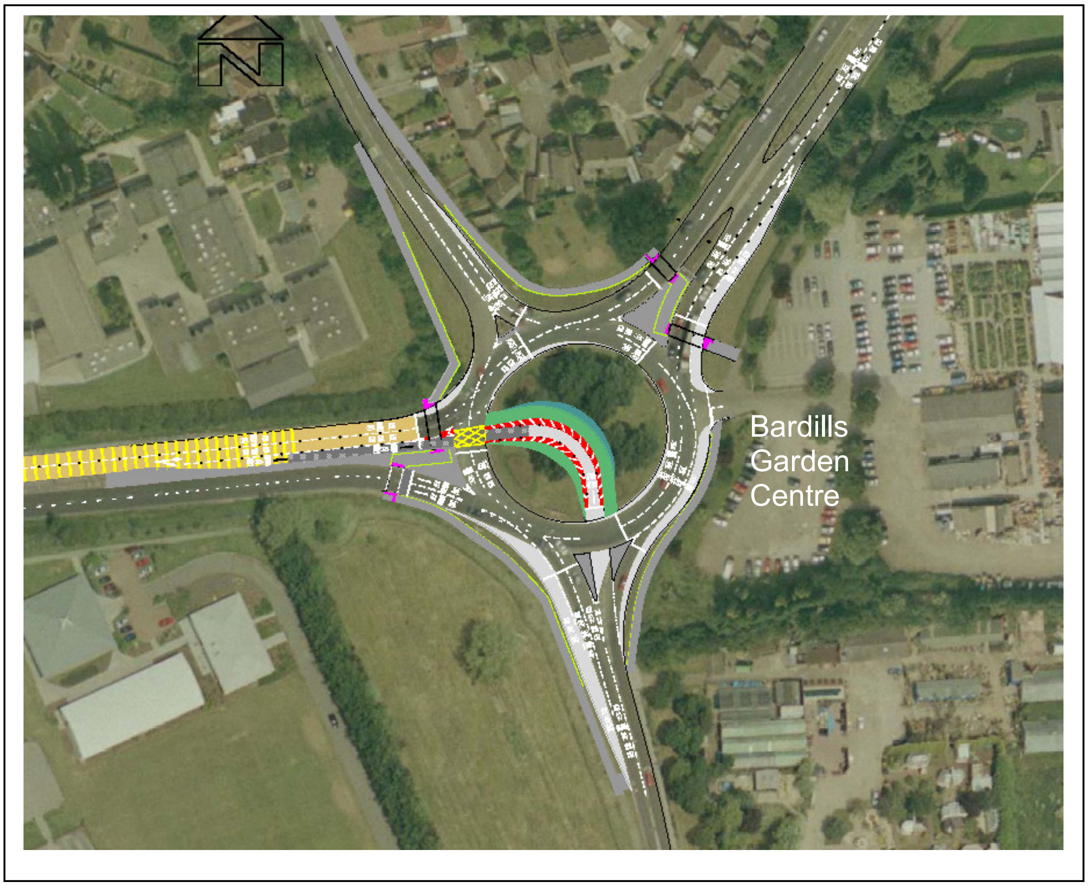
Cutting Corners at Bardills –
An innovative signalled roundabout solution

by

Barbara Chard (BCC Ltd); and
Stuart Beniston (Amscott)



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1. Introduction

Bardills roundabout joins the A52 Brian Clough Way to the B6003, at Stapleford, Nottingham (Figure 1). The roundabout is named after the Bardills Garden Centre that accesses and egresses onto this roundabout (Figure 2).

Currently, three of the four approaches into this priority roundabout suffer significant queue and delay problems throughout the peak traffic periods, with queues in excess of 300 and 200 vehicles commonly recorded in the AM and PM peak periods on the A52(E) and Stapleford Lane, respectively. The A52(E) is far worse than A52(W) in both peaks, with delays on this arm regularly 5-10 minutes. This is directly attributable to the o-d pattern of traffic movements at this roundabout which results in a significantly higher controlling flow past the A52(E) entry *(i.e. 830 in the AM peak, 810 in the PM peak, year 2003 flows)* than past the A52(W) entry *(i.e. 324 in the AM peak, 443 in the pm peak, year 2003 flows).*

Detailed studies of numerous capacity improvement designs were carried out using Transyt and LINSIG and these resulted in the proposal set out in this paper, i.e. a short-term improvement in the form of signalisation of the existing layout. *(In the longer term, a much more major scheme may be the only alternative to achieving significant further improvement).* If the scheme works well to start with, indications from SATURN modelling are that little traffic growth is likely at this location over the next few years, in which case the performance should remain satisfactory for some time.

The proposal is unusual in that it involves diversion of the right-turn movement from the A52(W) to Stapleford Lane through the roundabout island in order to achieve a 'close to within-capacity' solution. The development of this option and the design considerations and modifications proposed since the original Transyt evaluation work are discussed in this paper.

Paramics microsimulation software was used to provide confidence in the viability of the solution, facilitate public appreciation of how the roundabout would operate in practice, and most importantly, enable fine-tuning' of signal control operation prior to implementation. The Paramics model will be illustrated during presentation of this paper at the symposium. The proposed design is due for construction by AMScott by March 2007 and will operate primarily under Mova control. The clf plans produced using Transyt will be specified as a 'fall-back' operation mode, with linked VA as an alternative which will also be tested.

2. Trafic Flows

A traffic and queue count was conducted in September 2003. Origin-destination matrices for the AM (0730-0830) and PM(1700-1800) peak hours based on this count and including measured 'un-serviced queue demand', are given in Figures 3A and 3B for years 2003 and 2008, respectively.

3. Design Options

Following an earlier wide-ranging study of options by Scott Wilson for AMScott, the following three short-term (interim) solutions were to be evaluated in greater detail by BCC Ltd, based on more detailed Transyt work and Paramics modelling:-

Option 1 All nodes to be signal controlled, design to be superimposed on the existing highway (Figure 4)

Option 2 Three of the 4 Arms to be signal controlled (A, B and D). Arm C to be left as giveway, and the right-turn from A52(W) is to pass through the roundabout (Figure 4B)

Option 3 As Option 2, but signal control to be re-inserted at Arm C entry, Toton lane

The design option evaluation work was conducted assuming year 2003 demand flows.

4. Design Evaluation

Lane/Flow diagrams were first assembled for the Option 1 layout assuming year 2003 flows (Figure 5). These indicated the following :-

Arm	Arm Name	Worst Lane Flow Summation	
		AM	PM
A	Stapleford Lane	1416	1419
B	A52 (W)	1314	1417
C	Toton Lane	1427	1445
D	A52 (E)	1452	**1541**

Note: Assuming 90% Deg of Sat, 60" cycle and 1900 pcu/hr, saturation flow values, the critical lane flow summation value will be 1500 pcu/hr (see Appendix A)

The very limited internal queuing capacity and high 'worst lane flow summation totals' at each node, particularly in the pm peak, indicated that a fully signal controlled design on the existing layout would result in:-

- over capacity in the peak periods
- that overcapacity would be exacerbated by the very limited queuing capacity within the roundabout
- that a major contributor to the overcapacity would be the large right-turn movement from the A52(W), Arm B (i.e. 330 in the AM peak and 298 in the PM peak), which seriously impacts Nodes 3 and 4 (Arms C and D).

The above exercise naturally led to a more productive design solution whereby a 'by-pass' be provided for the right-turn movement from the A52(W), and that consideration be given to leaving one of the minor arms as giveway. This was verified by the assembly of the Lane/Flow diagrams shown in Figure 6, that assume a diversion of the right-turn movement from the A52(W) through the roundabout and provision of a third gyratory lane on the south side to funnel the left-turners from the gyratory to Stapleford Lane.

The effect of the right-turn cut through is to significantly reduce the critical lane flow summation values at Nodes 3 and 4 (Arms C and D), as follows:-

Arm	Arm Name	Worst Lane Flow Summation	
		AM	PM
A	Stapleford Lane	1416	1419
B	A52 (W)	1314	1417
C	Toton Lane	1427	1445
D	A52 (E)	1452	**1541**

<u>Note</u>: Assuming 90% Deg of Sat, 60" cycle and 1900 pcu/hr, saturation flow values, the critical lane flow summation value will be 1500 pcu/hr (see Appendix A)

<u>Provide Right-Turn Cut-Through (Figure 6)</u>

Arm	Arm Name	Worst Lane Flow Summation	
		AM	PM
A	Stapleford Lane	1418	1418
B	A52 (W)	1314	1417
C	Toton Lane	**1309**	**1336**
D	A52 (E)	**1301**	**1243**

Effect of addition of right-turn cut-through

5. Modelling Methodology and Transyt Results

As-Is: The 'lane-usage' (i.e. intercept-corrected) Arcady analyses for the existing roundabout (year 2003 flows) are shown in Figure 7 and Table 1 overleaf.

For Option 1, traditional Transyt modelling (for signalled roundabouts) was used to test signal controlling all nodes on the existing layout. The results for the AM/PM peak periods, year 2003, are illustrated in Figure 8 and summarised in Figure 11.

For Option 2, Linsig was first used to adjust the start and end times for phases representing each entry and gyratory arm, this to achieve optimal progression and minimum queuing within the gyratory sections (Figure 9A). This was achieved by assuming a two stage cycle, i.e. east/west then north/south movement and incorporating appropriate phase delays. Use was made of actual cruise time measurements to adjust the phase start and end times in the Linsig model/s. The Linsig Phase-Stage Diagrams for the AM and PM peak periods were used to formulate equivalent Transyt stage-based diagrams. The roundabout was then modelled in Transyt as though one node with two stages. The Linsig node timings were entered into the Transyt model as 'fixed times' and the Transyt Optimiser constrained to offset optimisation only. The results for the AM/PM peak periods, year 2003, are illustrated in Figure 9B and summarised in Figure 11.

For Option 3, the Transyt run for Option 2 was maintained with respect to timings for Nodes 1, 2 and 4. Node 3 was converted to signal control, the timings for which were manually derived through studying the Transyt graphs from the Option 2 run/s, and also through observation and further manual adjustment using a Paramics model. The timings for Node 3 were incorporated as fixed times and no further optimisation was permitted. The results for Option 3, year 2003, are illustrated in Figure 10 and summarised in Figure 11.

The Transyt results for the 'as-is' (Arcady analyses, and Option 1, 2 and 3 tests for year 2003 flows are summarised in Table 1 below:-

Table 1

	A		B		C		D	
AM Peak Year 2003	Stapleford Lane		A52 (W)		Toton Lane		A52(E)	
	Deg Sat	(MMQ)	Deg Sat	(MMQ)	Deg Sat	(MMQ)	Deg Sat	(MMQ)
Arcady As-Is Year 2003	139%	(120)	101	(19)	105	(18)	131	(144)
Option 1: AM Peak 2003	118%	(63)	108%	(65)	127%	(67)	126%	(118)
Option 2: AM Peak 2003	93%	(11)	96%	(24)	73%	(5)	102%	(37)
Option 3: AM Peak 2003	93%	(12)	96%	(24)	96%	(13)	102%	(37)

	A		B		C		D	
PM Peak Year 2003	Stapleford Lane		A52 (W)		Toton Lane		A52(E)	
	Deg Sat	(MMQ)	Deg Sat	(MMQ)	Deg Sat	(MMQ)	Deg Sat	(MMQ)
Arcady As-Is Year 2003	139%	(62)	112%	(55)	108%	(20)	122%	(201)
Option 1: PM Peak 2003	97%	(14)	113%	(86)	117%	(49)	117%	(89)
Option 2: PM Peak 2003	95%	(13)	97%	(28)	77%	(6)	98%	(27)
Option 3: PM Peak 2003	95%	(14)	97%	(28)	97%	(14)	98%	(27)

6. Discussion of Results (year 2003 flows)

Option 1: In year 2003, this design affords some benefits to the A52(E) and Stapleford Lane arms but at cost to the A52(W) and Toton Lane arms in both peaks. The signalling of all arms together with the need to accommodate within-roundabout storage for the high volume right-turn movement from the A52(W), severely limits the potential for this design.

Option 2: This design directly addresses the problems identified in Option 1 by providing a right-turn 'diversion' through the roundabout island, leaving Arm C entry as giveway and expanding the southern gyratory section from 2 to 3 lanes. The Arm C giveway entry will receive significant gaps during the upstream junction interstage periods. The right-turn 'diversion' will relieve pressure on the 'worst lane flow summation' values at both Nodes 3 and 4. Option 2 offers significant capacity and operational benefits over both Option 1 and the 'existing' priority control scenario.

Option 3: The effect of re-introducing signals at the Node 3 entry, but maintaining the Option 2 timings at each of the remaining nodes is to produce a significantly improved design over the existing priority controlled roundabout junction, but a less favourable outcome for the Toton Lane, Arm C entry than over Option 2.

The Transyt results for Options 1, 2 and 3, years 2003 and 2008 flows, are summarised in Figure 11.

7. Paramics Microsimulation

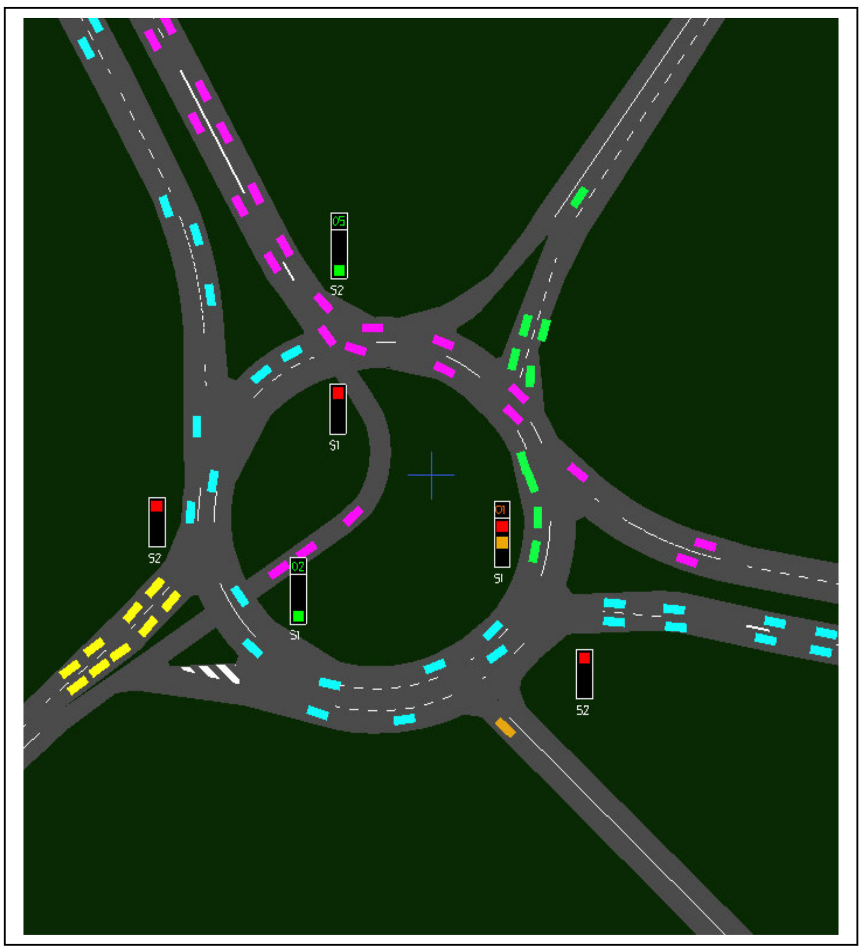
Paramics Models

The following Paramics Models will be shown during the symposium presentation:-

1 : Option 2: Nodes 1, 2 and 4 signal controlled, , cut-through for right-turn movement from A52(W) added, Toton Lane to remain under priority control.

2. Option 3: As Option 2, but Toton Lane returned to signal control. (Note; the Paramics model for Option 2 was used to aid setting the timings for Arm C entry in Option 3).

The Paramics model for Option 2 proved invaluable when inserting and adjusting the signal control at Toton Lane to create Option 3 . The microsimulation visualisation provided immediate reassurance that optimum and satisfactory queuing behaviour was possible on the adjacent gyratory links with these additional signals in place. Such re-assurance is difficult, if not impossible to achieve using just the Transyt software.



8. Post-evaluation Design Changes

The final design (Figures 12A and 12B) is due for construction by AMScott from January to March 2007 and will operate primarily under Mova control. VA and CLF will both be tried as fall-back modes and the better-performing will be chosen for permanent fall-back use.

A conventional Transyt model has been built by AMScott for the final design and the CLF timings will be based on this. These Transyt results are summarised as follow;

AM Peak: Arm A D of S 73%, MMQ 12

Arm B D of S 91%, MMQ 37

Arm C D of S 93%, MMQ 14

Arm D D of S 94%, MMQ 37

PM Peak: Arm A D of S 72%, MMQ 11

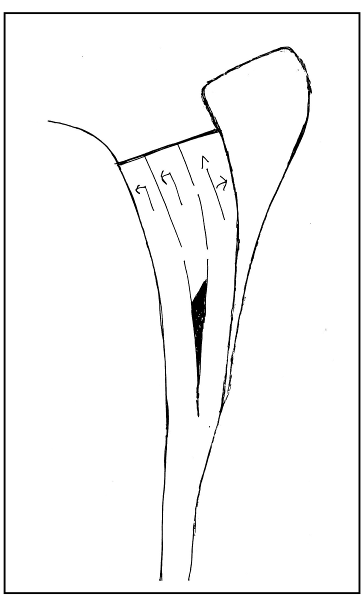
Arm B D of S 95%, MMQ 42

Arm C D of S 94%, MMQ 15

Arm D D of S 92%, MMQ 34

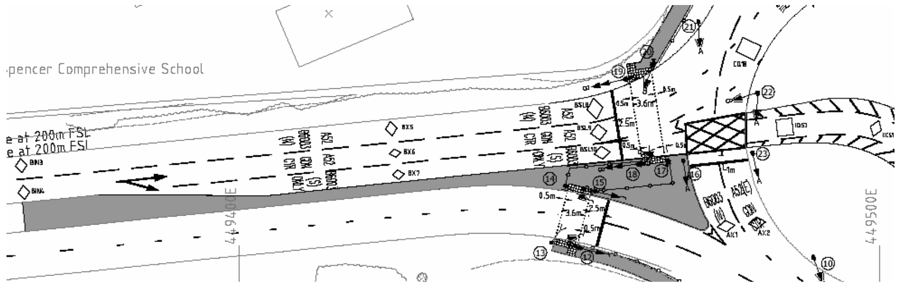
Features of the final design which resulted from the main assessment or from other considerations are:-

a) Flaring of the Stapleford Lane approach from 2 to 3 lanes, with the left turn, the dominant AM peak flow, allowed from both lanes 1 and 2, lane 2 also being used by the ahead flow, with the right turn only from lane 3.



This reduces the 'worst lane flow summation value' on this entry from 346 to 295 pcu/hour in the AM peak hour and from 393 to 273 pcu/hour in the PM peak. This also allows the double left turn without the use of a triple-headed arrow, a non-prescribed sign.

b) Provision of a much longer right turn lane lead-in on the A52(W) approach.



This effectively increases the number of right turners which can store without blocking ahead traffic on the A52(W) approach and so offers additional capacity for growth in the right turn movement.

Just as importantly, it increases capacity by taking most of the right turners out of the main flow. The recent final scheme Transyt model included modelling this arm including a flare. The actual flare length usage was derived using LINSAT.

Note that the yellow box is now permitted by the 2002 TSRGD at signalised entries to roundabouts.

c) The decision was taken to signalise the north arm (Toton Lane) despite the analysis showing less queuing with it as a Give Way.

Concerns with the Give Way were:-

(i) reliance on non-prescribed use of a yellow box, with an uncertain level of compliance and the potential highly-adverse worst-case consequences
(ii) safety concerns about the ability of drivers to simultaneously judge approach traffic on the roundabout, queuing traffic downstream on the roundabout and the signals to the left for the exit Toucan which has also been added (see below).

d) The decision was also taken to signalise the left turn exit to the south arm (Stapleford Lane). There was no issue either way in capacity terms and signalisation was considered safer, especially with the unusual layout in this area and the angled-back view which drivers would have at a Give Way.

e) A left turn lane was added to the A52(E) approach as this both improved the geometry leading into the three downstream circulatory lanes and also gave a small capacity increase. (Once again LINSAT was used to derive the actual flare usage length for Transyt).

f) Toucans across the A52 arms were added following pedestrian and cyclist usage surveys of the existing unsignalled crossings of those arms. While the signalisation alone would have improved the facilities a great deal, and the pedestrian movements are currently very low (i.e. about 100 movements across the east arm per day, 30 across the west arm), the site already had very high political priority for the provision of the best possible facilities because of understandable major safety concerns. Severe criticisms were expressed also by users who were interviewed as part of the surveys.

Only the exit crossing into the west arm has any possible capacity implications and in practice we expect no problems as the frequency of usage is extremely low in the peak periods (2 or 3 per hour). We do not expect a large increase. However, even with heavy demand, we would expect that the brief stopping of left turners from the south arm could be accommodated.

The crossings will have on-crossing detection and this will shorten the intergreens following the crossing stages as virtually all crossings will be completed within one or two seconds of the end of green to users. This will result in intergreens similar to the traffic intergreens.

g) Since the start of the design process, a Puffin crossing has been added by Nottinghamshire County Council to the south arm about 150m from the roundabout. This will be linked to the roundabout signals as needed, though any interaction is expected to be minimal.

h) A queue loop on the unsignalled garden centre access approach has been added. This will assist egress for graden centre traffic should excessive queues build by forcing a little extra all-red on the A52(E) east arm signals. This will not adversely affect coordinated flow on the roundabout itself.

i) The current intention in the Mova design is to have linking between two main streams controlling the northern and southern . the latter will be allowed to appear after passing of the main A52 platoons. The north and south arms will be linked by phase delays to the A52(W) and A52(E) phases respectively.

9. Closing Comments

Nottinghamshire County Council is the highway authority for the B6003 so they were the most important consultee. They are supportive of the scheme and expressed a strong preference for full signalisation, including the crossings over both A52 arms.

The garden centre owners are also supportive. Clearly the signals will make their centre much easier to egress, but hopefully customers from the west can find their way in!

Signing is a very important issue and there have been detailed discussions with the DfT specialists, especially about signing from the A52(W) arm. The restrictive effects of TSRGD on what arrows can appear on vertical lane indication signs has been an issue on which we do not totally accept the DfT view but we trust the end result will be clear to drivers. One important factor which has eased the way forward is that the police have accepted a new 40mph speed limit for 400m on both A52 approaches (it will not apply to the leaving directions) – this has avoided the need to consider gantry signs, which would have been a major problem to accomodate.

Appendix A

Deriving the CRITICAL Lane Flow Summation Value

On the Lane Flow Diagram

Check that the sum of the critical Lane flows at each node are less than or equal to 1500 pcus/hr. If they are, then all links will be at or less than 90% saturated assuming, as in this instance, S = 1900 pcu/hr, cycle = 60”, intergreens = 5”.

At each junction Yprac = (qe +qg) / S

where:

qe + **q**g = sum of the critical lane flows (i.e. sum of the worst lane flow for each stage in the cycle – see illustration overleaf)

Yprac = deg of sat x (C – L) / C

qe = critical entry lane flow
qg = critical gyratory lane flow
C = Cycle time
L = effective lost time (i.e for two stage 5” intergreen times, L= 10-2 = 8”)
S = Saturation Flow(pcu/hr) assumed for the entry and gyratory lanes

For example, for a 60” cycle, intergreens of 5”, and an assumption that you wish all degrees of saturation to be at or below 90%:-

Deg of Sat x (C-L)/C = (qe +qg) / S
i.e. the sum of the critical entry and gyratory flow at any junction:-
(qe +qg) = S* Deg of Sat * (C-L) / C
= 1900 * 0.9*(60-8) / 60 pcu/hr
= 1482
i.e. approximately **1500 pcu/hr**

Figure 1 Site Location

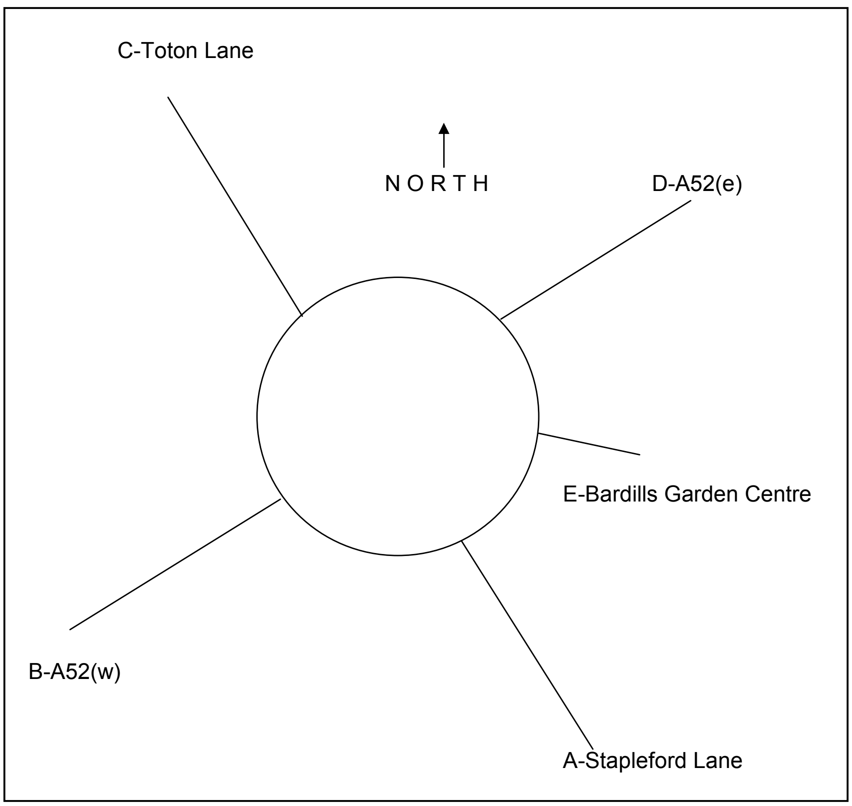


Figure 2 Bardills Roundabout, Arm Labelling

Arm A	Stapleford Lane	Yellow
Arm B	A52 (West)	Pink
Arm C	Toton Lane	Green
Arm D	A52 (East)	Blue
Arm E	Bardills Garden Centre	

Year 2003 Traffic Flows derived from Traffic Count Thurs 18/9/05
(with unserviced observed queue demand added)

AM Peak 0730 - 0830 (Provided) Year 2003

	A	B	C	D	E	Tot
A	1	402	188	101	2	694
B	330	6	219	1625	5	2185
C	166	335	0	49	5	555
D	113	1764	34	0	3	1914
E	4	4	1	0	0	9
Tot	614	2511	442	1775	15	5357

PM Peak 1700 - 1800 (Provided) Year 2003

	A	B	C	D	E	Tot
A	1	283	262	131	0	677
B	298	14	250	1650	2	2214
C	282	215	0	57	4	558
D	180	1682	49	0	8	1919
E	9	10	6	3	0	28
Tot	770	2204	567	1841	14	5396

Figure 3A
Year 2003
Design Flows
(pcu/hr)

Year 2008 derived as Year 2003 X 1.08

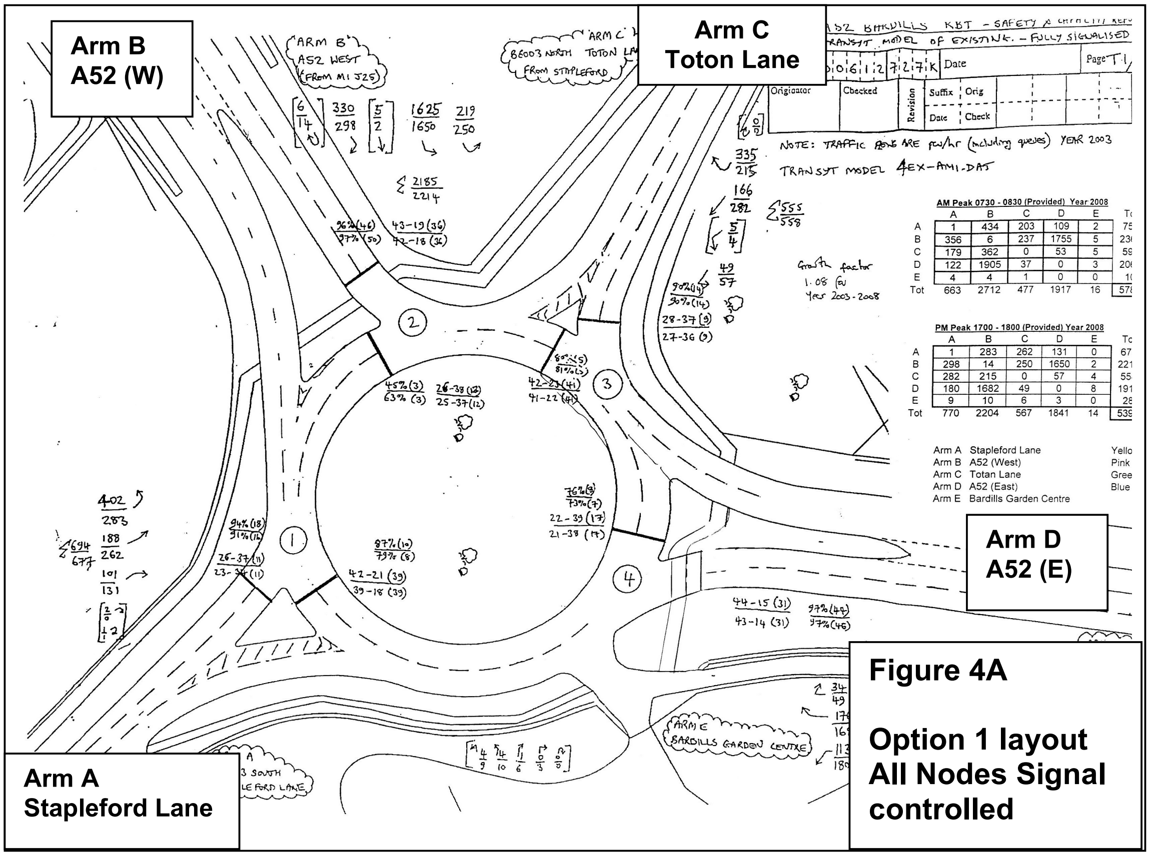
AM Peak 0730 - 0830 (Provided) Year 2008

	A	B	C	D	E	Tot
A	1	434	203	109	2	750
B	356	6	237	1755	5	2360
C	179	362	0	53	5	599
D	122	1905	37	0	3	2067
E	4	4	1	0	0	10
Tot	663	2712	477	1917	16	5786

PM Peak 1700 - 1800 (Provided) Year 2008

	A	B	C	D	E	Tot
A	1	306	283	141	0	731
B	322	15	270	1782	2	2391
C	305	232	0	62	4	603
D	194	1817	53	0	9	2073
E	10	11	6	3	0	30
Tot	832	2380	612	1988	15	5828

Figure 3B
Year 2008
Design Flows
(pcu/hr)



AM Peak 0730 - 0830 (Provided) Year 2008

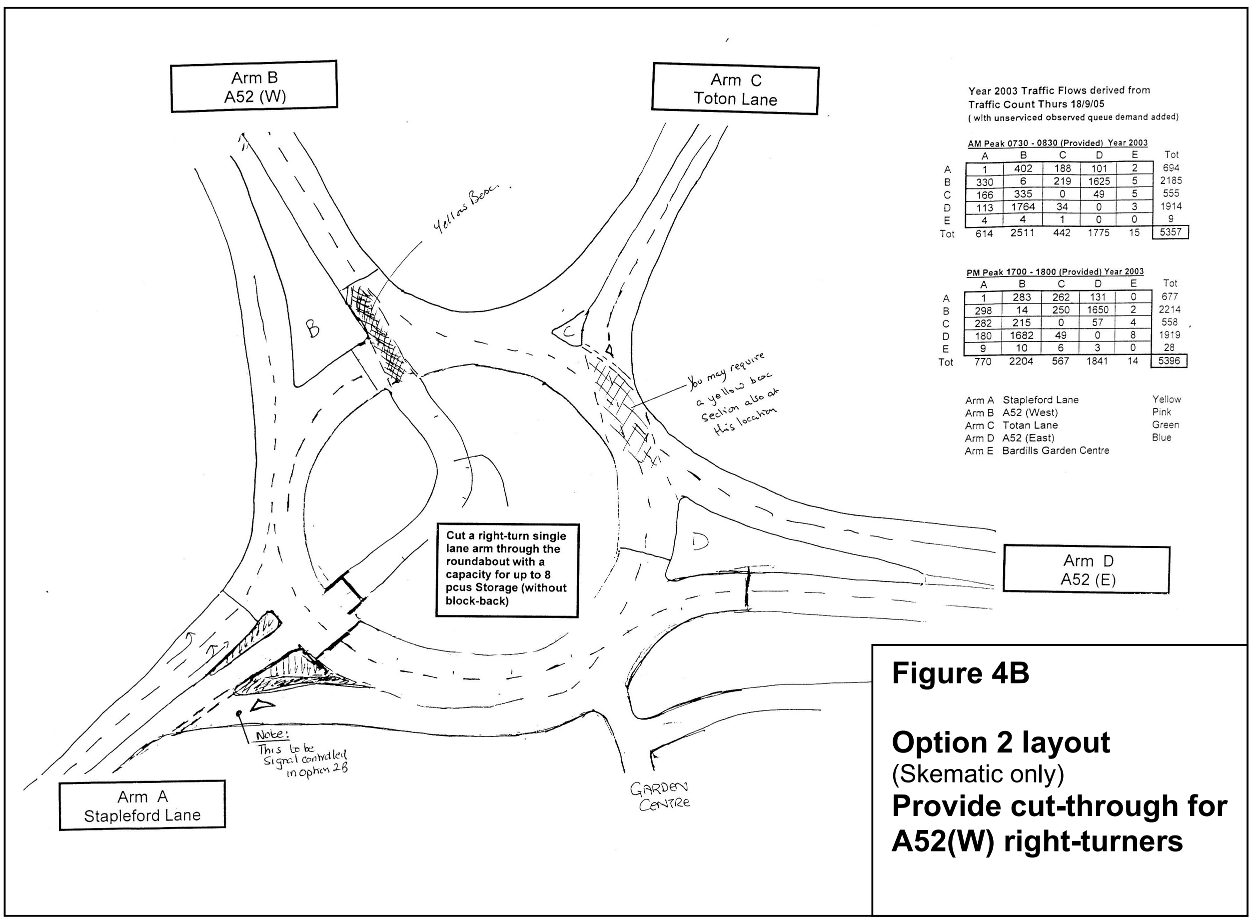
	A	B	C	D	E	Tc
A	1	434	203	109	2	75
B	356	6	237	1755	5	23
C	179	362	0	53	5	59
D	122	1905	37	0	3	20
E	4	4	1	0	0	1
Tot	663	2712	477	1917	16	57

PM Peak 1700 - 1800 (Provided) Year 2008

	A	B	C	D	E	Tc
A	1	283	262	131	0	67
B	298	14	250	1650	2	221
C	282	215	0	57	4	55
D	180	1682	49	0	8	191
E	9	10	6	3	0	28
Tot	770	2204	567	1841	14	539

Figure 4A

Option 1 layout
All Nodes Signal controlled



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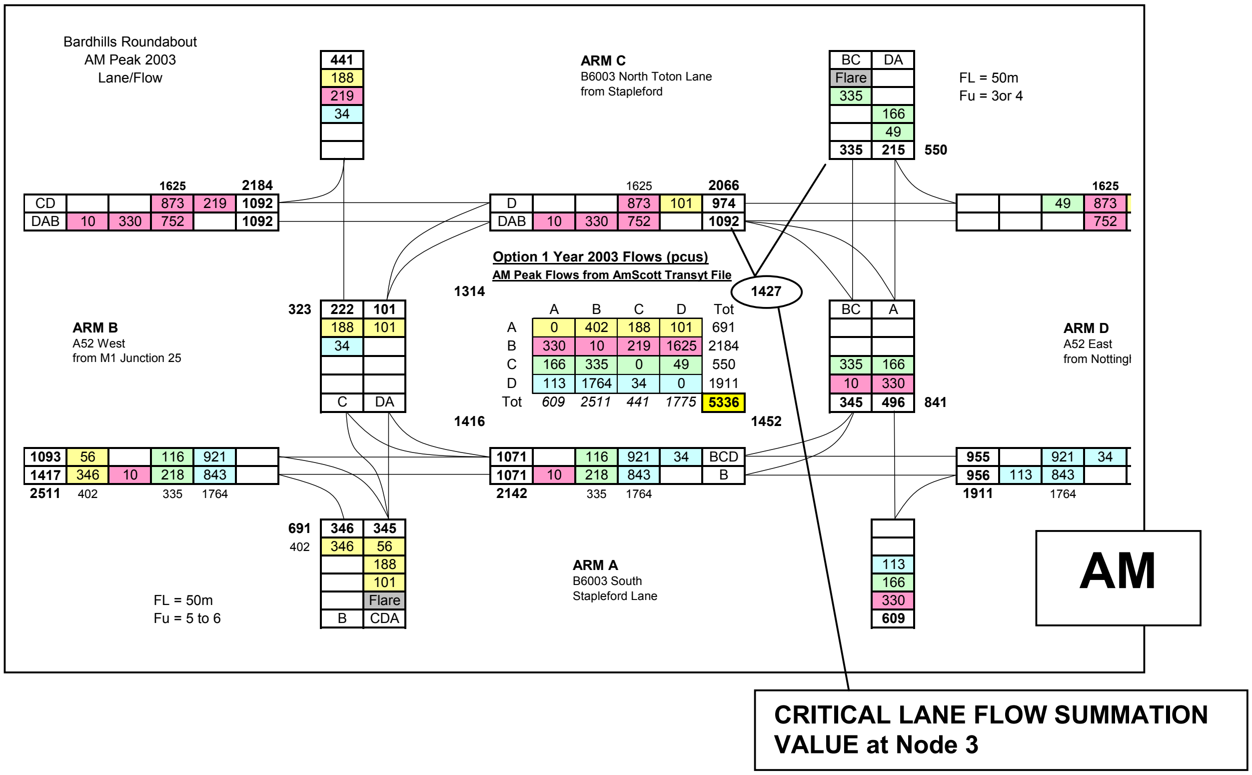
E	4	4	1	0	0	9
Tot	614	2511	442	1775	15	5357

PM Peak 1700 - 1800 (Provided) Year 2003

	A	B	C	D	E	Tot
A	1	283	262	131	0	677
B	298	14	250	1650	2	2214
C	282	215	0	57	4	558
D	180	1682	49	0	8	1919
E	9	10	6	3	0	28
Tot	770	2204	567	1841	14	5396

Figure 4B

Option 2 layout
(Skematic only)
Provide cut-through for A52(W) right-turners



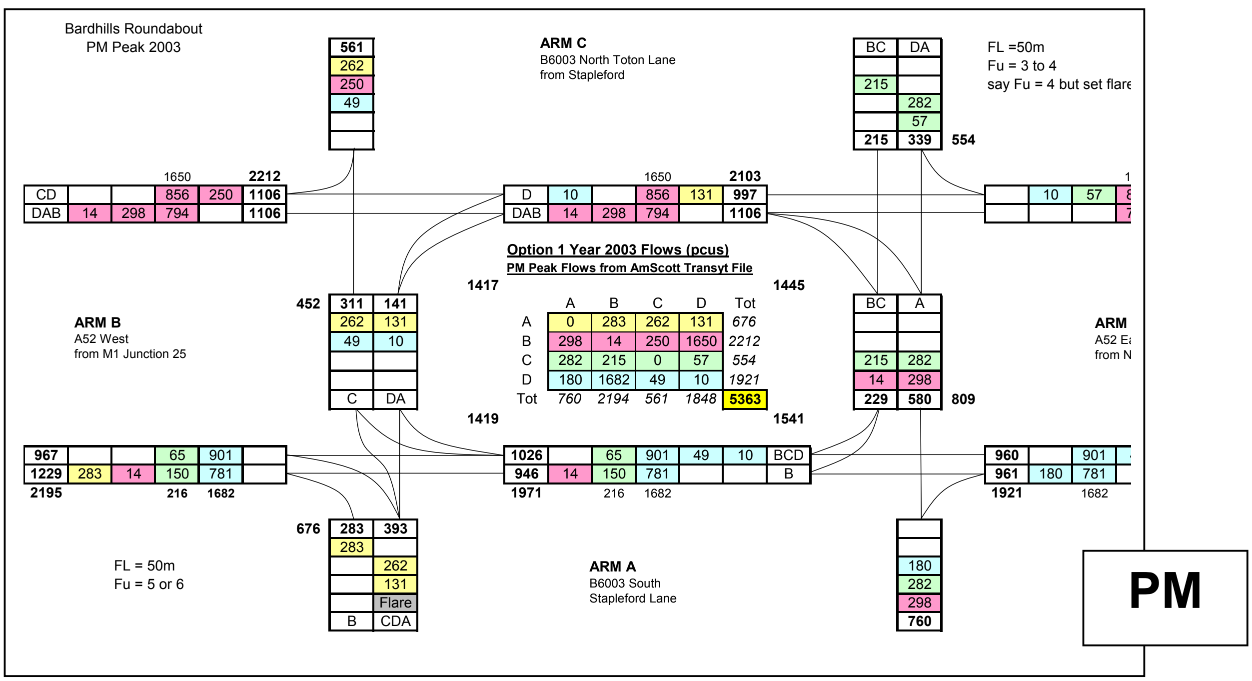
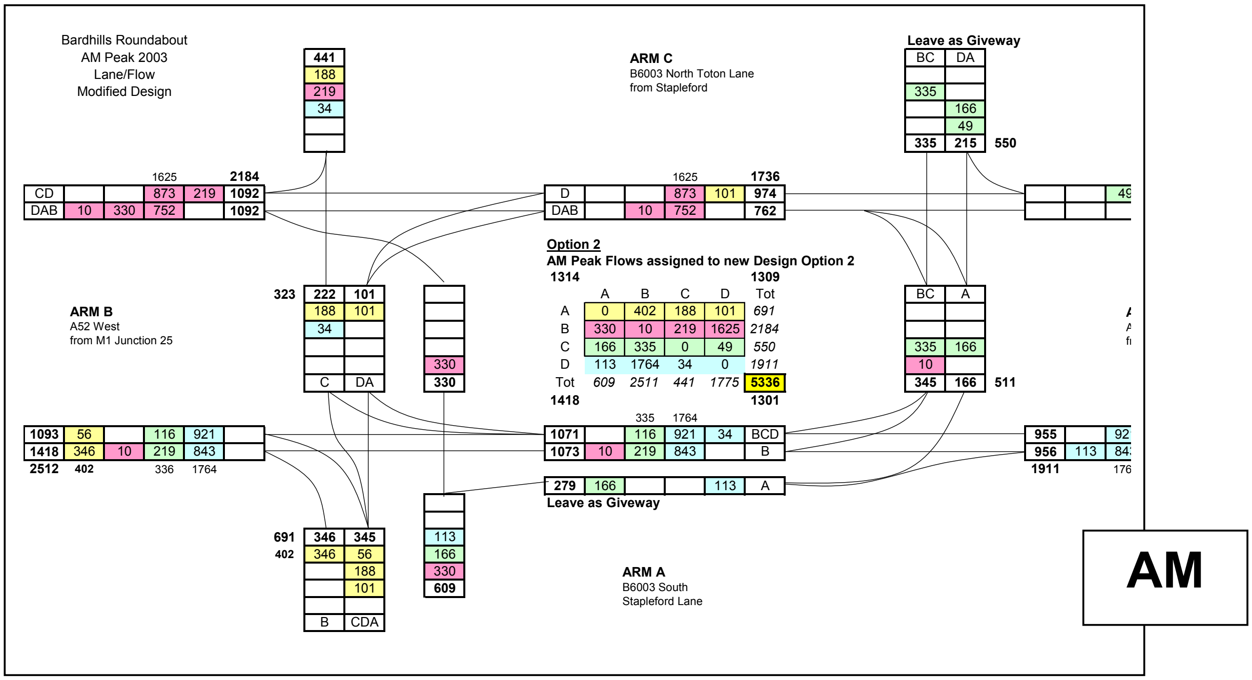


Figure 5

Lane Flow Diagrams (Am/PM) for Year 2003 flows (As-Is and Option 1)



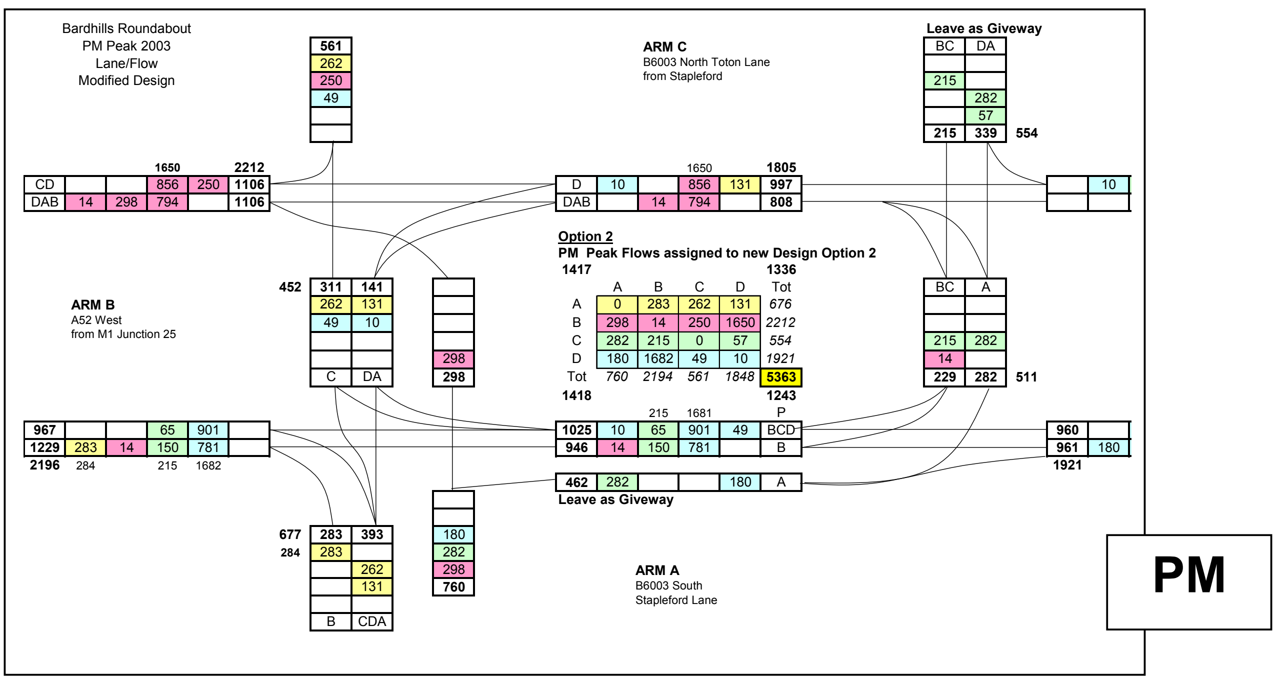


Figure 6

Lane Flow Diagrams (Am/PM) for Year 2003 flows with cut through (Options 2 and 3)

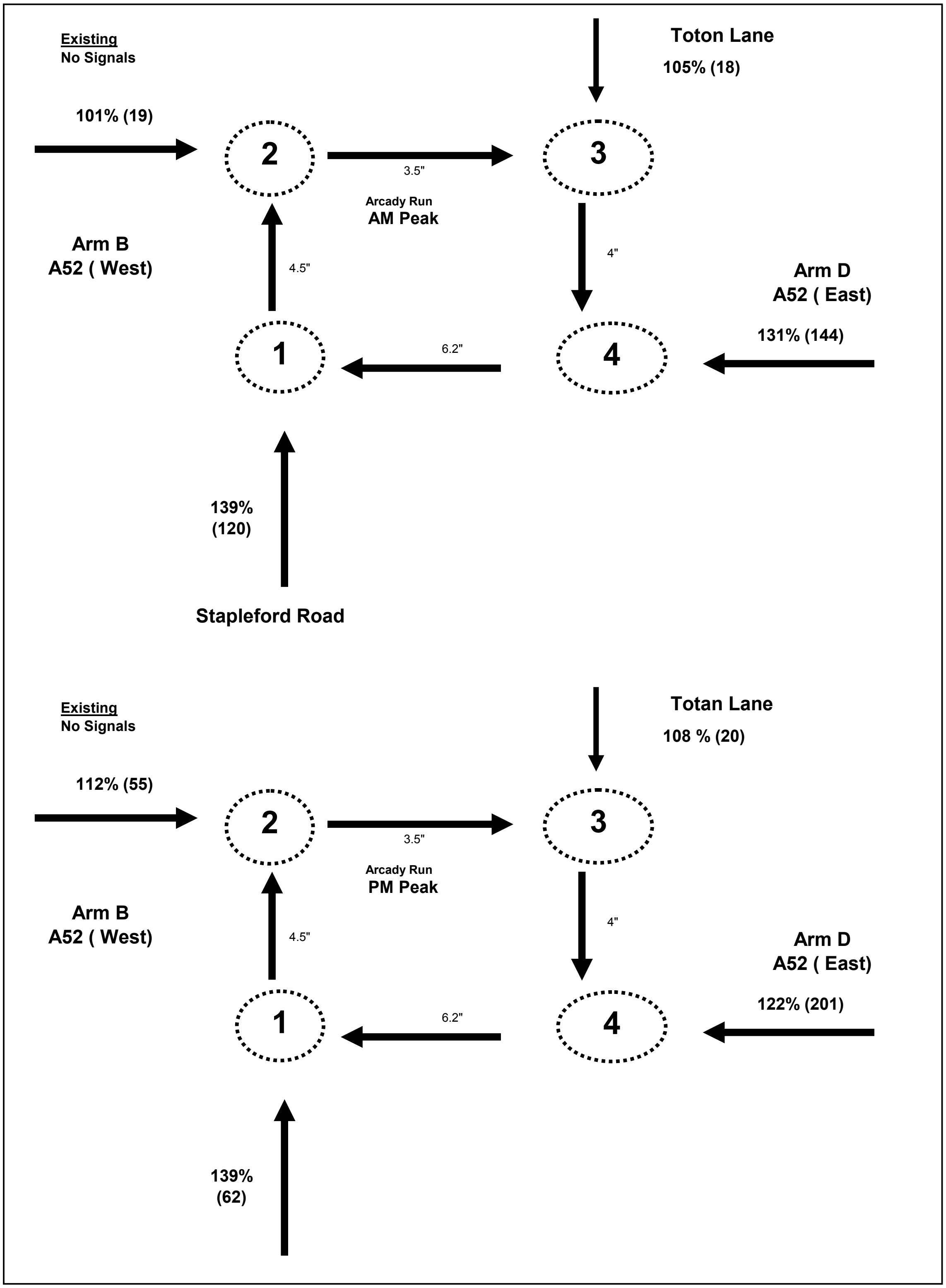
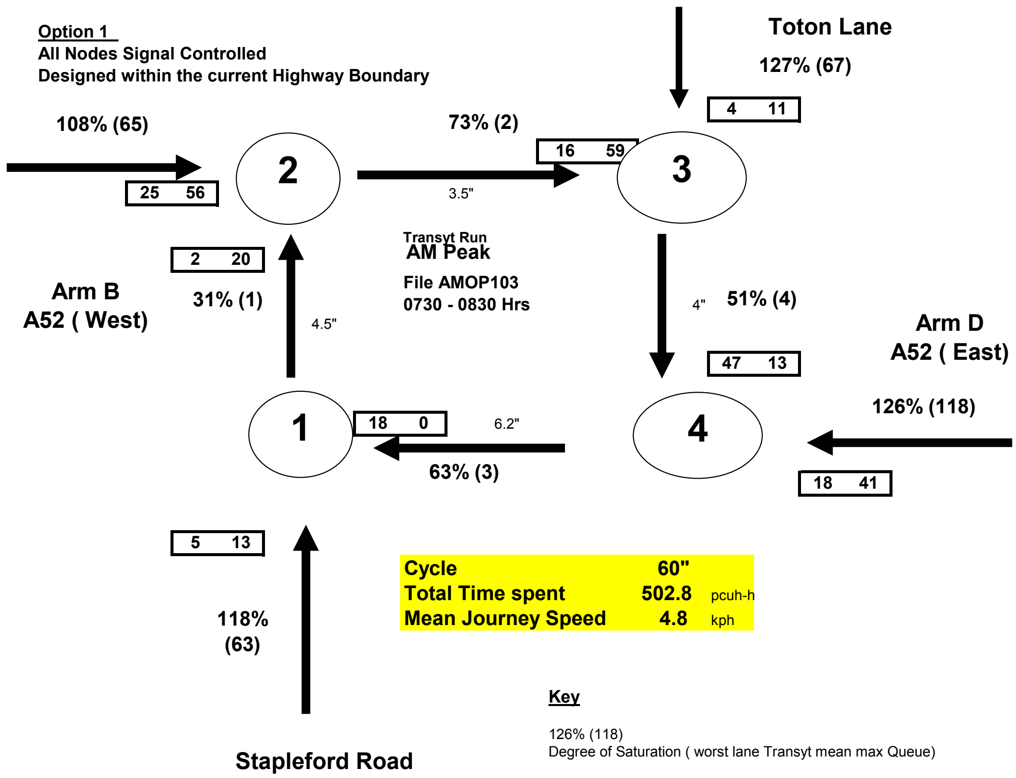


Figure 7 **Arcady Results for year 2003**
Existing Design



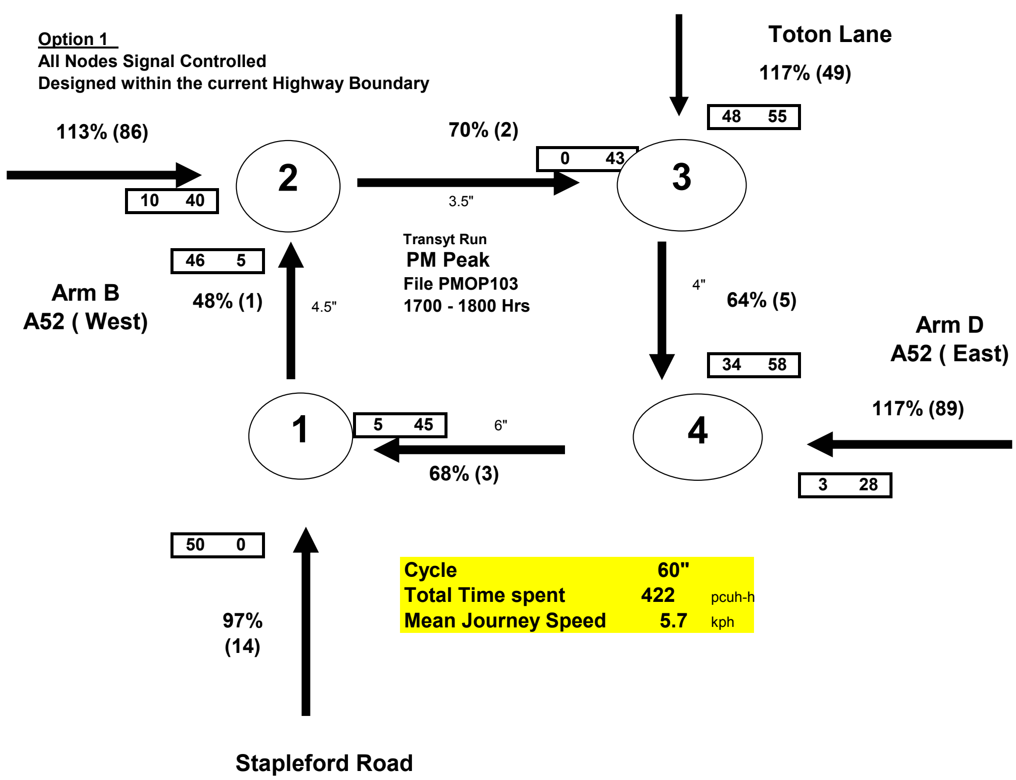
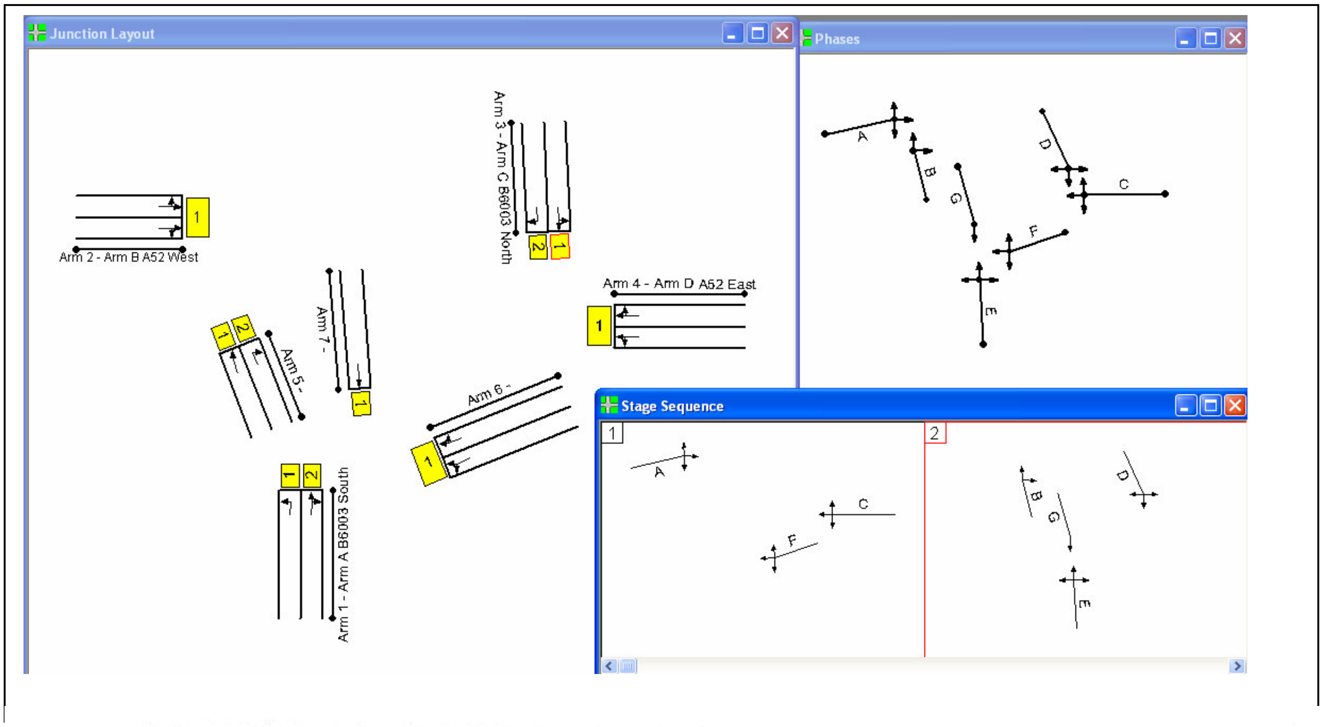
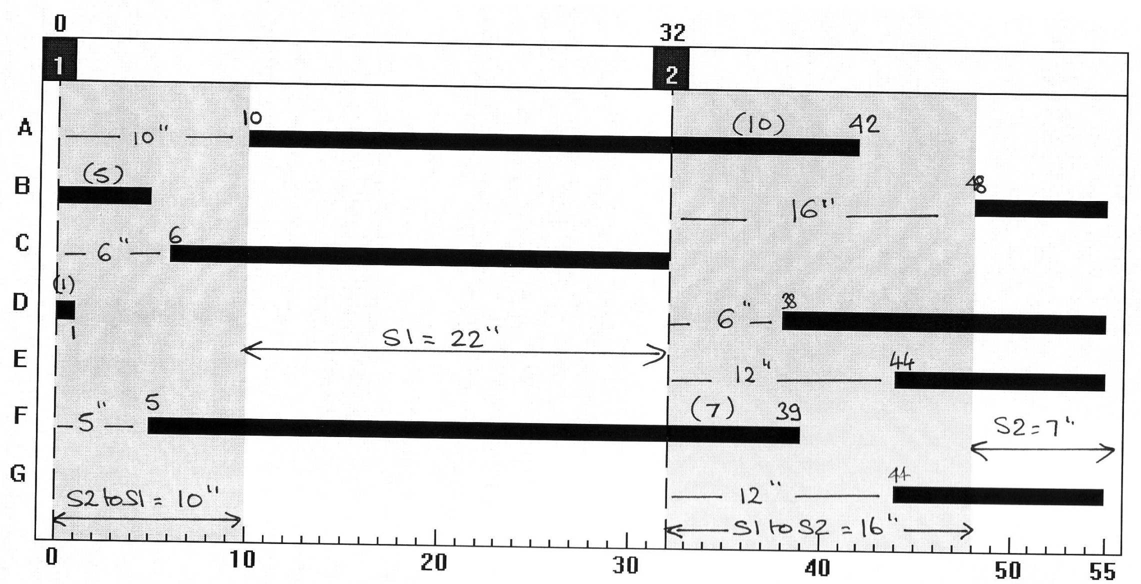
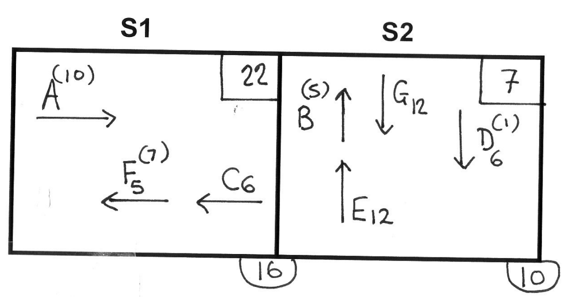


Figure 8 **Option 1 Year 2003**

All Nodes Signal controlled, Existing Layout







Transyt & Linsig File AM2A
AM Peak
Option 2A
Cycle = 55"

Figure 9A Modelling Roundabout in Linsig (AM Peak)

Linsig was used to achieve optimal progression and thus to provide Transyt Stage Diagrams for each peak period (the roundabout was then modelled as though one node in Transyt)

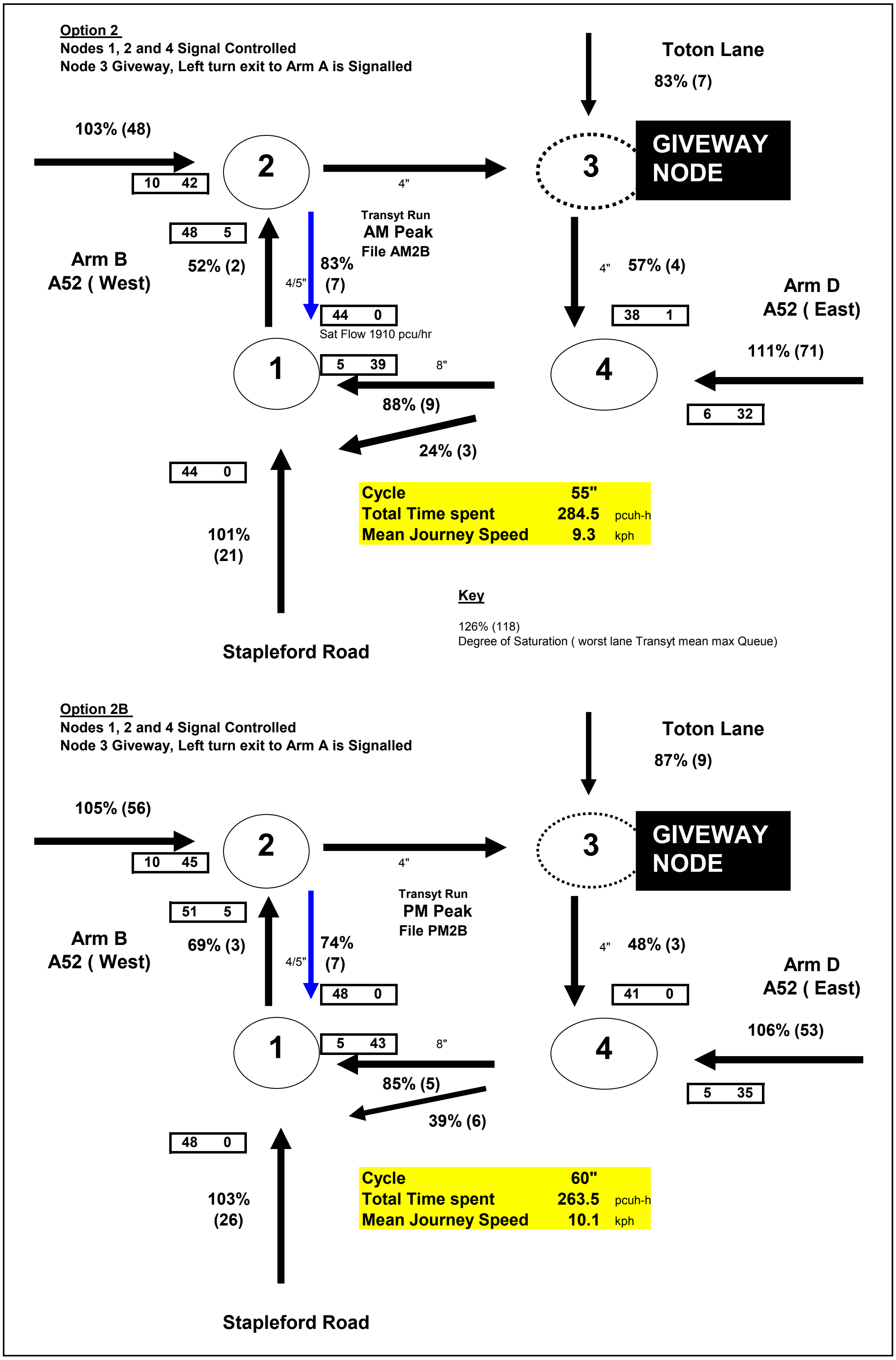


Figure 9B Option 2 Year 2003

Nodes 1, 2 and 4 Signal controlled, Node 3 as Giveway, A52(W) right-turn diverted through R'bt

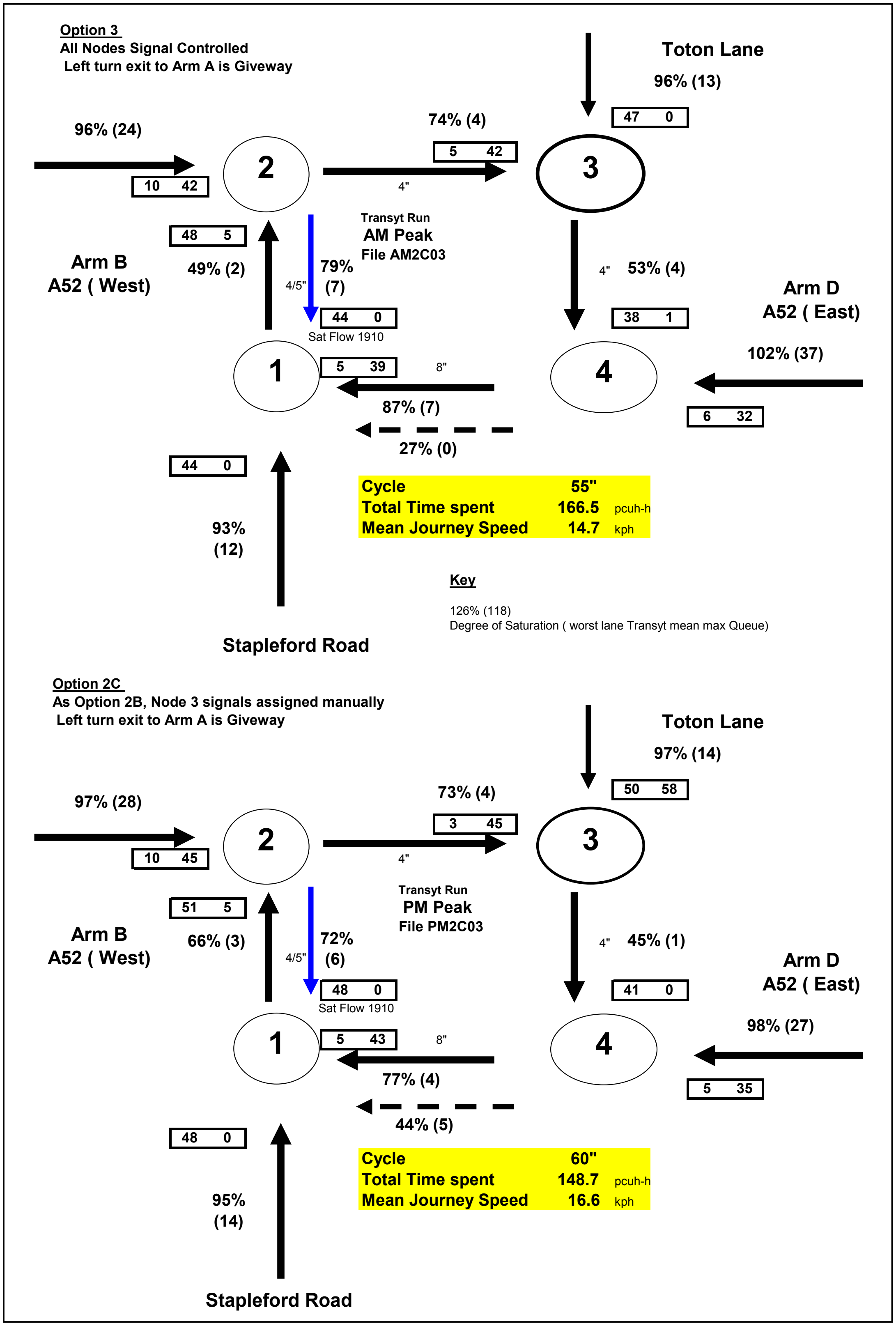


Figure 10 Option 3 Year 2003

All Nodes Signal controlled, A52(W) right-turn cut through roundabout

AM Peak Year 2003	A		B		C		D		see Fig
	Stapleford Lane		A52 (W)		Toton Lane		A52(E)		
	Deg Sat	(MMQ)	Deg Sat	(MMQ)	Deg Sat	(MMQ)	Deg Sat	(MMQ)	
Arcady As-Is Year 2003	139%	(120)	101	(19)	105	(18)	131	(144)	7
Option 1: AM Peak 2003	118%	(63)	108%	(65)	127%	(67)	126%	(118)	8
Option 2: AM Peak 2003	93%	(11)	96%	(24)	73%	(5)	102%	(37)	9B
Option 3: AM Peak 2003	93%	(12)	96%	(24)	96%	(13)	102%	(37)	10

PM Peak Year 2003	A		B		C		D		see Fig
	Stapleford Lane		A52 (W)		Toton Lane		A52(E)		
	Deg Sat	(MMQ)	Deg Sat	(MMQ)	Deg Sat	(MMQ)	Deg Sat	(MMQ)	
Arcady As-Is Year 2003	139%	(62)	112%	(55)	108%	(20)	122%	(201)	7
Option 1: PM Peak 2003	97%	(14)	113%	(86)	117%	(49)	117%	(89)	8
Option 2: PM Peak 2003	95%	(13)	97%	(28)	77%	(6)	98%	(27)	9B
Option 3: PM Peak 2003	95%	(14)	97%	(28)	97%	(14)	98%	(27)	10

AM Peak Year 2008	A		B		C		D		
	Stapleford Lane		A52 (W)		Toton Lane		A52(E)		
	Deg Sat	(MMQ)	Deg Sat	(MMQ)	Deg Sat	(MMQ)	Deg Sat	(MMQ)	
Arcady As-Is Year 2008									
Option 1: AM Peak 2008	121%	(76)	113%	(93)	137%	(90)	148%	(190)	
Option 2: AM Peak 2008	101%	(21)	103%	(48)	83%	(7)	111%	(70)	
Option 3: AM Peak 2008	101%	(21)	103%	(48)	104%	(24)	111%	(71)	

PM Peak Year 2008	A		B		C		D		
	Stapleford Lane		A52 (W)		Toton Lane		A52(E)		
	Deg Sat	(MMQ)	Deg Sat	(MMQ)	Deg Sat	(MMQ)	Deg Sat	(MMQ)	
Arcady As-Is Year 2008									
Option 1: PM Peak 2008	105%	(33)	112%	(91)	115%	(49)	129%	(141)	
Option 2: PM Peak 2008	103%	(26)	105%	(56)	87%	(9)	106%	(53)	
Option 3: PM Peak 2008	103%	(26)	105%	(56)	105%	(26)	106%	(53)	

Figure 11 **Transyt Evaluation Results Summary**

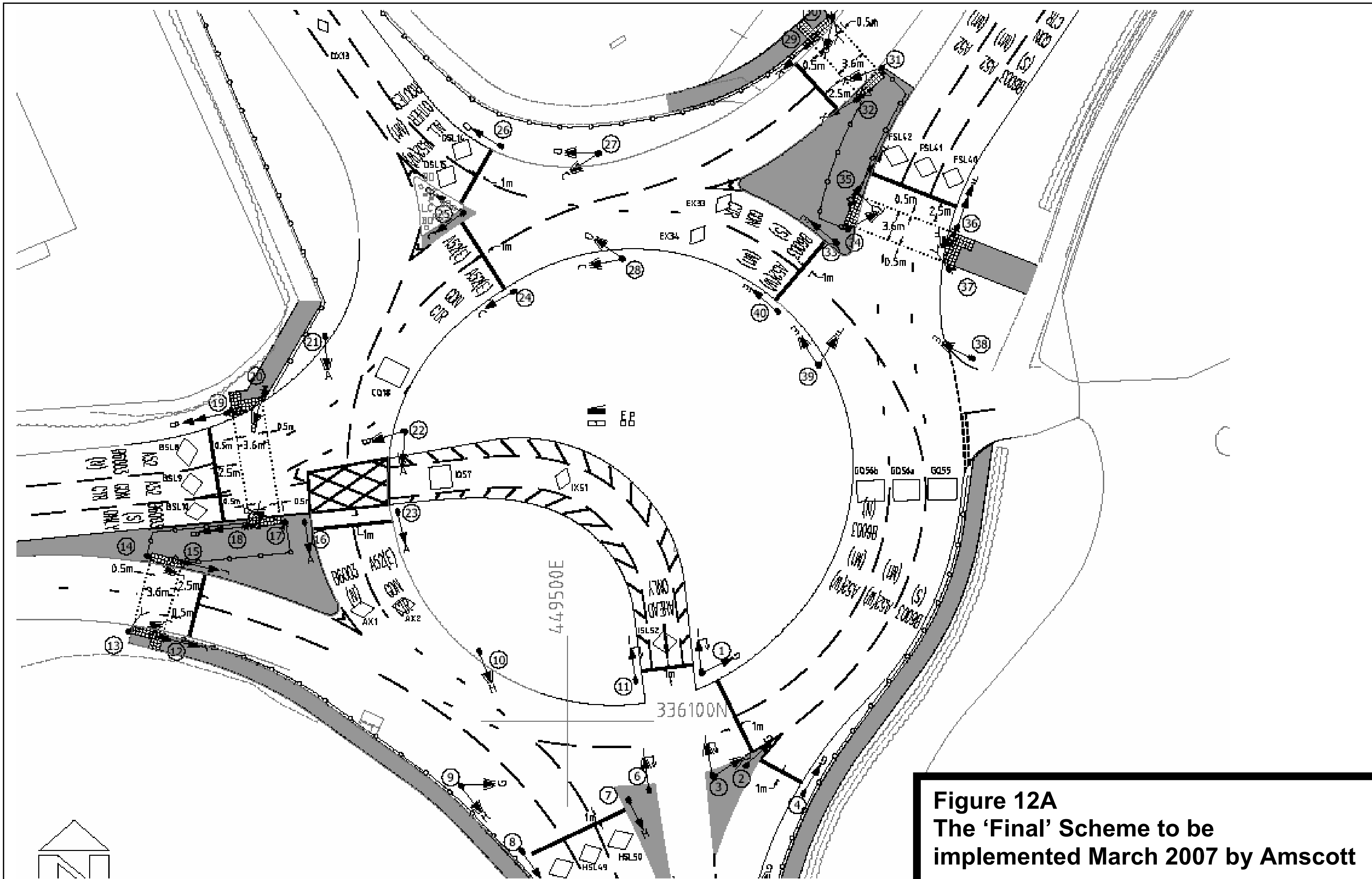


Figure 12A
The 'Final' Scheme to be implemented March 2007 by Amscott

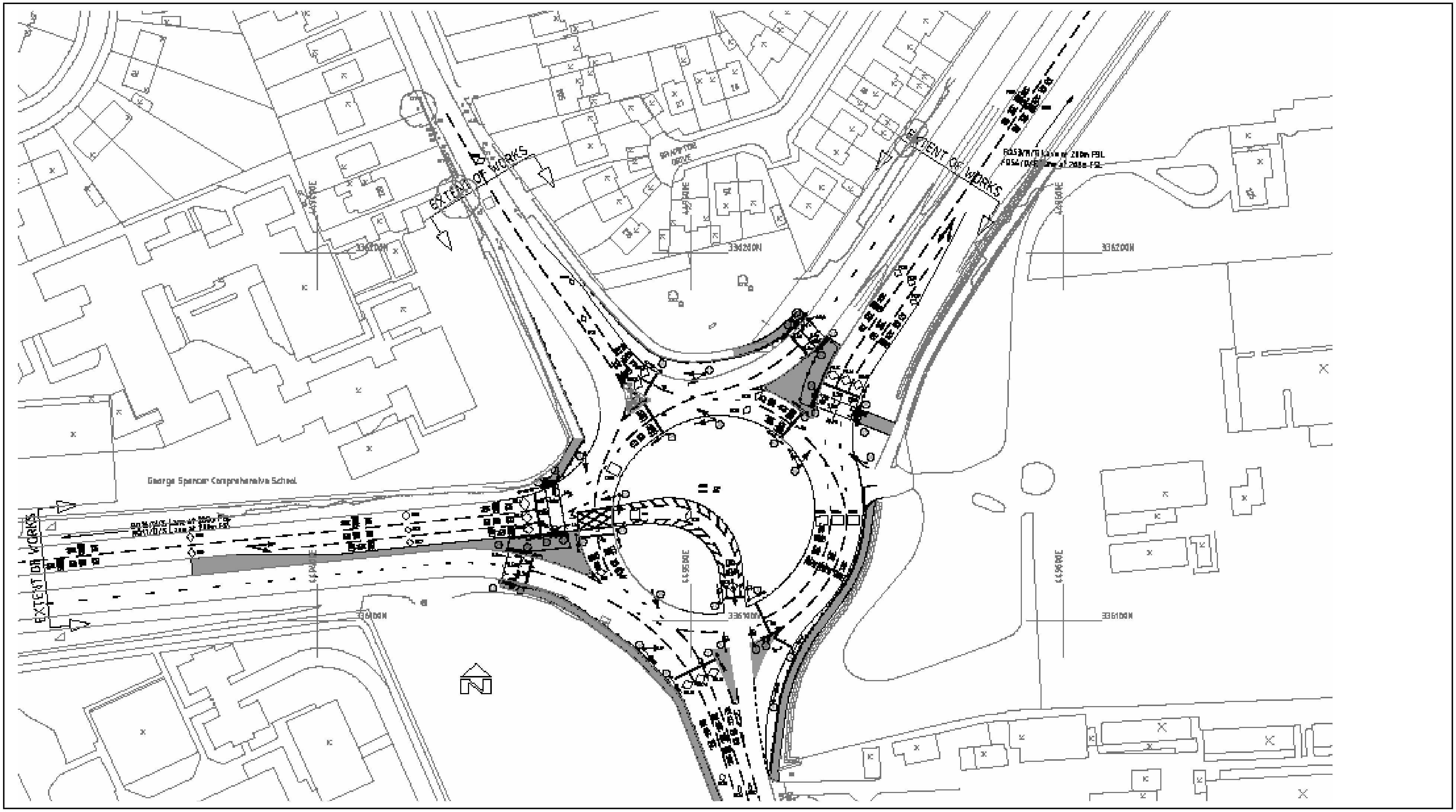


Figure 12B

The 'Final' Scheme to be implemented March 2007 by Amscott