times:

A to F=5"
C to H=5"
E to B =5"
G to D = 5"

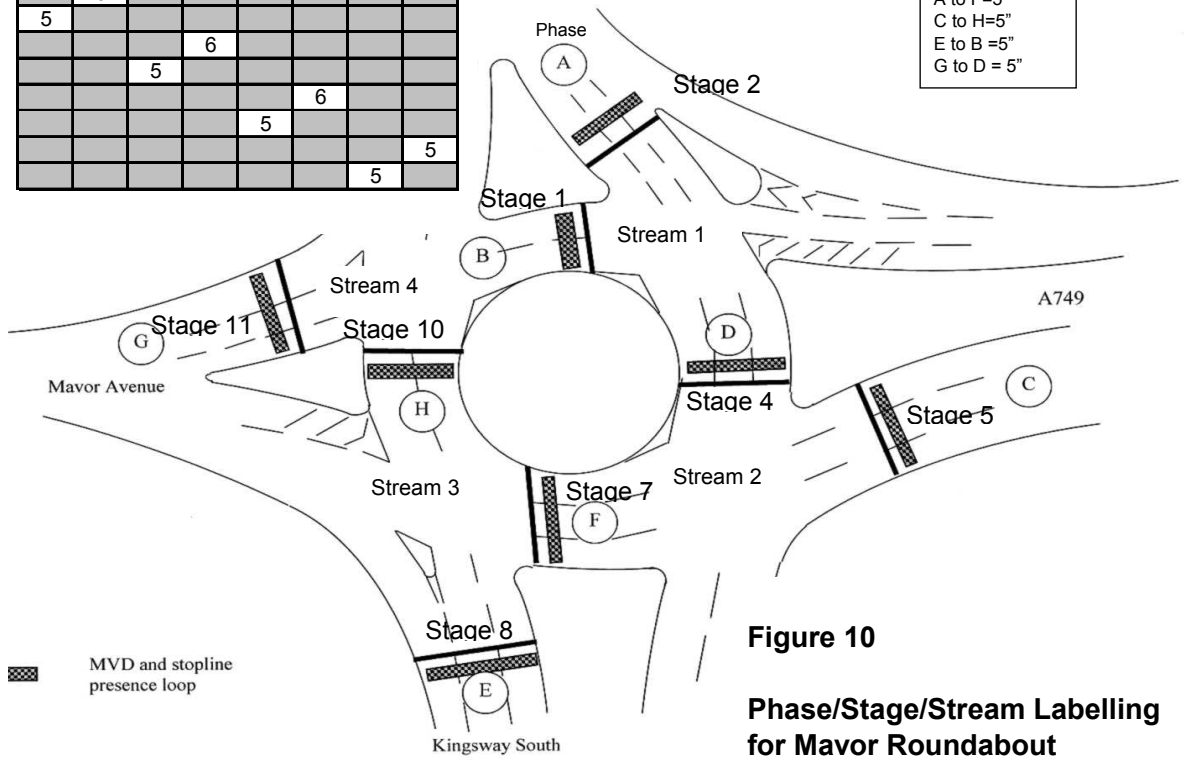
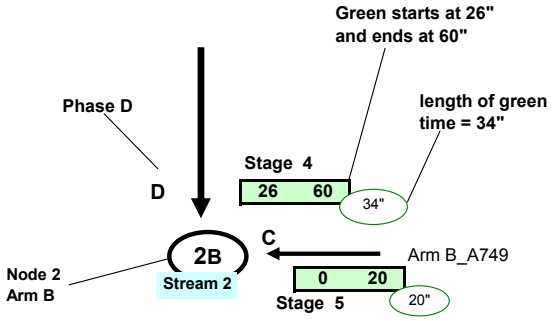


Figure 10

Phase/Stage/Stream Labelling for Mavor Roundabout

spreadsheet Mavor_CLF180605.xls

Key1 for Mavor Roundabout



Intergreens

Please Note that:

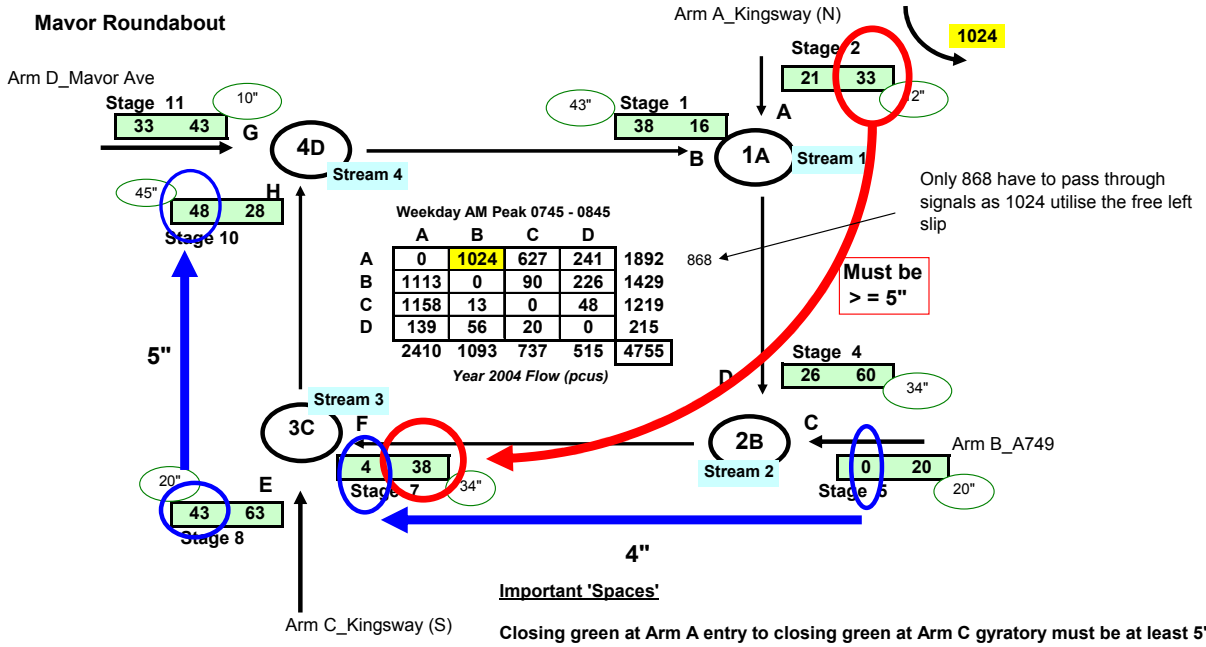
At Nodes 4 and 1, the intergreens are all 5"

At Nodes 2 and 3, the intergreens are as follows:-
Approach to Gyratory = 6"
Gyratory to Approach = 5"

Intergreens for Mavor Roundabout

	A	B	C	D	E	F	G	H
A		5						
B	5							
C				6				
D			5					
E						6		
F					5			
G								5
H							5	

Figure 11A



Important 'Spaces'

Closing green at Arm A entry to closing green at Arm C gyratory must be at least 5".
Closing green at Arm B entry to closing green at Arm D gyratory must be at least 5".
Closing green at Arm C entry to closing green at Arm A gyratory must be at least 5".
Closing green at Arm D entry to closing green at Arm B gyratory must be at least 5".

Figure 11B

Key3 for Mavor Roundabout

Weekday AM Peak period Plan

	18/06/2005		
	CLF	PLAN	1
	Time	Influence	
Node 1	30	PR	1
	33	IM	1
	255	PR	2
	16	IM	2
Node 2	17	PR	4
	20	IM	4
	255	PR	5
	60	IM	5
Node 3	60	PR	7
	63	IM	7
	255	PR	8
	38	IM	8
Node 4	40	PR	10
	43	IM	10
	255	PR	11
	28	IM	11
	Cycle		65"

The PR influences are set as follows:-

You can never close the gyratory stoplines down early due to a 'gap', hence the setting PR=255 to disable this option for gyratory stages 1,4,7 and 10.

On all the approach stoplines, if large gaps are detected during the green time , then the PR influence is set to close down the approach stage early and hence, open up the gyratory stopline earlier. Great care has been taken in setting these PR values to ensure that the gyratory stopline can never open up earlier than the upstream approach stopline, this to prevent 'see through' problems occurring.

(For example, at Node 1, Stage 2 (the approach) commences at 21". Provided there is enough queuing traffic on Arm A, stage 2 will run until 33". However, the PR1 instruction at 30", says if traffic on Arm A has run out by 30", then do not wait until 33", but move immediately to open up the gyratory stopline. The latter will thus open up at 35" instead of 38, some 2"after the release of traffic from Arm D (i.e. at 33"), Mavor Avenue, instead of the normal 5".

Figure 11C

Times for CLF Plans

Mavor Roundabout (16/6/05)

						Cycle Time
MTWTF	0600	to	0650	Plan	7	48"
MTWTF	0650	to	1000	Plan	1	65"
MTWTF	1000	to	1100	Plan	4	60"
MTWTF	1100	to	12.30	Plan	8	50"
MTWTF	1230	to	1400	Plan	4	60"
MTWTF	1400	to	1530	Plan	8	50"
MTWTF	1520	to	1900	Plan	2	54"
MTWTF	1900	to	2300	Plan	3	54"
MTWTF	2300	to	0600	Plan	5	36"
SS	0630	to	0800	Plan	7	48"
SS	0800	to	1530	Plan	3	54"
SS	1530	to	1800	Plan	4	60"
SS	1800	to	2000	Plan	3	54"
SS	2000	to	2300	Plan	8	50"
SS	2300	to	0630	Plan	5	36"

Figure 11D

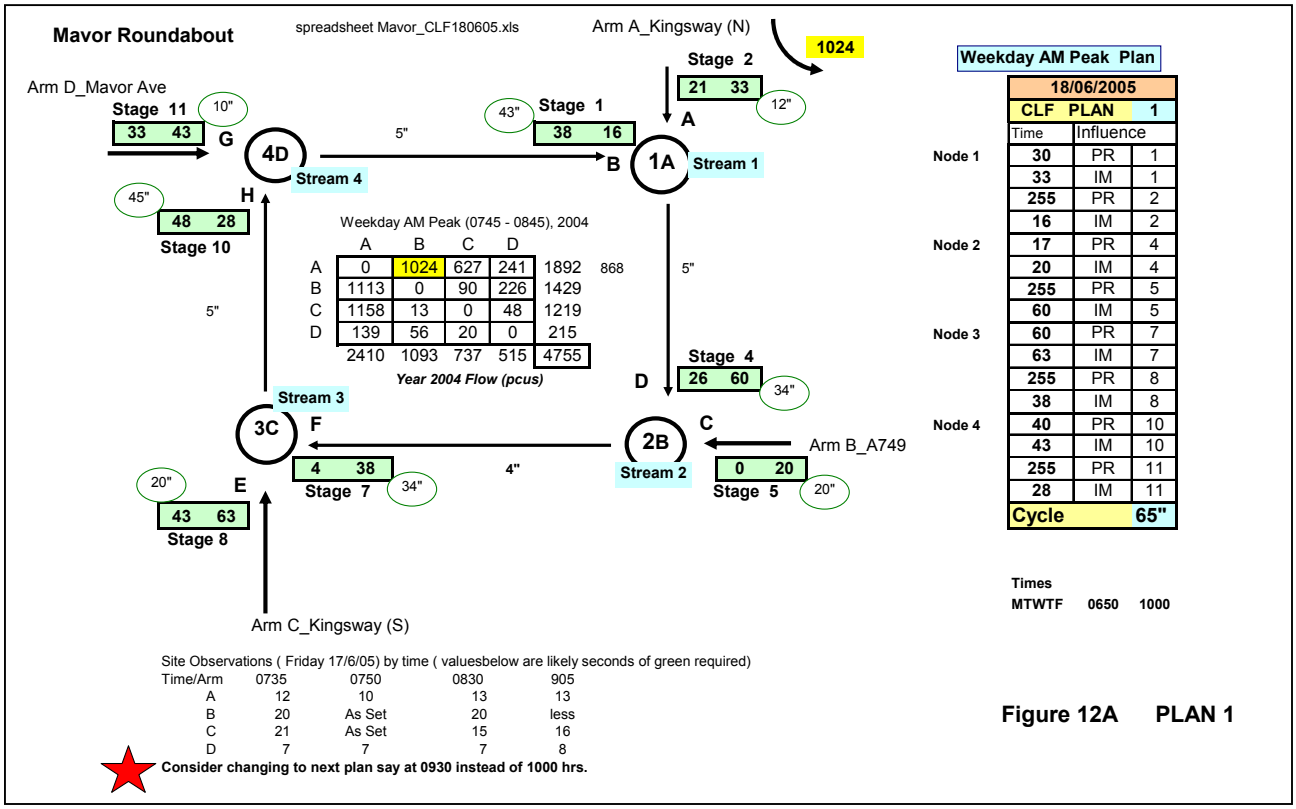


Figure 12A PLAN 1

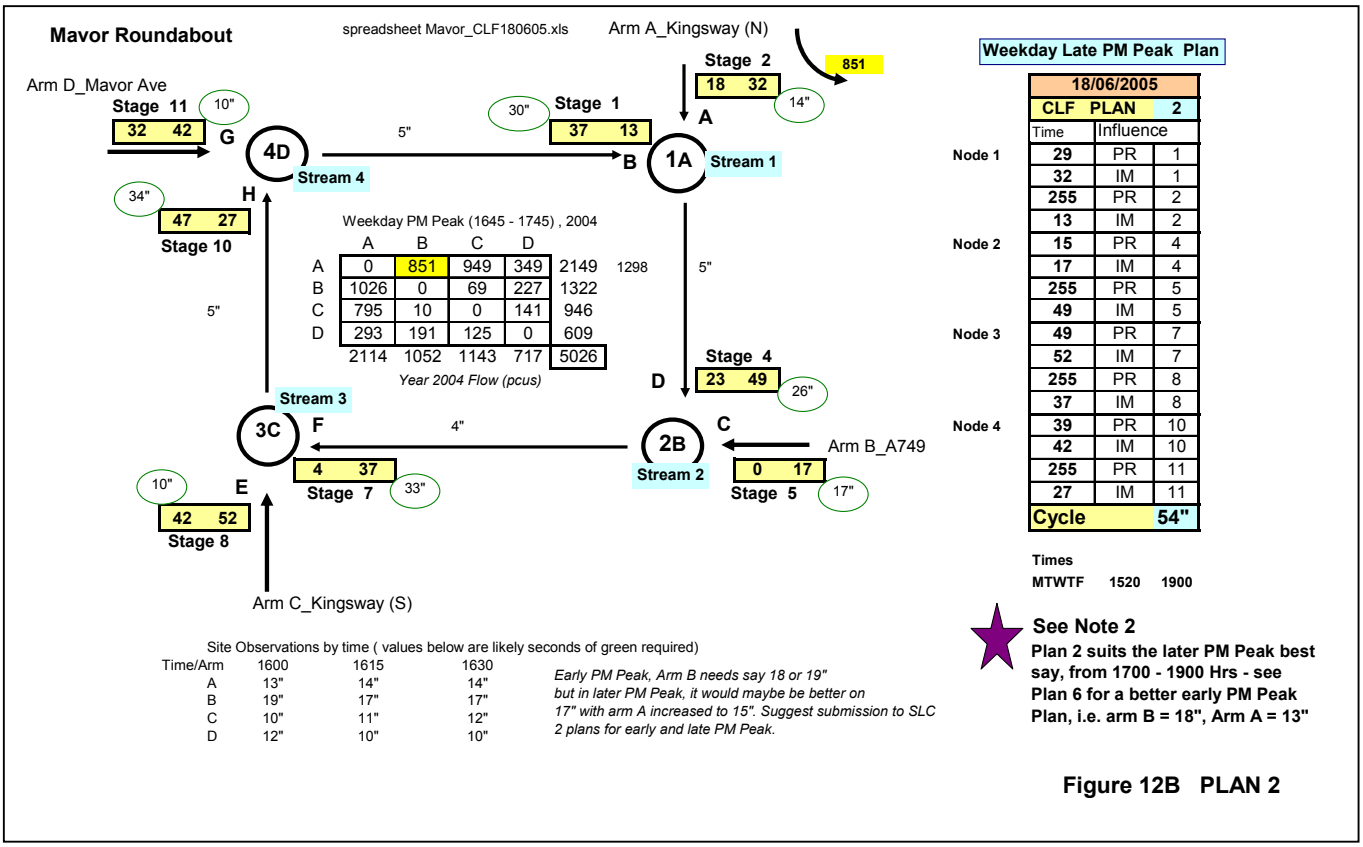
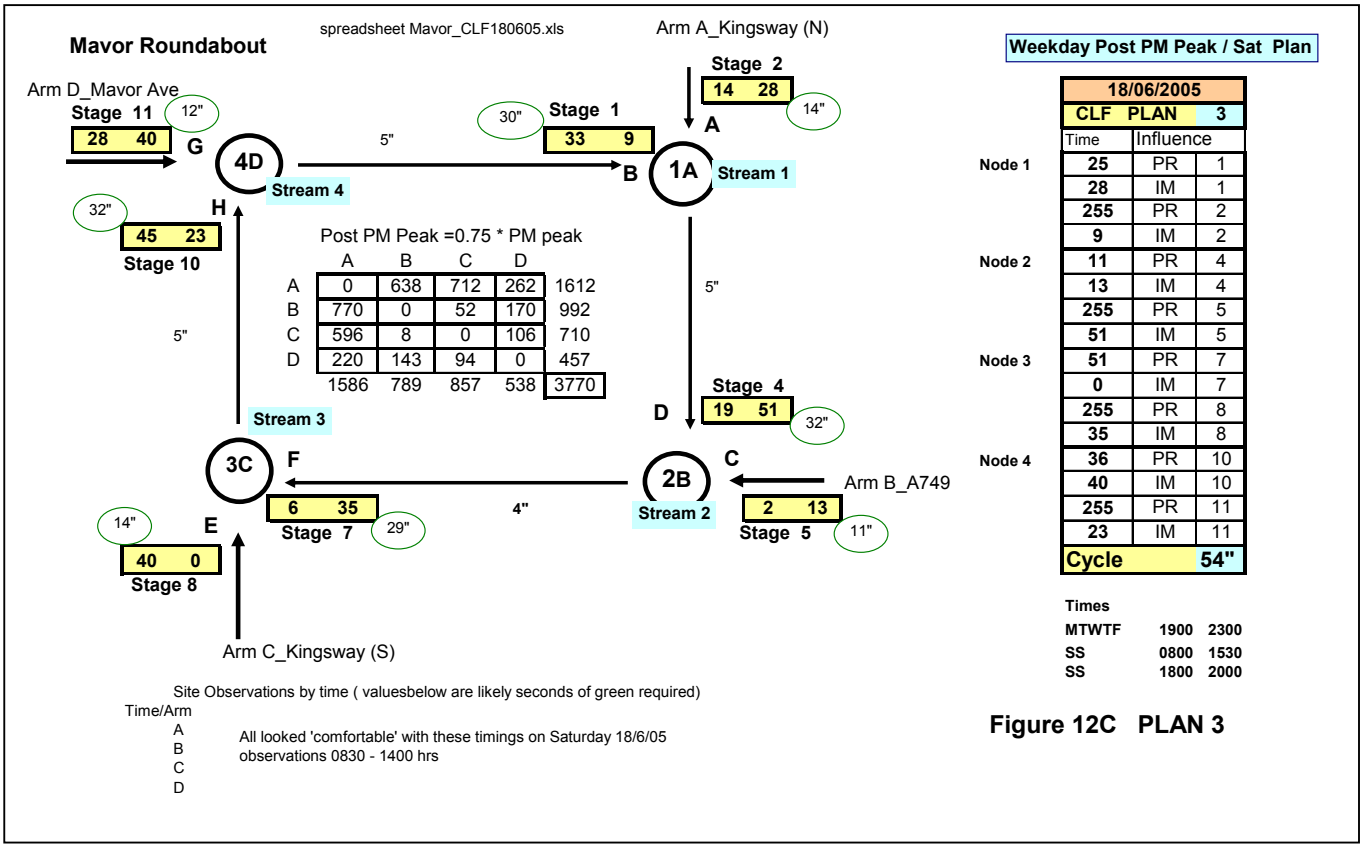


Figure 12B PLAN 2



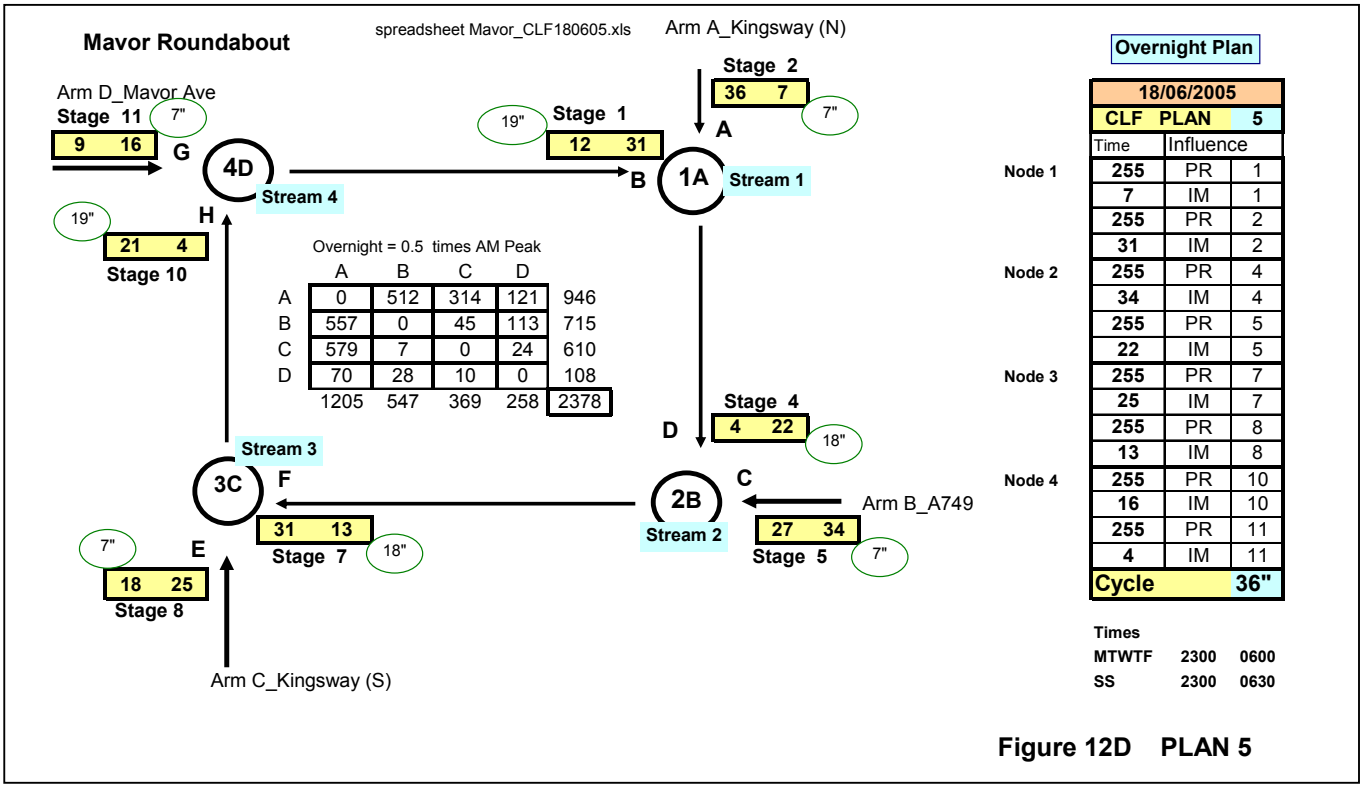
Weekday Post PM Peak / Sat Plan

	18/06/2005		
	CLF PLAN		3
	Time	Influence	
Node 1	25	PR	1
	28	IM	1
	255	PR	2
	9	IM	2
Node 2	11	PR	4
	13	IM	4
	255	PR	5
	51	IM	5
Node 3	51	PR	7
	0	IM	7
	255	PR	8
	35	IM	8
Node 4	36	PR	10
	40	IM	10
	255	PR	11
	23	IM	11
	Cycle		54"

Times

MTWTF	1900	2300
SS	0800	1530
SS	1800	2000

Figure 12C PLAN 3



Overnight Plan

	18/06/2005		
	CLF PLAN		5
	Time	Influence	
Node 1	255	PR	1
	7	IM	1
	255	PR	2
	31	IM	2
Node 2	255	PR	4
	34	IM	4
	255	PR	5
	22	IM	5
Node 3	255	PR	7
	25	IM	7
	255	PR	8
	13	IM	8
Node 4	255	PR	10
	16	IM	10
	255	PR	11
	4	IM	11
	Cycle		36"

Times

MTWTF	2300	0600
SS	2300	0630

Figure 12D PLAN 5