Signal Controlled Roundabout Methodology and its introduction to NZ at Welcome Bay, Maungatapu and Brookfield roundabouts in Tauranga North Island

by

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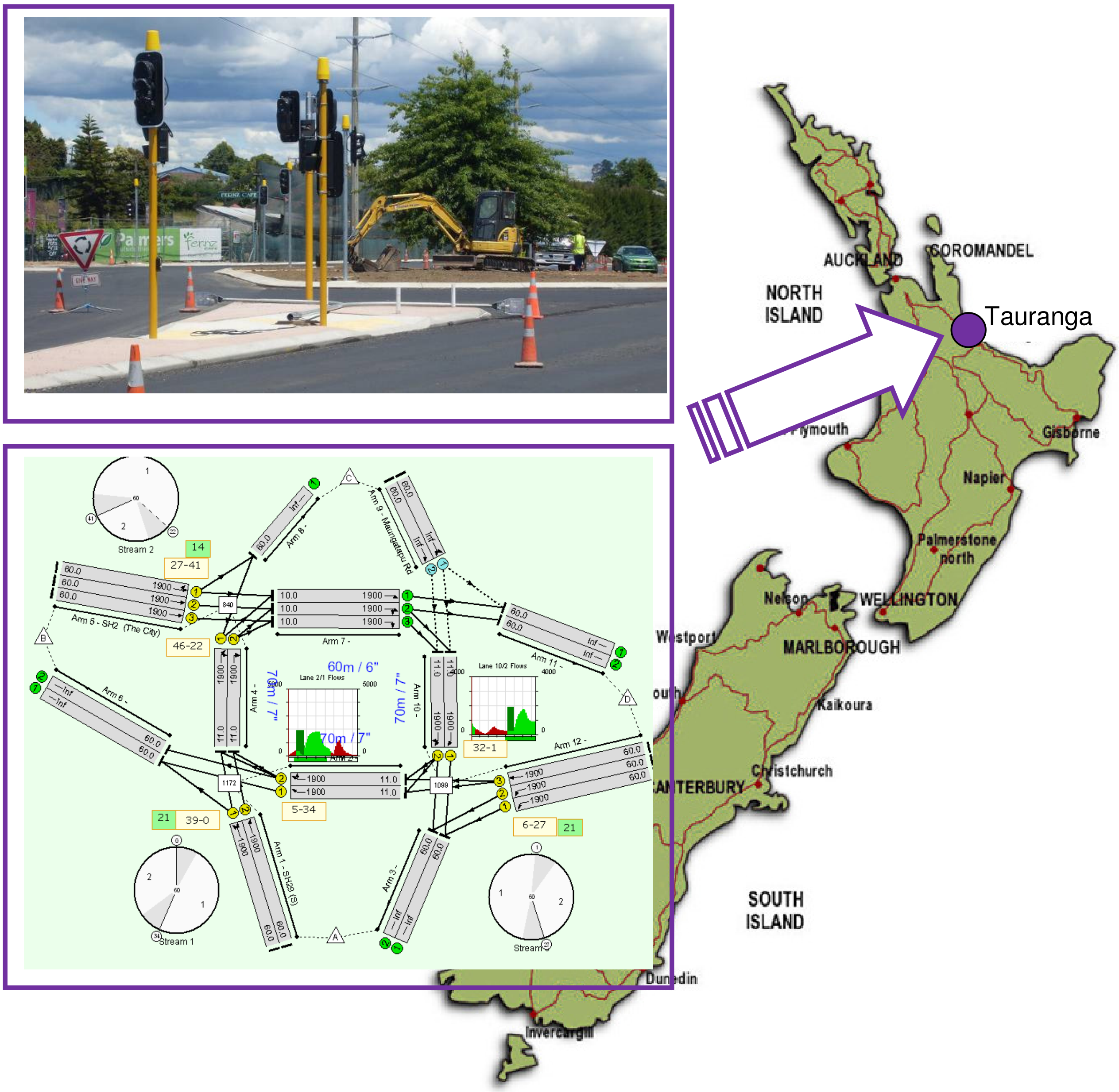


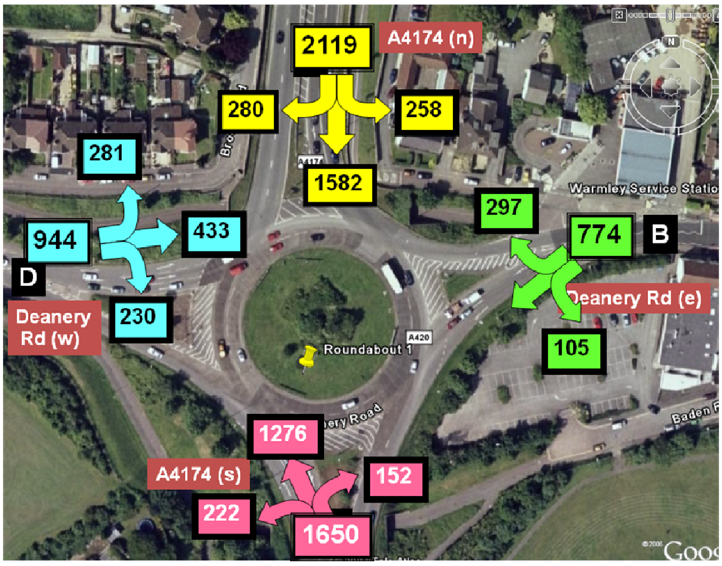
INTRODUCTION

Why do roundabouts fail and what can be done about it?

Priority controlled roundabouts offer an excellent means of sharing the available capacity by separating and managing conflicting movements within a single intersection. However, these ‘give-way’ roundabouts break down when:-

- one or more dominant movement takes up an unequal share of the available capacity;
- a small but persistent volume of traffic passes in front of a giveway line where a very high volume of traffic is trying to egress.

Figure 1 shows the origin-destination movements during the AM peak period on the A4174 / A420 Deanery roundabout east of the city of Bristol (UK). High volume traffic on the A4174 north and south arms makes it very difficult for traffic on the A420 west and east arms to enter the roundabout. In addition, the smaller but persistent flow of traffic in front of the northern approach giveway line seriously hampers egress from this high volume arm. These facts are reflected in the Arcady giveway analysis results quoted in Figure 1, where Arms A, B and D are all overloaded in the AM Peak period (note: the RFC value must be at or below 85% for a giveway arm to be within capacity where the RFC value for an arm is the ratio of flow to capacity).



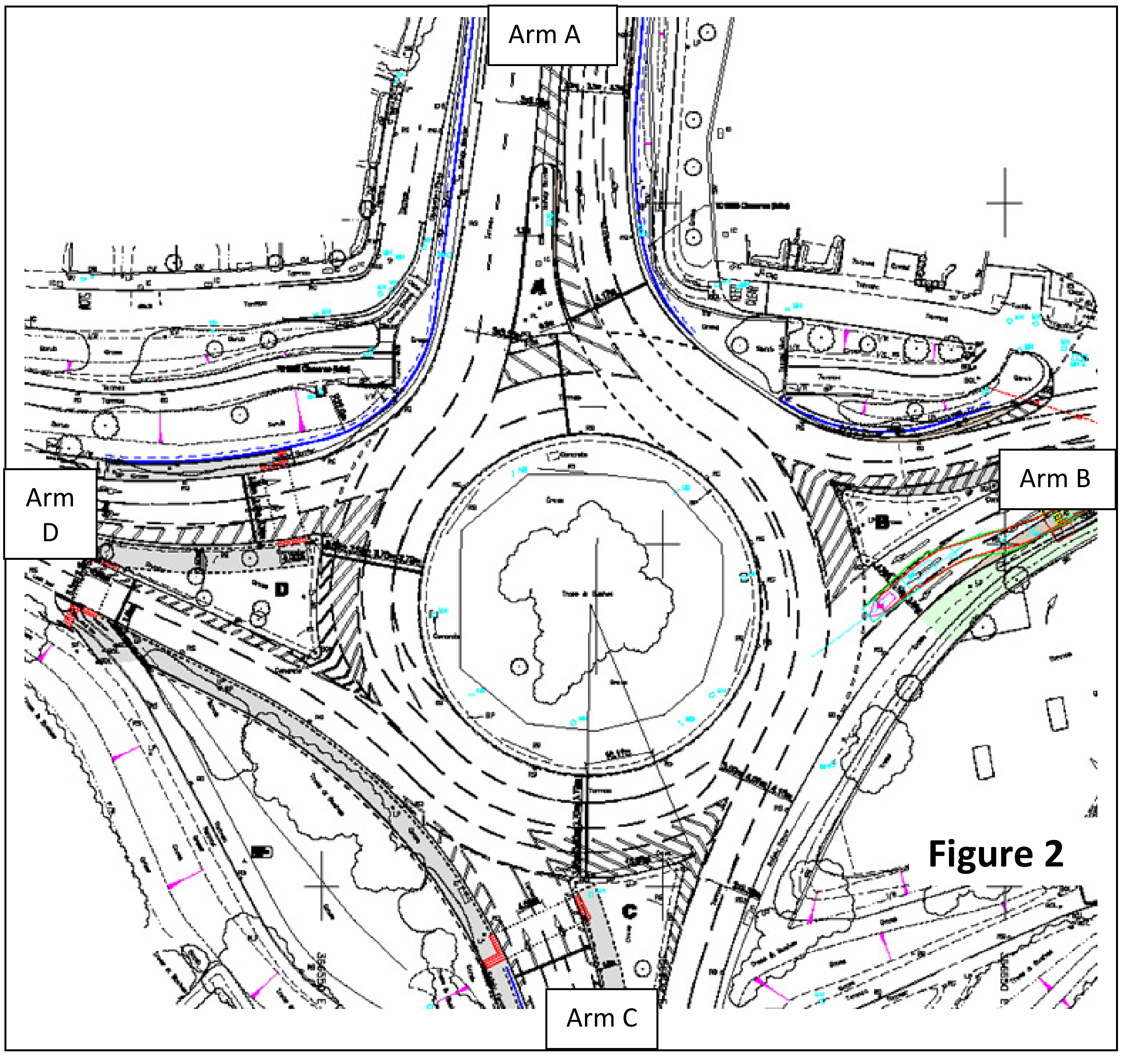
	Arm Name	RFC	Queue
A	A4174(N)	101%	71.2
B	A420(E)	97%	15
C	A4174(S)	80%	4
D	A420(W)	106%	40

Figure 1

By placing signals on a ‘failed’ priority roundabout, you can more equably share the available capacity between all the approach arms. In so doing, you can immediately achieve a better practical reserve capacity for the intersection as a whole. By then adding one or more of the following, in combination with signals, you can significantly further increase the design life of the signalled roundabout:-

- add short flare lanes on the approaches;
- add short 2 to 1 or 3 to 2 merge lanes on the exits;
- add additional lanes on the gyratory sections;
- re-route one or more movements through the central island itself.

In the example above, signals were placed on three of the four arms (Arms A, C and D), the north and south approaches were widened from 2 to three lanes, the gyratory sections were widened from 2 lanes to 3 lanes everywhere except the southern section which was widened to 4 lanes. A short 2 to 1 merge lane was added on the exit to Arm B and Arm B was left as a giveway arm. The proposed design improvement and LinSig results are shown in Figure 2. The new signalled roundabout will afford an eight to ten year life before becoming overloaded once more. Lane/Flow analyses was used to determine the geometric additions required and named above.



Proposed Signal Controlled Design Figure 2

Arm	Arm Name	Deg Sat	Queue
A	A4174(N)	83%	12
B	A420(E)	63%	5
C	A4174(S)	83%	10
D	A420(W)	83%	7

Compare Existing Layout, Figure 1:-

	Arm Name	RFC	Queue
A	A4174(N)	101%	71.2
B	A420(E)	97%	15
C	A4174(S)	80%	4
D	A420(W)	106%	40

So why signal control a roundabout ?

Reasons why you might signal control a roundabout are:-

- the roundabout no longer 'works' for one or more arms;
- the addition of signals allows you to more 'equably' share the available capacity between the approach arms;
- affords you better control of vehicle movements and thereby reduce accidents; and
- facilitates providing controlled pedestrian crossing facilities around or 'through' the roundabout island (see Figure 3).

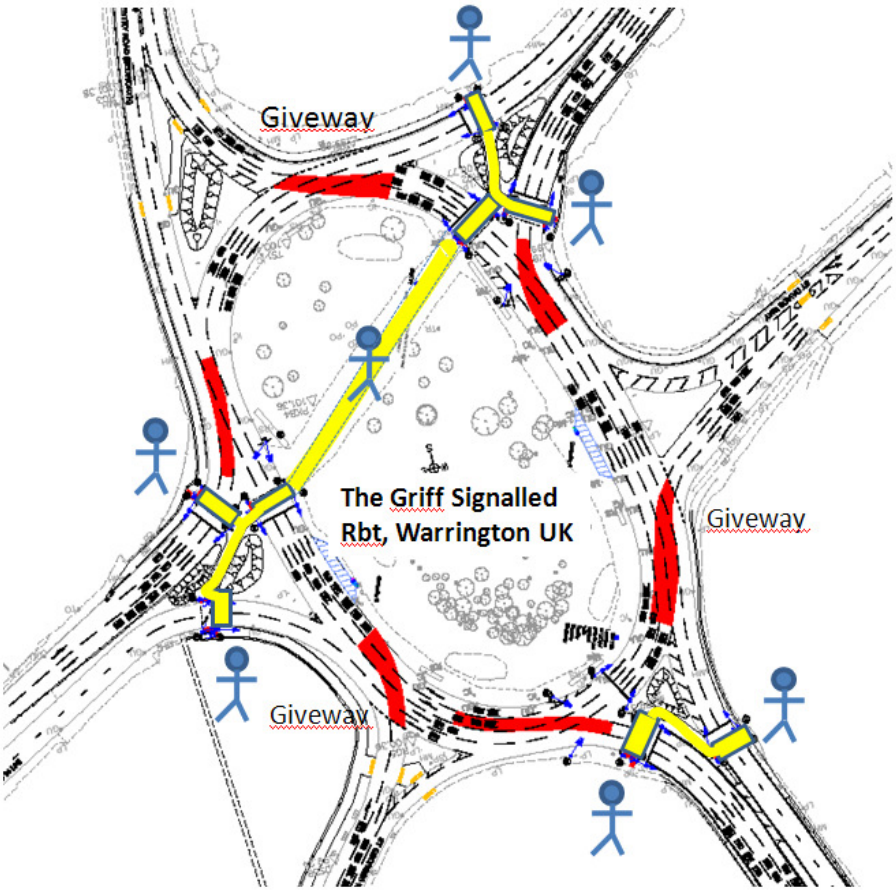


Figure 3

Should you apply signal control at all the arms ?

Not all the entries have to be signal controlled. Indeed, leaving one or more entry under priority control often provides better progression for all traffic through the roundabout. Often a roundabout that will not work with all the arms signalled, will work if one or more arms are left as giveway. Full signal control requires more storage space for queuing within the roundabout. Three signal controlled arms only is the ideal! In such cases, no newly entering traffic into the roundabout will be stopped at the first stopline within the roundabout. Not stopping the traffic at the first stopline after entering the roundabout is now a recommended safety requirement. Please note that this does not mean that only three arms can be signalled. It means that you get 'perfect progression', if only three arms are signalled! (Note: good progression means that traffic newly released into the signaled roundabout travels all or a significant way through the roundabout without being stopped at an internal stopline).

Which arms might you consider leaving as giveway?

You should look for entries where (see Figure 4):-

- the entry flow is low (i.e. below say 850 pcu/hr in both peak periods);
- there is sufficient stacking room for gap takers to store at the next stopline within the roundabout;
- there is a closely associated signal controlled roundabout node to provide interstage gaps;
- where, if you were not to leave an entry as giveway, this would necessitate three traffic stages at one of the roundabout nodes to control.

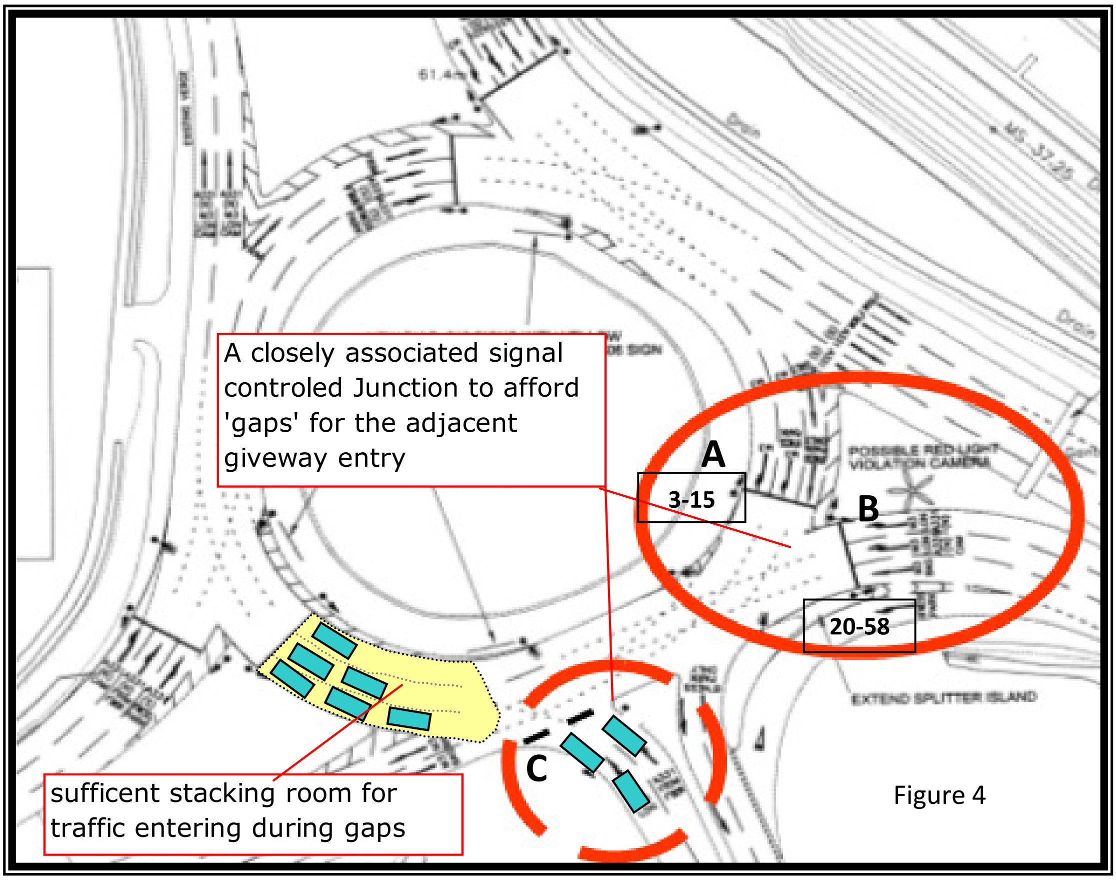


Figure 4

Traffic entering through gaps afforded by the intergreens at a closely associated upstream junction will get two opportunities per cycle.

Sometimes we refer to such opportunities as 'Virtual Green Times' for the giveway approach.

If the cruise time from the upstream signalled junction is say 6", then the Virtual Green times at C will be 21"-26" and 4" to 9" (*i.e. 15 + 6 =21, 20 + 6 = 26, 58+6 = 4 and 3+ 6 = 9).*

DESIGN CONSIDERATIONS

Signalled Roundabouts need to be Spiral Marked It is now recommended that you should always spiral mark the lanes within the roundabout as a prerequisite to signal controlling it. Spiral lane marking means that cars on the approaches are 'flight-path led' through the roundabout from origin to destination without ever having to change lane. Accordingly, Spiral Marking (see Figure 5) :-

- makes it 'safer for the cars within the gyratory sections' because they do not have to change lanes, often at speed, and in close proximity to other moving vehicles; and
- improves the operational performance of the roundabout since cars no longer have to slow up within the roundabout to account for traffic 'weaving' across into their lane.

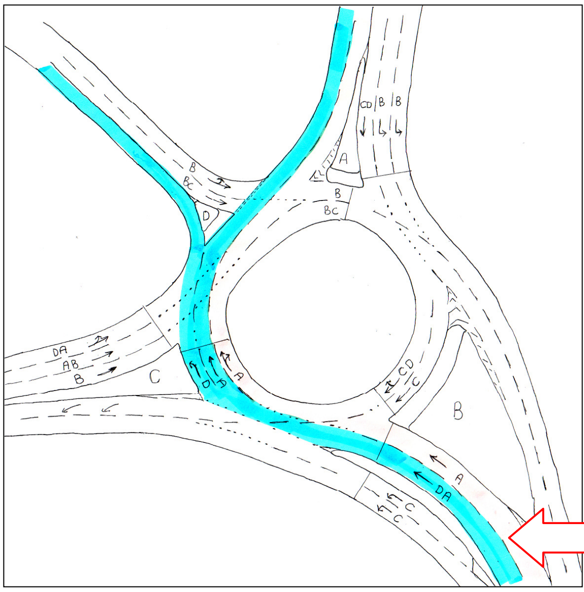


Figure 5

Traffic approacing the roundabout on this lane on Arm B is 'flight-path-led' to the 'desired' Arm D and Arm A exits without having to change lane, thanks to the Spiral Marking

Construction Tip: Consider using coloured tarmac (doubles as ant-skid) to aid driver comprehension of the spiral design (Figure 6)

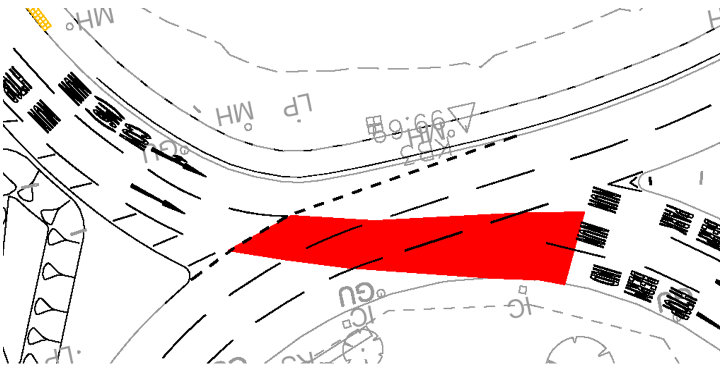
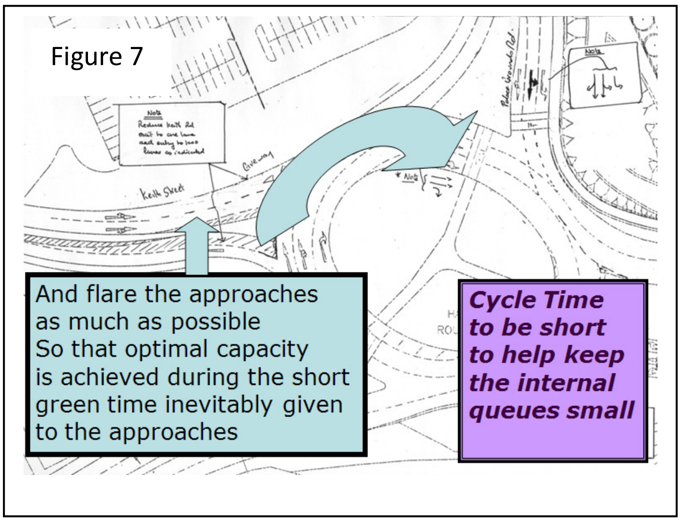


Figure 6
Griff Roundabout UK

Cycle Time needs to be kept short and the Roundabout Approaches often need to be Flared



In a signalled roundabout there is usually limited internal queuing space. To keep internal queuing to a minimum, the cycle time must be kept short and most of the green time at each entry must be given to the internal roundabout arms rather than the entry arms. Accordingly, the entry arms need to be flared so that they can achieve multilane discharge for the short period of green time that they are awarded. It is a fact that nearly all signalled roundabouts will work at cycle times of 60" or less.

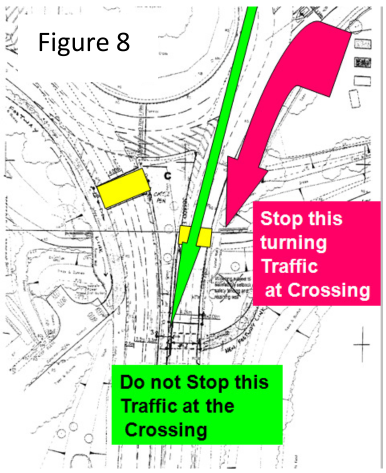
What Saturation Flow, and Cruise Speeds should you assume?

A good guide, proven through use of these values for many signaled roundabouts designed and implemented throughout the UK and also adopted for the three NZ roundabouts designed by the lead author are:-

Cruise Speed - Assume 10m/s for small roundabouts (Inscribed diameter < 60m say); and
Assume 12m/s for larger roundabouts (inscribed diameter > 60m say)

Stopline Saturation Flow: Assume 1900 pcu/hr everywhere and model every lane separately. Note that the nature of spiral marked roundabouts is that you will never have occasion to model any internal roundabout lanes as though flared lanes. Also you must never model more than one internal roundabout lane as a multi-lane link. This will give, on almost every occasion, an incorrect and 'too-generous' capacity prediction.

Safety - At Roundabout Exit Crossings, who should be stopped?



It is generally safest to 'hard-link' exit crossings to the roundabout, i.e. include them in the linking plan. The linked timing must endeavor to achieve:-

- Traffic leaving the roundabout gyratory (usually at speed) is never stopped; and
- Accordingly, stop the newly entering traffic turning left – this will generally be travelling much slower.

Visibility for turning traffic will need to be carefully considered here. The lead author's preference is that the exit crossing be placed as far into the exit as possible, a personal preference is for about 40m plus.

Safety – Who should be stopped within the roundabout?

For safety, you want to derive timings that ensure, where possible, that newly entering traffic is never stopped at the first gyratory stopline after entry.

Safety – Signal Head See-Through

This is often a problem at small signalled roundabouts and great care must be taken to minimise the possibility of driver confusion and hence potential accidents. Choice of equipment, angling, louver shuttering and setting of the signal timings can be critical to safety. That said, the author managed to fully signal a 48m diameter roundabout in East Kilbride, Scotland (Mavor roundabout) and more recently signal all but one arm at the equally small Welcome Bay roundabout, North Island, New Zealand. On small roundabouts, it is important for stopped drivers on an approach never to see the next set of stoplines newly turn green before they receive green.


Figure 9 Mavor Rbt, East Kilbride, Scotland

The roundabout opposite is the Mavor roundabout, the middle roundabout of a series of three signalled roundabouts along the East Kilbride corridor, Scotland.

To the north and south of this roundabout lie the Nerston and Whirlies roundabout. NZTA consulted Councillors at South Lanarkshire Council about these roundabouts, when considering implementation of this methodology in NZ for the first time at Welcome Bay.

Mavor roundabout, at 48m inscribed diameter, required an innovative 'release one arm at a time in an anticlockwise direction' type of approach to get a working solution and was the subject of a paper by the lead author presented at the JCT UK Signals Conference at Nottingham University, September 2005 *(ref: 'Doing it Backwards! An innovative Signal Control Solution for A Very Small Roundabout in East Kilbride).* A copy of this paper may be downloaded from www.jctconsultancy.co.uk / publications. By running each arm separately in an anticlockwise direction, the next arm to receive green is able to start early so that this traffic reaches the running arm at exactly the intergreen time after it has received red. In this way, some of the inefficiency of having to run each arm separately in turn is offset by effectively removing all the 'lost time'. It must be pointed out that the origin-destination pattern of traffic at this particular roundabout was such that a more traditional method of control could not have produced a working solution. A Paramics movie of this roundabout in operation will be shown at the presentation.

Lane/Flow Diagrams and their use to create Working Design Options

A Lane/Flow diagram is a diagram that plots the path taken by each origin-destination platoon of traffic that enters a roundabout and passes through it to an exit, following the prescribed lane marking. When completed, the Lane/Flow Diagram allows you to see if the proposed lane marking is 'efficient' or 'inefficient', and most importantly, whether the proposed roundabout layout, if signalled, will 'Work' or 'Not Work'. For example, returning to our A4174/A420 roundabout east of Bristol, the Lane/Flow Diagram for the existing priority design (Figure 11) is s shown in Figure 12 for the AM Peak period.

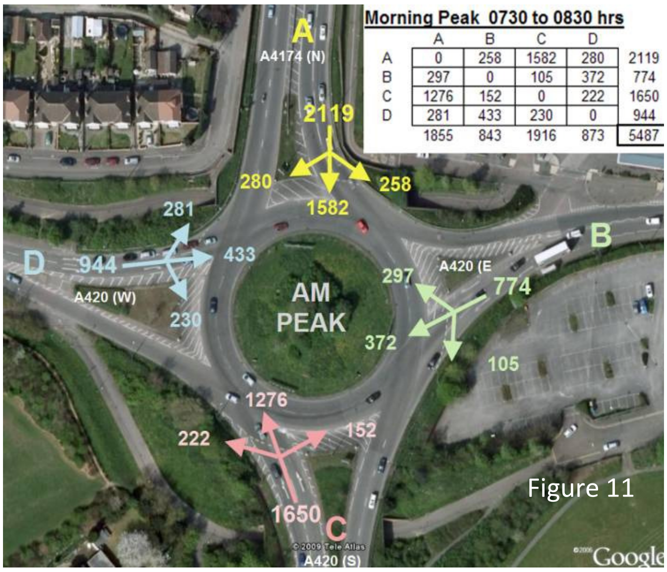


Figure 11

Because each signalled junction on a roundabout is simple 2-stage, basic traffic theory allows us to 'see' if the design represented by the Lane/Flow Diagram will work – i.e. can all the entries function at less than 90% deg of saturation? By calculating Lane Flow Summation Values (LFS) at each signalled entry node, and provided these are at or less than the THRESHOLD LFS value of 1500 pcu/hr, then the design has a good chance of 'working'. LFS is the sum of the worst lane flow on the entry (after accounting for flare usage if flares are present) and the worst Lane Flow on the gyratory.

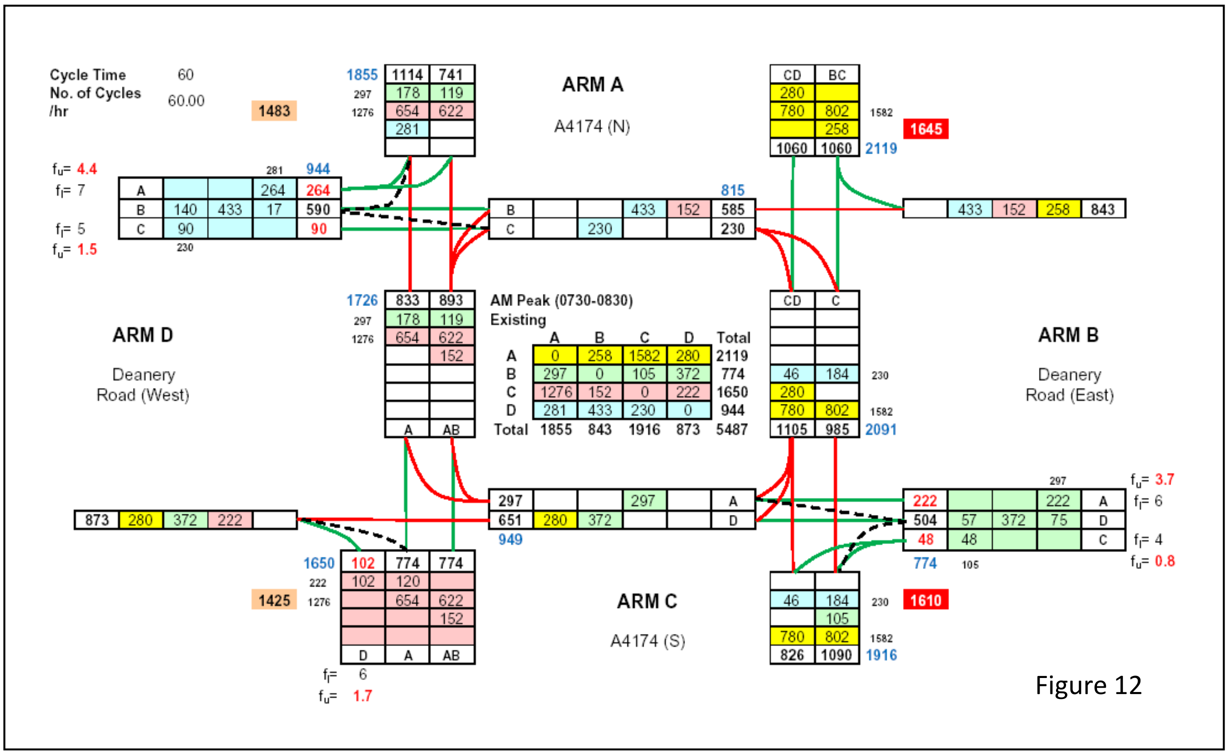


Figure 12

The LFS threshold value of 1500 pcu/hr assumes a 60” cycle, 1900 Saturation flow and 5” intergreens and is derived from the simple traffic theory relationship (S*D*(C-L)/C) where C is the cycle time, S is the saturation flow, L is the Lost Time (i.e. sum of the intergreens - 2”) and D is the desired maximum degree of saturation. Figure 12 Lane/Flow Diagram clearly indicates that if signals were simply installed on the existing layout, the resulting roundabout would ‘not work’ in the AM peak, as Arms A and B, with LFS values of 1645 and 1610, respectively, are well over the threshold value of 1500 pcu/hr, and accordingly, they would be overloaded with degrees of saturation well above 90%. The Lane/Flow for the PM peak indicated that only Arm B would be in trouble, with an LFS value of 1642.

Thus a simple Lane/Flow Diagram enables us to ‘see’ right away, that we have not got a ‘working design’ and therefore there is no point at this stage wasting anymore of our own or our Client’s time (and money) proceeding to use software to evaluate it! Instead, we can now use the Lane/Flow Diagram itself to direct us towards working design options. Our choices are, to:-

- add additional short flare lanes on the approaches;
- add short 2 to 1 or 3 to 2 merge lanes on the exits;
- add additional lanes on the gyratory sections; and/or
- re-route one or more movements through the central island itself.

Accordingly, it soon became evident for this roundabout that the design layout shown in Figure 13 was required to give both a working solution now, and afford an up to 10 year life before arms would once again become overloaded. A cycle time of 50” was adopted and Arm B was left as giveway. Note that the LFS values at problematical arms A and B have been reduced below the 1500 pcu/hr level by the addition of lanes on the gyratory sections, on the north and southern approaches and on the arm B exit.

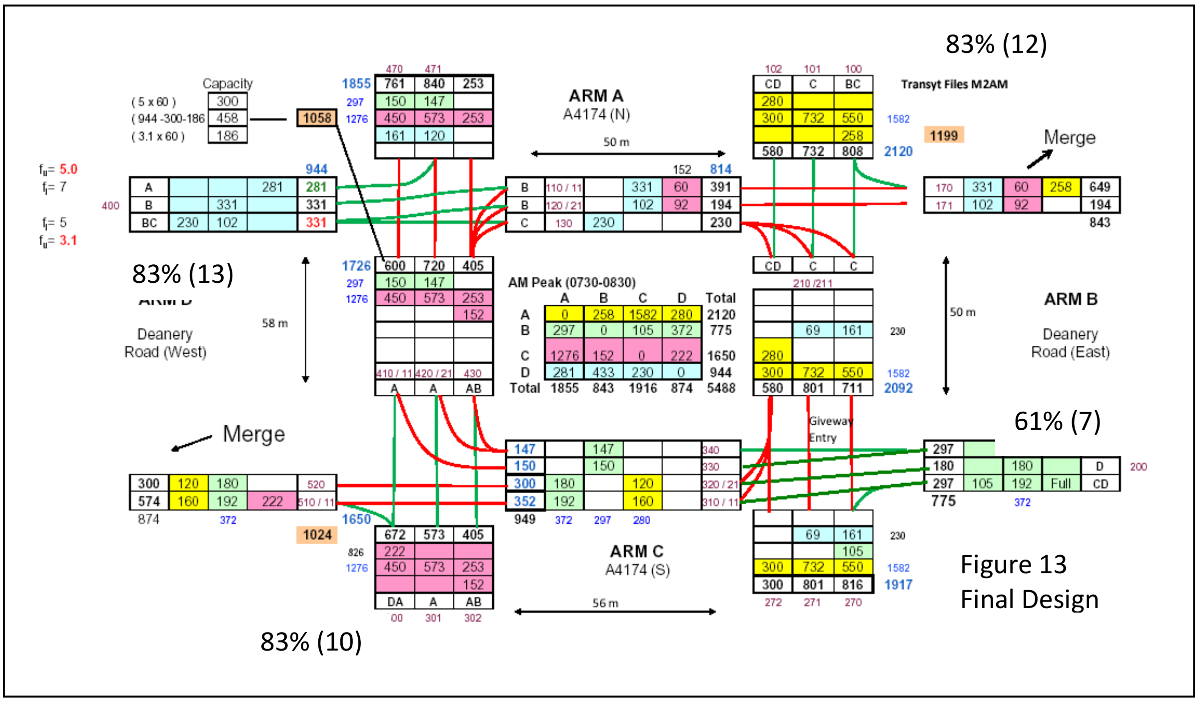


Figure 13
Final Design

The above final design and optimum operational timings were produced using the JCT LinSig software. The Lane/Flow Diagrams illustrated above use the Microsoft Excel program. This is purely for teaching purposes. Lane/Flow diagrams are created automatically by the JCT LinSig software as you model build and explore various design options.

A Paramics movie was produced post-design to show local Councilllors how the proposed design would work. This will be shown during the presentation of this paper and copies will be made available for interested parties.

Lane/Flow Diagram methodology may be used to also improve the operational efficiency of existing, but poorly performing signalled roundabout designs. They do this by immediately indicating whether or not the existing lane direction marking is 'optimum' and/or whether additional approach flaring or gyratory section widening is required.

Examples of successful and/or just-about to be implemented JCT signalled roundabout designs are:-

- M25 Junction 14 near Heathrow airport UK;
- Whirlies, Mavor and Nerston roundabouts, East Kilbride Corridor, Scotland UK *(ref: Doing it Backwards: An innovative Signal Control solution for a very small roundabout in East Kilbride, JCT Signal Symposium, Nottingham, September 2005)*;
- Hamilton Roundabout, Scotland UK *(ref: Signalled controlled roundabouts: Breaking the Rules: JCT UK Signals Symposium, Nottingham, September 2002);*
- Bardills Roundabout, Nottingham UK - this is a partial 'through-about design' (see Figure 14) conducted in association with AmScott UK and winner of an Institute of Civil Engineers design award *(ref: Cutting Corners at Bardills – an innovative signal controlled roundabout solution, JCT Signal Symposium, Nottingham, September 2006);*
- Griff Roundabout Warrington UK (currently under construction- ref Figures 3 and 6)
- Deanery Rd A4174/A420 Roundabout South Gloucestershire UK (currently under construction)
- Welcome Bay Roundabout, Tauranga, North Island, NZ, commissioned December 2008
- Maungatapu Roundabout, Tauranga, North Island, NZ, commissioned December 2008
- Brookfield Intersection, North Island, NZ, commissioned April 2009.

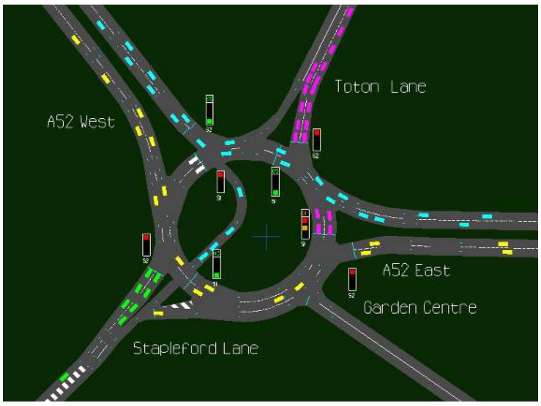


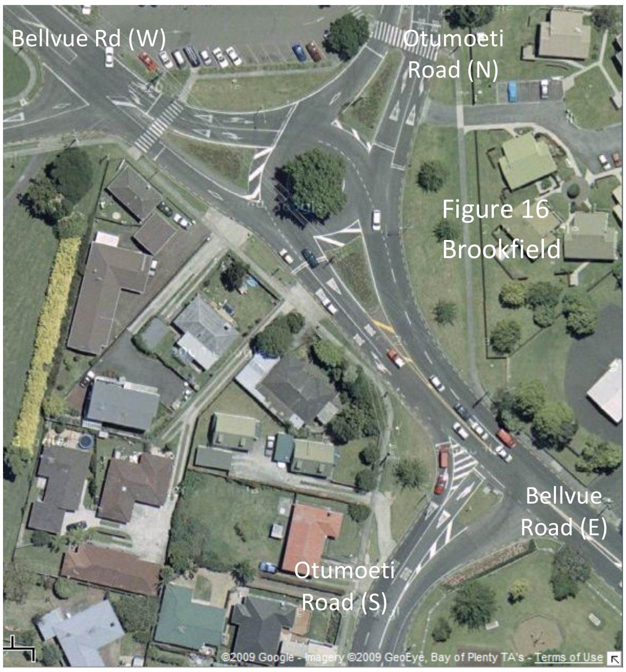
Figure 14
Bardills Signalled Rbt

Copies of the above papers may be downloaded from www.jctconsultancy.co.uk / publications.

Paramics movie demonstrations for Mavor and Bardills roundabouts will also be demonstrated at the presentation (time permitting).

Introduction of Signalled Roundabout Design Methodology at Welcome Bay, Maungatapu and Brookfield Intersections, Tauranga, North Island, New Zealand

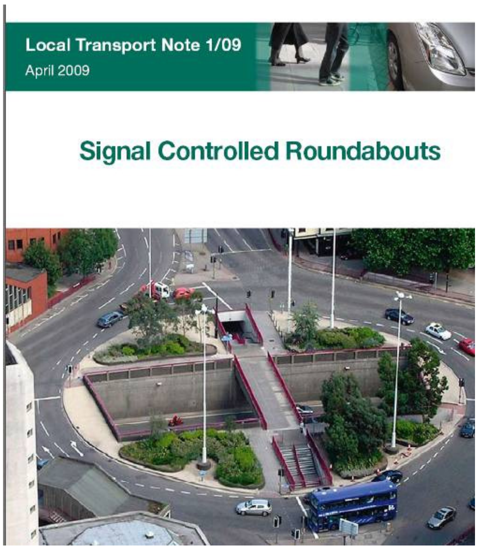
Background: Following the highly successful implementation of the three signalled roundabouts, Whirlies, Mavor and Nerston on the East Kilbride Corridor, the South Lanarkshire officer responsible for commissioning this design work emigrated to NZ taking up a post with NZTA, Tauranga. One of his early responsibilities was to seek more affordable solutions for the highly congested Welcome Bay Corridor.



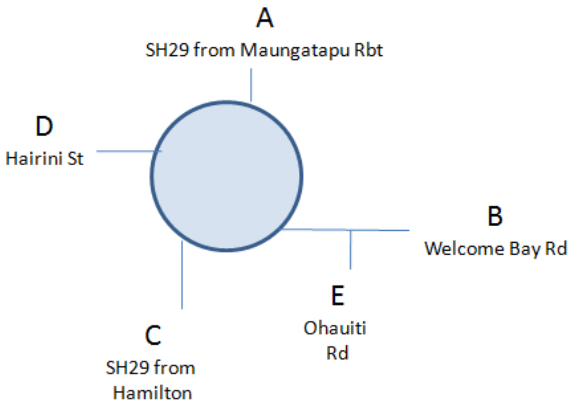
Recognising the similarity with problems prevalent but solved along the East Kilbride corridor, NZTA requested that I travel over to Tauranga, examine the problem, and suggest whether signalled roundabouts could offer a less expensive solution than the already proposed grade separation at Maungatapu and a tunnel solution at Welcome Bay. The original Welcome Bay Roundabout had only a 36m inscribed diameter and a closely associated Tee junction sited only 40m distance from the roundabout on the Welcome Bay Road approach. At the time, i.e. November 2006, there were no signal controlled roundabouts, and therefore no experience of signal controlled roundabouts, in NZ. The subsequent success of implementing the first two permanent signalled roundabouts at Welcome Bay and Maungatapu, both of which were designed, built and commissioned in under two years, led to a further invitation to JCT, this time by Tauranga City Council, to resolve a serious congestion problem at Brookfield intersection (see Figure 16). Our solution, which we thought of as a 'dumb-bell' or 'bone-about', was immediately nicknamed the 'peanut' by NZ engineers. However, following its successful implementation in April 2009, the press gave it the nickname 'Jelly Bean', and 'Jelly Bean', it has been ever since! All three signal controlled designs were produced using the JCT LinSig software. Welcome Bay and Maungatapu roundabouts were switched on for the first time on the 17th and 22nd December 2008, respectively. The Brookfield Jelly Bean was commissioned the week before Easter and switched on for the first time on Thursday 2nd April 2009. *(No one was quite brave enough to switch on something called the Jelly Bean on April Fool's Day)!*

Tyco, type Eclipse Traffic controllers were used at all three sites. These have an excellent history running the SCATS (*Sydney Coordinated Adaptive Traffic System*) responsive traffic control systems throughout many major cities in the world. However, they presented an interesting challenge for NZ Signal Control specialist Ross Thomson to get them to mimic UK type CLF time-of- day plans.

The remaining sections of this paper describe the successful application of the above design methodology (now formally recognised in the UK *Department for Transport Local Transport Note 1/09 Signal Controlled Roundabouts)* at Welcome Bay, Maungatapu and Brookfield. The interesting challenge each presented both prior to, at and post- implementation is also discussed.



Welcome Bay Roundabout



Pre-Signal Performance: Regular and severe congestion occurred on the Welcome Bay approach (Arm B) in the AM peak period and on the northern SH29 approach (Arm A) in the PM peak period. The latter regularly led to block-back to the Maungatapu roundabout, causing serious congestion in the PM peak there also.


Looking down towards the Welcome Bay Road approach (i.e. Rbt on RHS) in the AM Peak


Looking towards WB Rbt from Maungatapu Rbt in the PM

Derivation of a 'Working' Design: Lane/Flow analyses were used to determine a 'best' working layout. At 36m inscribed diameter, it was obvious from the start that the current 'size' of the roundabout would have to increase. Land within the highway boundary was available to the north and south, and a little to the west, but was severely constrained in the north-east, and eastern sections by the presence of a Maori graveyard and commercial garden centre. The answer was to 'elongate' and reduce the width of the central island, flare to three lanes on the north and south approaches, and increase the west and east gyratory sections to three lanes. The nearside lane on the northern approach and eastern gyratory was designated a dedicated left-turn lane for Welcome Bay. Hairini Street was left as giveway.

Originally, at the intersection of Welcome Bay Road with Ohauiti Road, there was a full length controlled pedestrian crossing on the Welcome Bay Road approach. To get a working design, it was also necessary to change this to a split 'walk with traffic' design. Despite our best efforts we could not get permission to advance the eastbound stopline to within 3m of the north side of the split crossing. Local safety auditors felt that this was unsafe and that this stopline should remain adjacent to the stopline for right-turn traffic into Ohauiti Road.

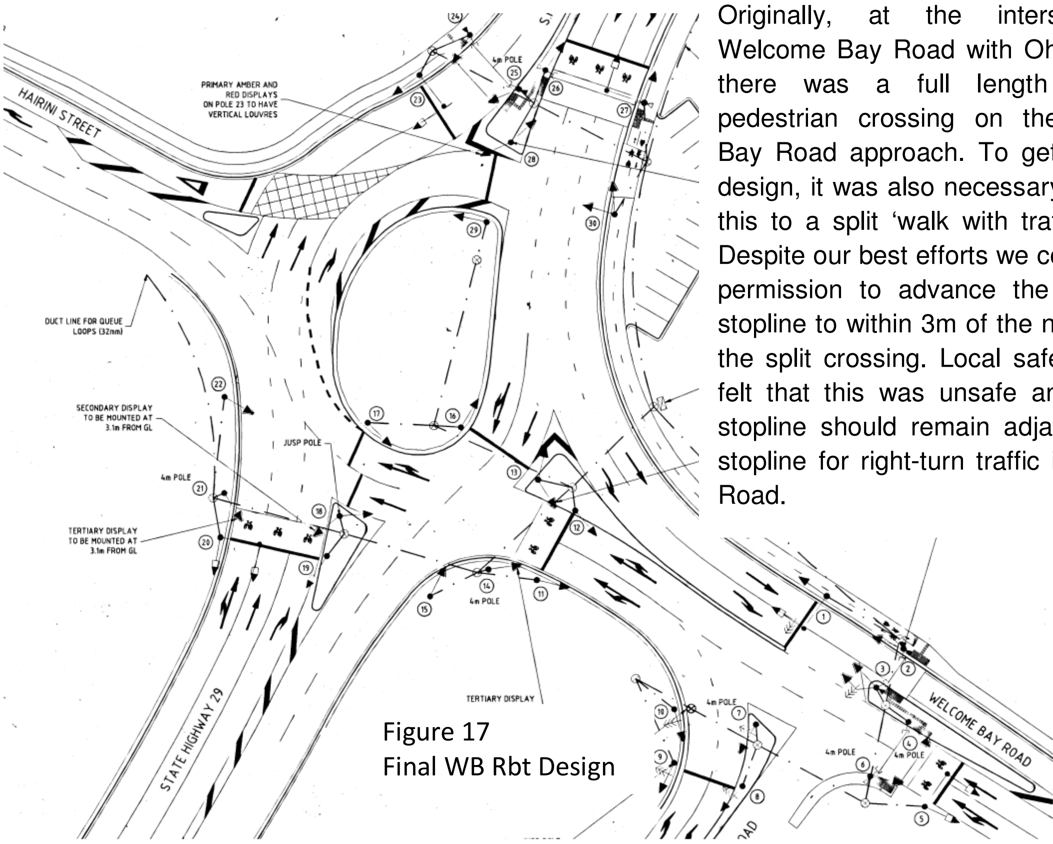


Figure 17
Final WB Rbt Design

You can view the Welcome Bay Roundabout In operation on the Tauranga City Council Web Cam (Site 7) at: www.trustpower.co.nz/TrafficCam.

The still pictures refresh every 30".

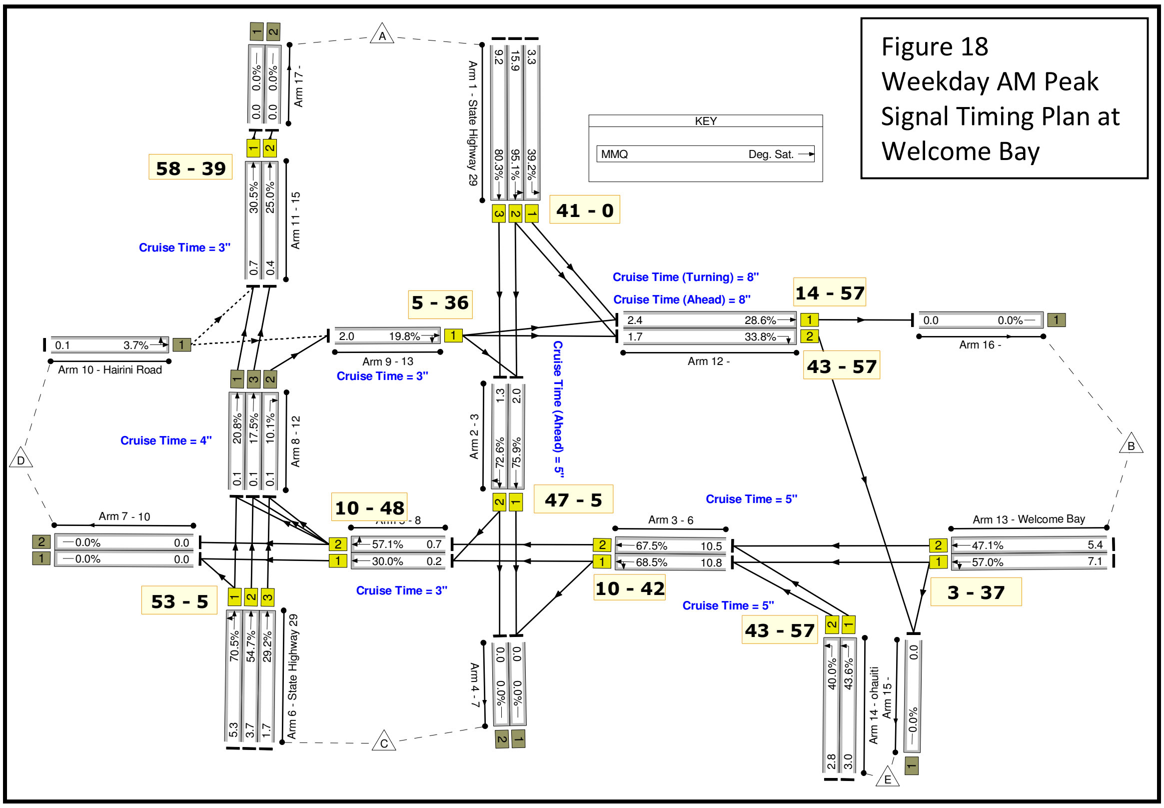
AM Peak - Number Plate Survey 2007

	A	B	C	D	E	Tot
A	0	236	933	0	122	1291
B	187	22	336	513	78	1136
C	416	83	18	60	10	587
D	10	0	10	0	0	20
E	125	48	10	170	10	363
Tot	738	389	1307	743	220	3397

PM Peak - Number Plate Survey 2007

	A	B	C	D	E	Tot
A	0	863	657	0	289	1809
B	104	30	270	237	93	734
C	615	241	10	123	10	999
D	28	11	27	0	10	76
E	81	132	10	87	10	320
Tot	828	1277	974	447	412	3938

WB Signal Control in Operation: The LinSig CLF Plan for the AM peak period at WB is as follows:-



Essentially, the mode of operation is as described below and illustrated overleaf. Although there is a 12" stagger in start-up times, traffic from the north and south broadly runs together with right-turns from each stopped within the gyratory. The right-turn movement from the north, was, at the time of design, minimal (about 1 pcu/cycle according to traffic count data). While these two movements are running, traffic from the side road, Ohauiti Rd (Zone E), also receives green and cars from here proceed into the empty reservoir between Welcome Bay Rd stopline and the stopline at the roundabout on this approach. The right-turn movement from Ohauiti Road is banned and traffic wishing to turn right to Welcome Bay must u-turn at the Welcome Bay roundabout. The timings ensure that no traffic from the north is caught at the next gyratory stopline. On closure of the North/South Traffic, the Welcome Bay Road traffic is released. The first gyratory stopline for this traffic goes green at the same time as the Welcome Bay approach stopline. In our original design, we achieved further capacity gains if this gyratory stopline started 3" later. However, at commissioning, it became clear that 'nobody would move' until they saw the next stopline primary signal head go green! Once again, the closing times ensure that the reservoir between Welcome Bay Road and the roundabout is left empty ready to receive Ohauiti Road traffic at the start of the next cycle. **Commissioning:** Thunderstorms, refusal to move on green, traffic cones not removed in time, red light jumping, a major city accident necessitating the re-routing of several thousand additional vehicles via Welcome Bay without informing us, are but a few of the events that assailed us on commissioning day – definitely not a job for the weak hearted ! However all was soon resolved, the events giving JCT a chance to show off the LinSig software's versatility and speed which allowed the lead author to rapidly come up with emergency plans to more rapidly clear the very large queues that built up as a result of the accident-related re-routed city traffic.

As the Bay of Plenty Times put it so quaintly the next day "Traffic this morning from the Welcome Bay area was flowing like a runny nose". Since commissioning on 17th December 2008, Ross Thomson, the NZ signal control specialist assigned to this project, managed to also link timings between the two roundabouts, favouring primary movements in the AM and PM peak periods.

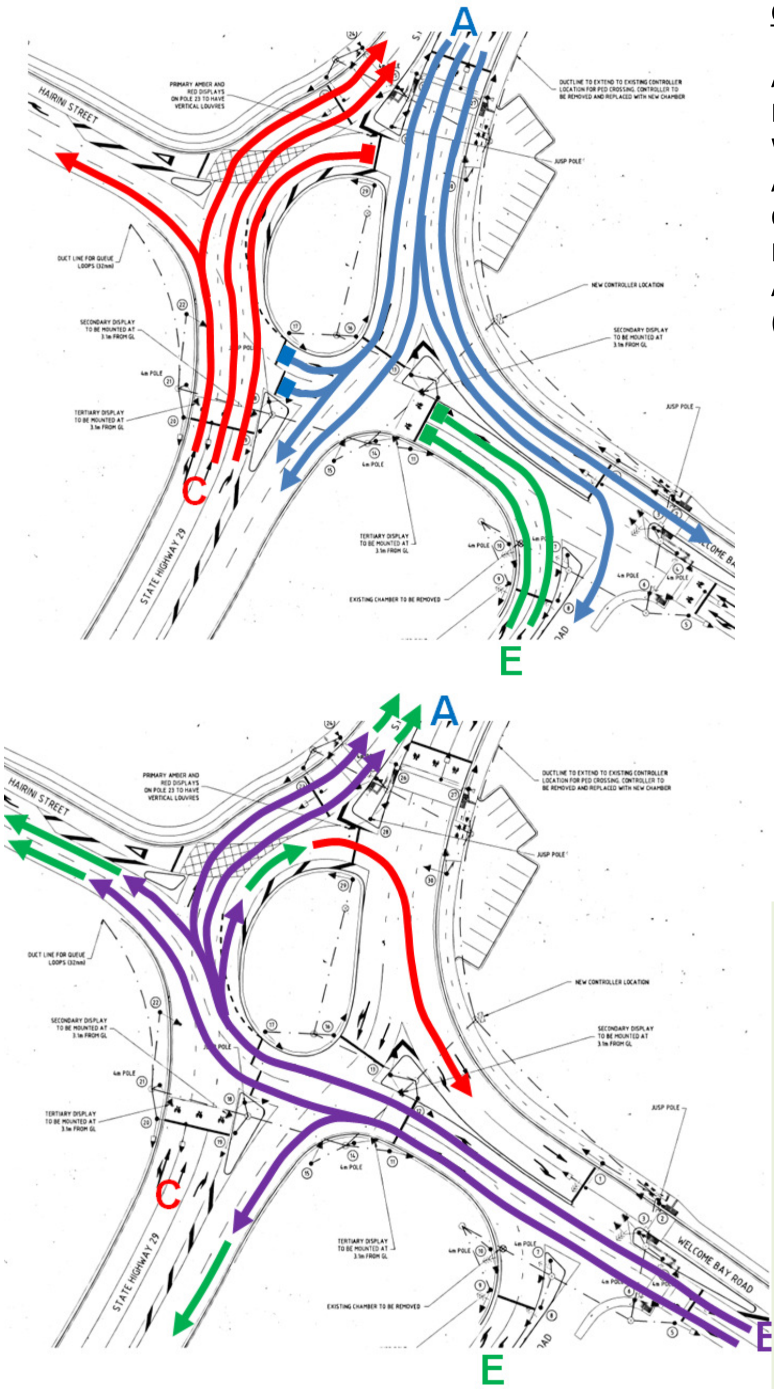


Figure 18
Traffic Progression through the Linked Signals at Welcome Bay

Cycle Times were as follows:-

AM and PM peak	60"
Post AM and Pre-PM Peak	50"
Weekday Mid-Day	40"
After 1845 hrs	40"
Overnight	35"
Number of CLF Plans	8

Advised CLF Plan Schedule
(Code 8 = Weekday, Code 13 = Weekend)

Schedule	Code	Time	Plan
1	8	0600	1
2	8	0930	3
3	8	1030	4
4	8	1400	5
5	8	1545	6
6	8	1845	9
7	8	0030	8
8	13	600	3
9	13	1030	2
10	13	1500	6
11	13	1845	9
12	13	0030	8

Bay of Plenty Times Thursday December 18th 2008 – Day after Commissioning

by John Cousins
cousins@bopp.co.nz

"It was flowing like a runny nose."

This was the enthusiastic response of Welcome Bay resident Pamela Decke to the second day of the roundabout's new traffic lights.

Traffic flowed freely through the Welcome Bay roundabout this morning and she cruised virtually unhindered to work at the peak of the rush hour this morning.

Maungatapu Roundabout

Pre- Signal Performance: Significant congestion occurred on the SH2 from Tauranga City, and also on SH29 from Mount Maunganui in the PM peak period. This congestion was often exacerbated by block-back from the Welcome Bay Roundabout. Queuing was also significant on the Maungatapu Road approach in the AM peak period.

Derivation of a 'working' design: Maungatapu roundabout is a much larger roundabout than Welcome Bay (120m / 92m inscribed diameters) and accordingly it was much easier to find a working solution. Lane/Flow analyses quickly identified a 'best' design which necessitated widening Arms B and D, and also the north gyratory section from 2 to three lanes. Optimum direction lane marking was also quickly established from the Lane/Flow Diagrams for the weekday AM and PM peak periods. From the very start it was 'obvious' that Arm C, from Maungatapu, should be left as giveway. Residents using this approach were particularly concerned, since under the current priority regime, they regularly suffered significant delay in the AM peak. However, immediately following commissioning, they 'honked' their approval at the large gaps afforded for egress by the new signal control regime.

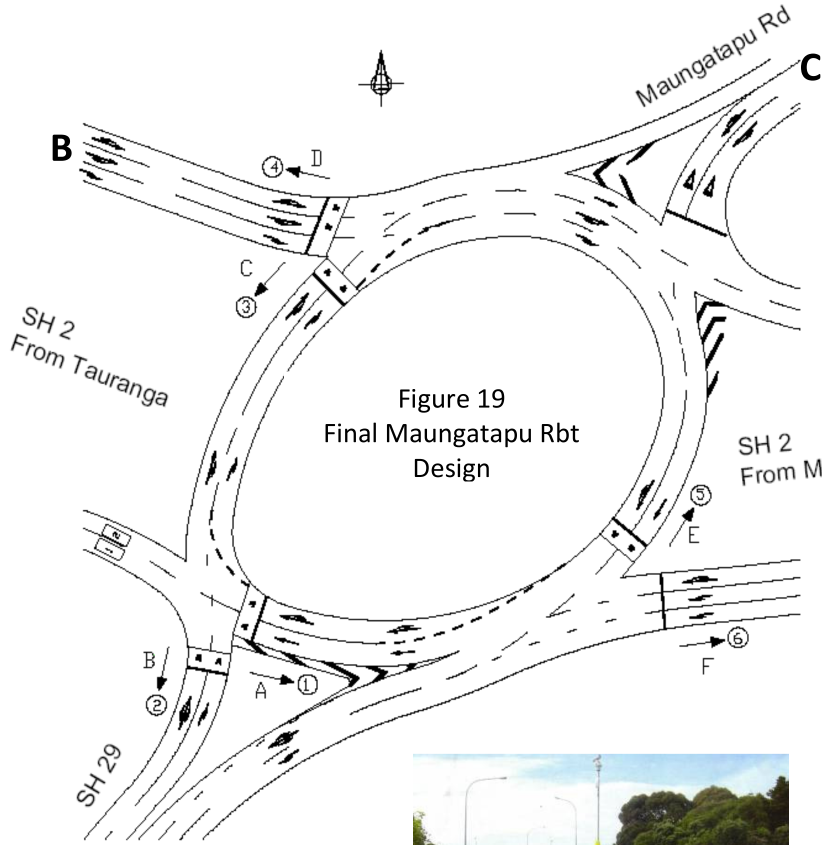


Figure 19
Final Maungatapu Rbt Design

AM Peak - Number Plate Survey 2007

	A	B	C	D	Tot
A	0	10	147	589	746
B	317	22	57	328	724
C	215	217	10	14	456
D	759	472	10	16	1257
Tot	1291	721	224	947	3183

PM Peak - Number Plate Survey 2007

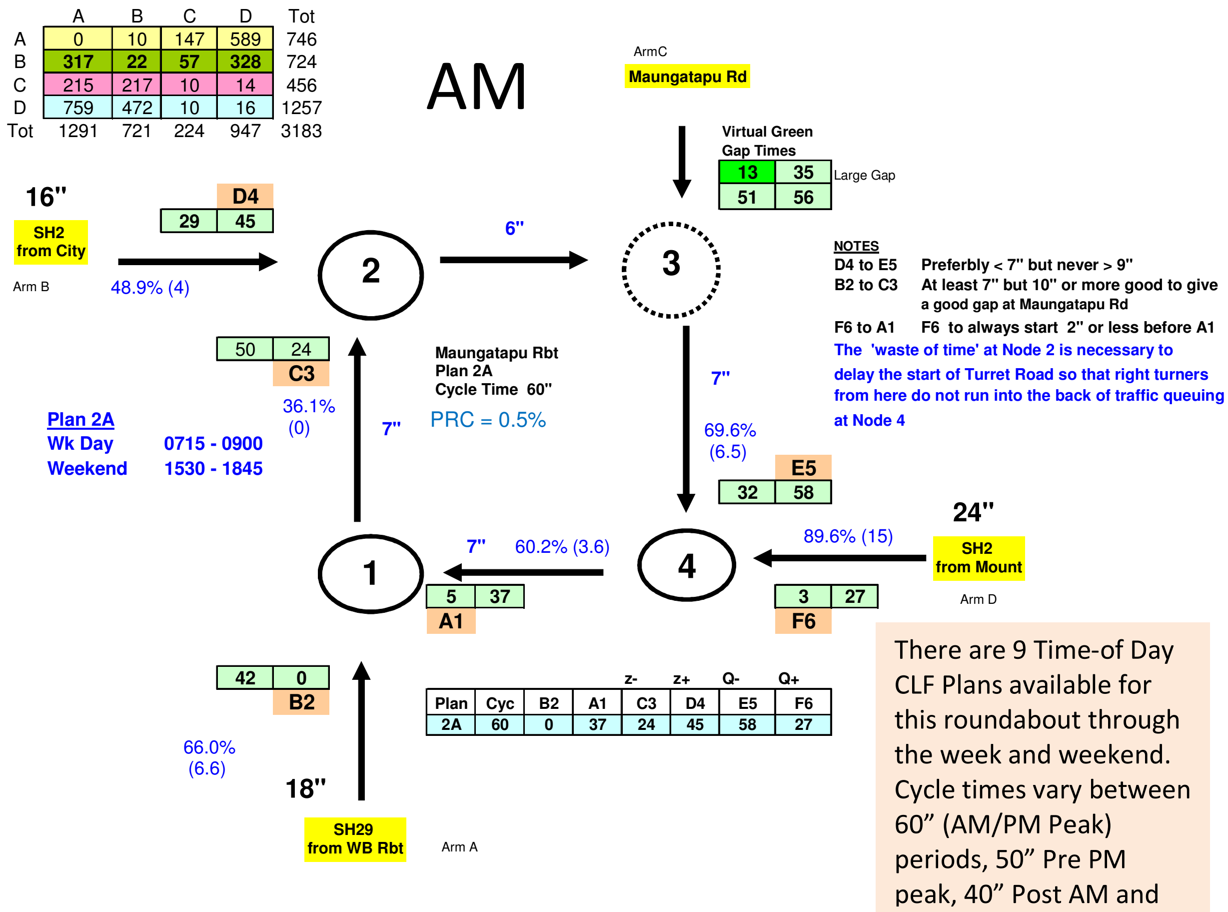
	A	B	C	D	Tot
A	0	10	76	751	837
B	902	20	73	691	1686
C	145	87	10	10	252
D	762	269	10	10	1051
Tot	1809	386	169	1462	3826

Signal Control in Operation: This is illustrated below for the AM peak period. A particular feature to note is that there is about 22" (AM Peak) and 10" (PM Peak) of wasted green time purposely introduced at the Arm B (SH2 from Tauranga city) gyratory stopline *(i.e. the last car from the SH29 Welcome Bay approach will pass the SH2 (City) stopline at about 7". The SH2 (City) approach does not receive green until 29", some 22" later).* This 'wasted green time' serves two purposes:-

- It affords large gaps for egress of the Arm C traffic from Maungatapu Road; and
- It ensures that the right-turning traffic from Arm B does not arrive too soon at the Arm D gyratory stopline. The timings ensure that as this traffic approaches the Arm D Gyratory stopline, that the back of the previous queue (i.e. gap-takers from Maungatapu Road) are already 'on the move').

Maungatapu roundabout favours a 50" Cycle time in the AM and PM peak periods. However this was increased to 60" to afford linkage with the Welcome Bay roundabout downstream, which needs to run at 60" in both peak periods.

Commissioning was uneventful *(other than for the elderly gentleman who decided to turn immediately right from the offside lane on the Arm B entry!).* Smooth progression was immediately evident and most of the time everyone got through in the first cycle. The hitherto congestion problem appeared to 'disappear', virtually overnight!



	A	B	C	D	Tot
A	0	10	147	589	746
B	317	22	57	328	724
C	215	217	10	14	456
D	759	472	10	16	1257
Tot	1291	721	224	947	3183

				z-	z+	Q-	Q+
Plan	Cyc	B2	A1	C3	D4	E5	F6
2A	60	0	37	24	45	58	27

There are 9 Time-of Day CLF Plans available for this roundabout through the week and weekend. Cycle times vary between 60" (AM/PM Peak) periods, 50" Pre PM peak, 40" Post AM and

The Brookfield "Jelly Bean"

Pre-Signal Performance: This intersection comprised a mini-sized roundabout at the western end and Tee Junctions to the west and east at Millers Road and Otumoeti Road (S). The site was very congested in the peak periods with many opposed movements. In both peak periods pedestrians complained bitterly about how difficult and dangerous it was to cross at this intersection. The decision by Tauranga City Council to seek a signal controlled solution was taken primarily to address the pedestrian safety and accident issues. The pedestrian flow at this intersection is particularly high at school start and end times (there is primary school on Millers Road). Pedestrian flow is also significant throughout the day and at weekends due to the presence of shops on the north-west quadrant.

Derivation of a 'working' design: Lane/Flow analyses was a secondary issue for this project in that within minutes of looking at the AM and PM peak period origin-destination matrices, the optimum design virtually presented itself!

AM Peak (0745 - 0845) Year 2007

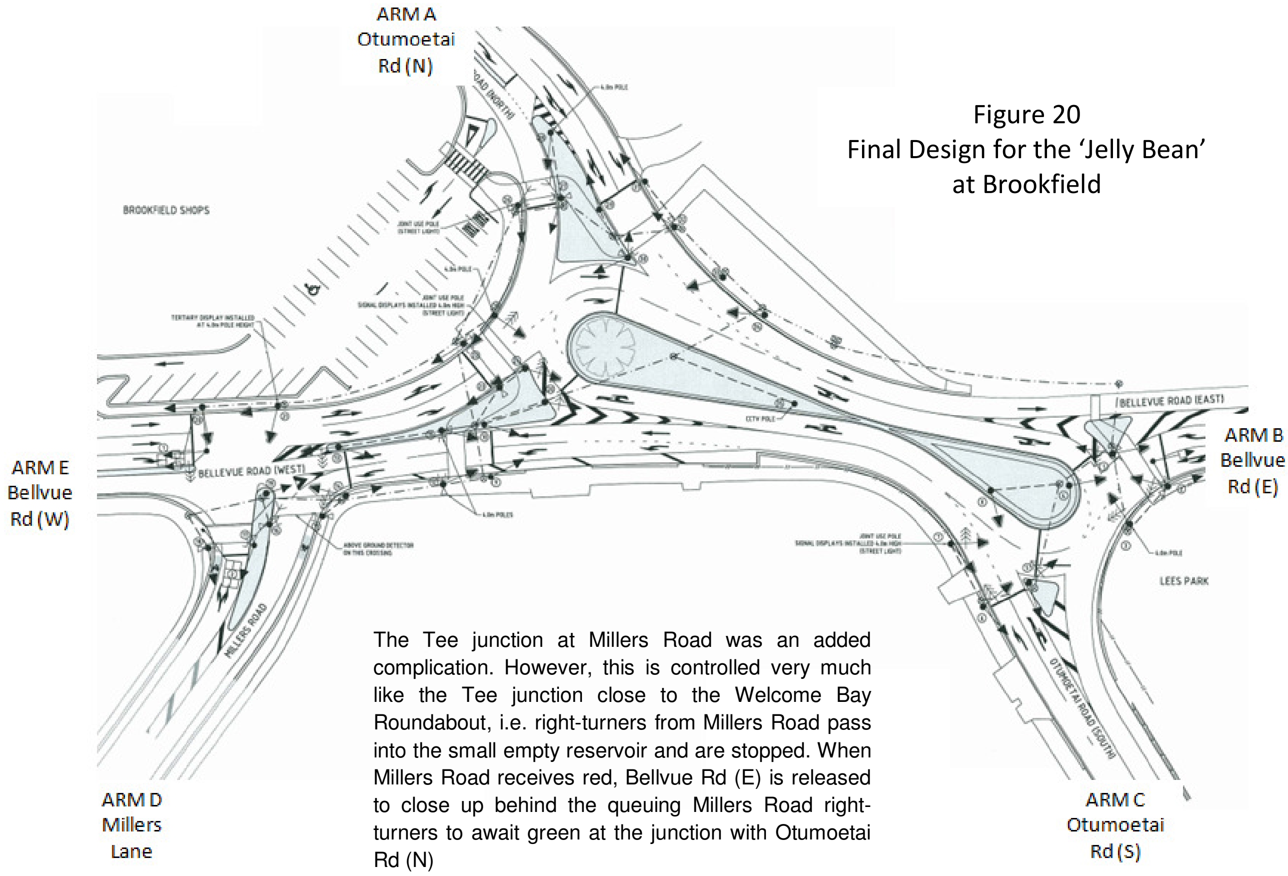
	A	B	C	D	E	F	Total
A	0	469	411	80	10	0	**970**
B	232	0	72	58	179	0	**541**
C	271	4	0	81	208	0	**564**
D	64	110	84	0	103	0	**361**
E	102	183	140	50	0	10	**485**
F	18	89	17	16	0	0	**140**
Total	**687**	**855**	**724**	**285**	**500**	**10**	**3061**

PM Peak (1630 - 1730) Year 2007

	A	B	C	D	E	F	Total
A	0	321	201	162	10	0	**694**
B	506	0	96	111	272	0	**985**
C	325	3	0	76	152	0	**556**
D	66	73	46	0	87	0	**272**
E	119	178	112	81	0	15	**505**
F	24	88	57	40	0	0	**209**
Total	**1040**	**663**	**512**	**470**	**521**	**15**	**3221**

In the AM peak – only 90 of the 970 pcus approaching Arm A want to travel to Arms D and E and only 4 pcus want to turn right from Arm C. In the PM peak, only 170 of the 694 approaching Arm A want to travel to Arms D and E and only 3 pcus want to turn right from Arm C. This immediately indicated that an elongated single signal controlled roundabout was an obvious choice and accordingly, the 'Dumb-Bell' shape (see overleaf) soon appeared beneath JCT Brian Simmonite's pencil!

Figure 20
Final Design for the 'Jelly Bean' at Brookfield

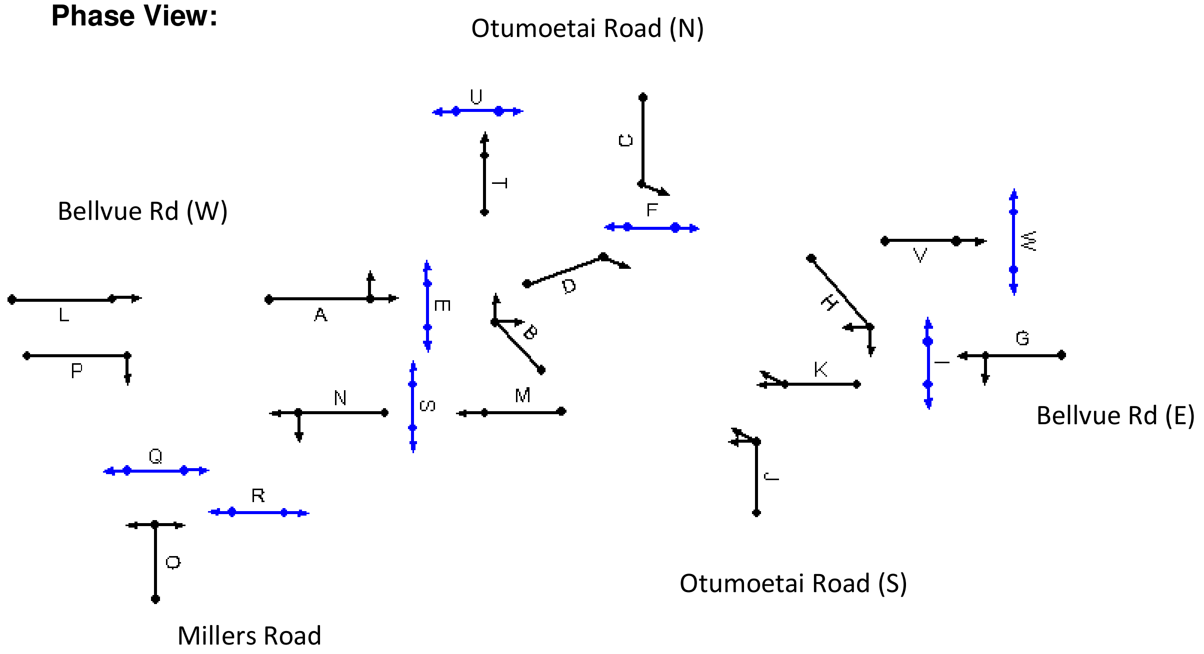


The Tee junction at Millers Road was an added complication. However, this is controlled very much like the Tee junction close to the Welcome Bay Roundabout, i.e. right-turners from Millers Road pass into the small empty reservoir and are stopped. When Millers Road receives red, Bellvue Rd (E) is released to close up behind the queuing Millers Road right-turners to await green at the junction with Otumoetai Rd (N)

Signal Control at Brookfield in Operation (UK signal terminology assumed)**:**

The LinSig Model

Phase View:



Streams: In the LinSig model, a single controller operates the following six streams

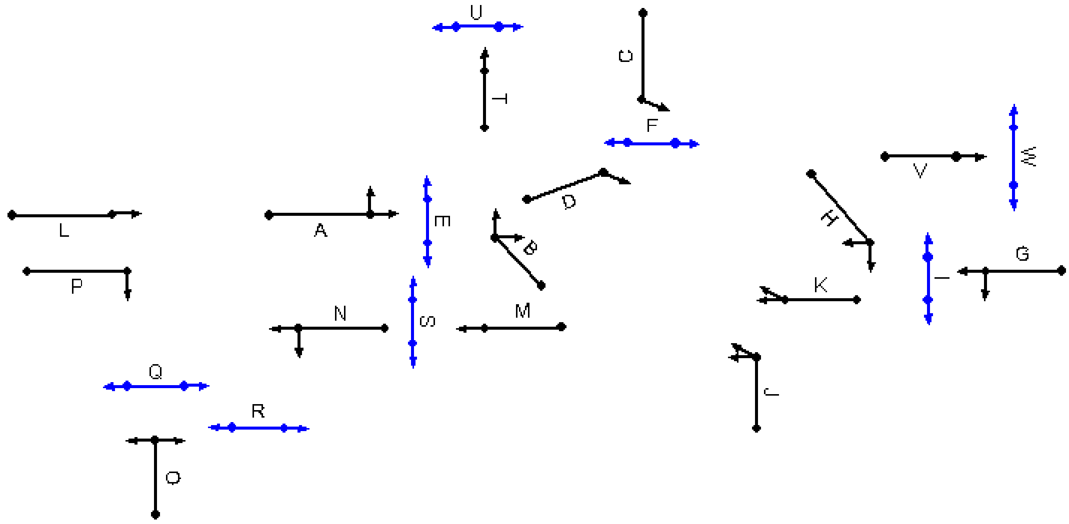
Stream	Stream Phases
1	ABCDEF
2	GHI
3	LMNOPQRS
4	JK
5	TU
6	VW

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
A		5			5																		
B	5																						
C				6		5																	
D			5																				
E																							
F																							
G								5	5														
H							5																
I																							
J											5												
K										5													
L															5								
M																			5				
N															5	5		5					
O												5		5		5	5						
P													6	6	5			7					
Q																							
R																							
S																							
T																					5		
U																				7			
V																							5
W																						7	

Please note that Stream 6, i.e. Phases V and W, have not yet been invoked on site. These are intended to control a future proposed exit crossing on Bellvue Rd (E).

Special Design Features of the Brookfield Signal Control (Please note that text below assumes UK signal terminology)

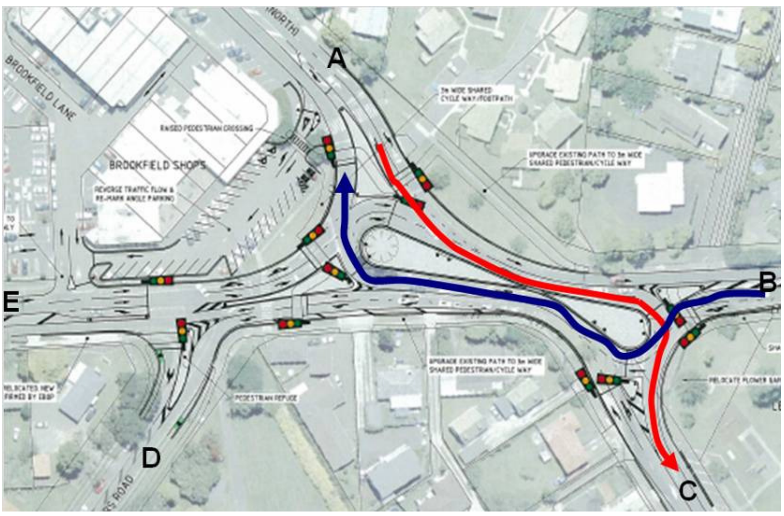
With respect to the phases, the following associations need to be maintained:-



In terms of UK Phase names:-

- G and K must start at the same time (safety issue)
- K must shut down at 3 or more seconds after G (to ensure clearout of traffic on G)
- C and B need to close at the same time (NZ Controller Programming Issue)
- H and J need to terminate at the same time (Controller Programming issue)
- L and P need to start at the same time (Safety Issue – no splitter island)
- L and N need to terminate at the same time (Controller Programmed)
- N is to close down 2" after M (to ensure clear-out of traffic on M)
- N is to start at the same time as M (Safety Issue)

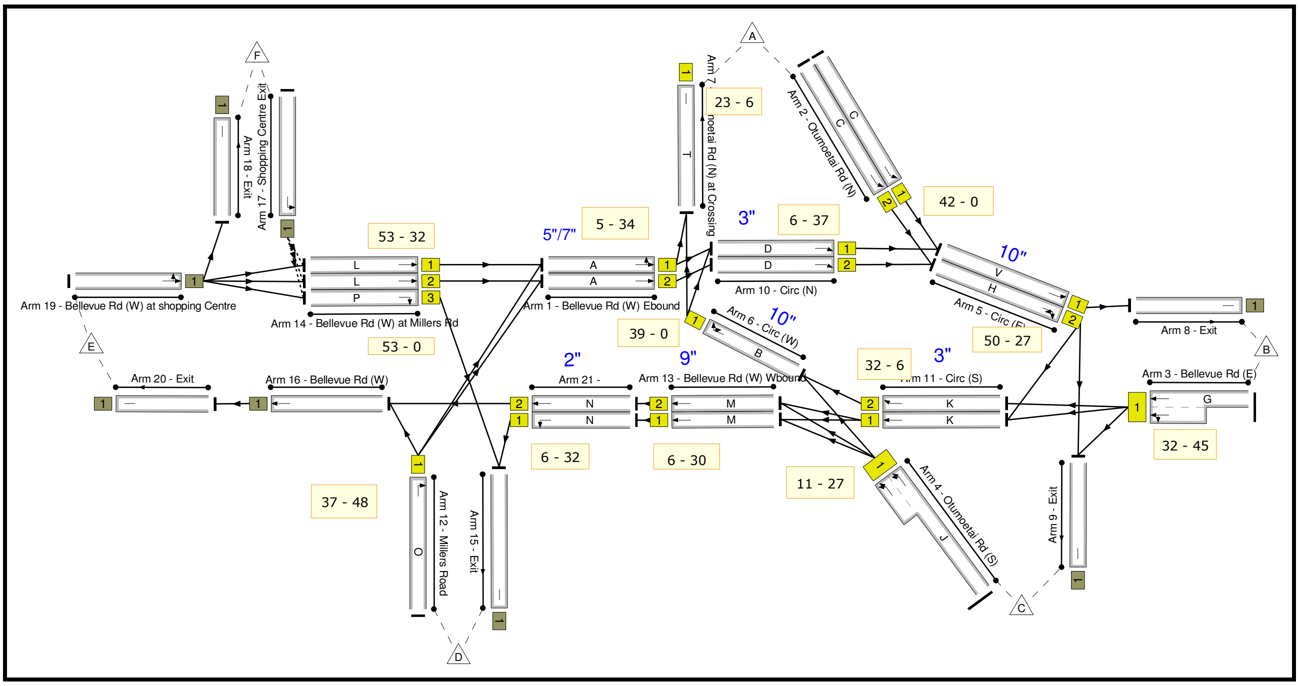
Coordination: 'Best coordination' proved to be to progress southbound traffic from Otumoetai Rd (N) and northbound traffic from Bellvue Road (E) in both peak periods. Use is made of the large queuing capacity on both the north and south sides of the dumb-bell design.



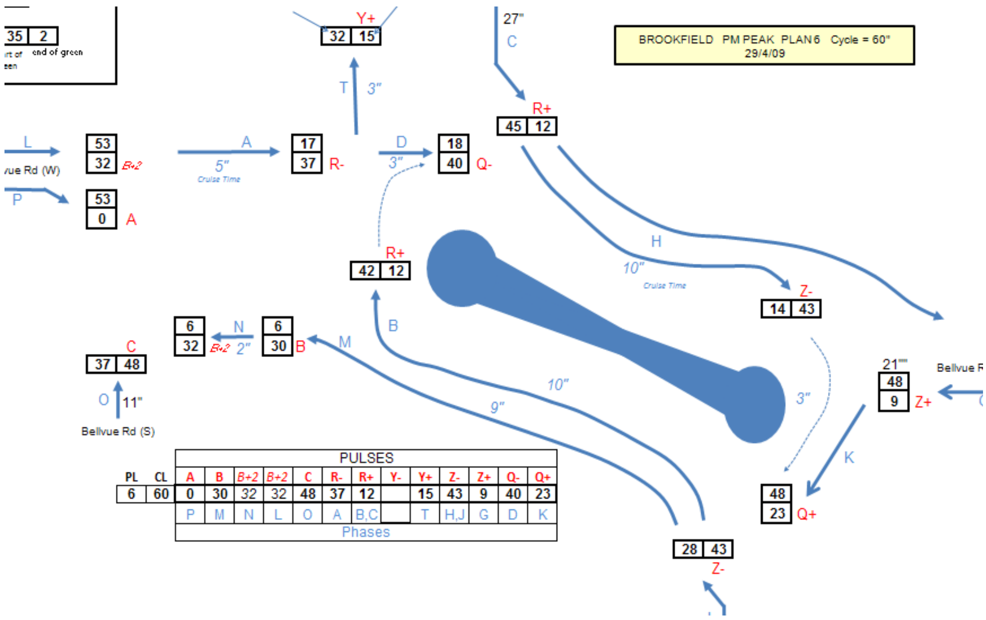
All pedestrian crossing points are split 'walk with traffic'. Demand is located kerb-side and all 'invitations to walk' are set to the minimum 6". The lead author is encouraging Tauranga Signal engineers to lengthen these 'pedestrian walk invitation' windows to their possible maximum.

Timings at the exit crossing on Otumoeti Rd (Arm A) are set so that traffic leaving the roundabout is never stopped.

Cycle times range from 60” (Peak) to 40 “ (off peak) in 11 CLF Plans. The LinSig Model for the busy AM Peak Plan (Cycle = 60”) is as follows:-



The PM Peak Plan (Cycle = 60”) is as follows:-



PL	CL	A	B	B+2	B+2	C	R-	R+	Y-	Y+	Z-	Z+	Q-	Q+
6	60	0	30	32	32	48	37	12		15	43	9	40	23
		P	M	N	L	O	A	B,C		T	H,J	G	D	K

Commissioning: Brookfield was commissioned on 8th April 2009. The initial concept design for this roundabout was produced by Brian Simmonite, founder of JCT Consultancy and the LinSig software. Sadly Brian lost his 7 year battle with cancer on the 18/4/09, but took great delight in hearing that Brookfield roundabout was successfully ‘launched’.

INTERSECTION designer Barbara Chard of English firm JCT Consultancy checks as technician Brian Duffy makes final adjustments to the master controls of traffic lights at the new Brookfield roundabout last week.

Peak flows now a piece of cake

BROOKFIELD'S new roundabout system has received a provisional thumbs-up from the local community.

Pedestrians "love" having controlled crossings instead of taking their lives in the hands to cross the road.

And the general opinion among people spoken to by *Bay News* this week is that traffic flows, particularly at peak hours, have been greatly improved too.

Perhaps the only fly in the ointment is the layout of the parking area at the small Brookfield shopping centre.

That is causing a good deal of confusion. But it is still early days and general opinion is that people will "get used" to the new layout.

Traffic lights on the new intersection, with its unusual elongated "jellybean" traffic island, were officially switched on last Friday after two days' of tests and synchronisation.

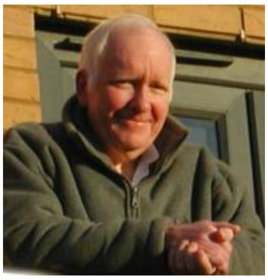
Of more than 20 local people approached this week none were unhappy with the result.

There was unanimous agreement that traffic flows had improved significantly. Traffic signals had eliminated lengthy delays at times for drivers waiting for a break in streams of traffic approaching from their right.

"It is great coming down Otumoetai Road or Bellevue Rd now," said one woman. "You get a clear run once you get a green light."

Several people said peak hour flows were now much better, though people were still getting used to the "right lanes".

Pedestrians, specially older people, were very happy. They said the light-controlled crossings were a vast improvement and they could now cross the roads with confidence where they had previously feared for their lives.



Brian Simmonite, founder of JCT Consultancy and concept designer of the Brookfield 'Jelly Bean', Tauranga, NZ

Programming the New Zealand Traffic Signal controllers

Signalised roundabouts require a different from of control than the standard New Zealand signalised intersection. In New Zealand traffic signal controllers operate on a phase based methodology where non-conflicting movements run together to form a phase. However the UK controllers operate on a movement based format in which any non-conflicting movement may operate at any time within the signal cycle.

The challenge was to duplicate the movement based format into the New Zealand controllers. The other option was to import a UK controller. However this was not considered desirable due to issues such as maintenance, spare parts, lack of technical knowledge, software programming etc.There were also problems with being able to connect the UK controllers to the Tauranga City Councils SCATS central management system.

Basically a signalised roundabout operates like a series of two phase intersections linked together to provide progression along the route, or in this case around the roundabout. In the normal situation there would be a separate controller at each intersection controlling the conflicting signal displays and the challenge was to make one controller act like several controllers to allow separate control of each approach to the roundabout.

Standard New Zealand controllers may operate in one of three control modes. The lowest level of operation is the Isolated, or Vehicle Actuated mode, in which the controller responds solely to the traffic at the particular junction. The highest level of operation is the SCATS Masterlink mode, in which the controller operates under the control of a SCATS Master management computer to provide adaptive control and coordinated traffic flow through a system. The third form of control is the Flexilink mode of operation in which phase times and cycle lengths are determined by fixed time plans that are selected on a day of week time of day basis known as schedules. The Flexilink operation is similar to the CLF method of control that the UK controllers use. Accordingly, the Flexilink mode was used as the basis of developing the controller operating software, or controller personality, for the New Zealand controller.

Flexilink normally operates by holding the current running phase until the “Call Pulse” for the next demanded phase is activated, at the appropriate point within the cycle. However by using the call pulse to terminate the signal displays controlling conflicting movements instead of terminating phases we were able to separate the control on each approach to mimic the movement based control methodology.

In developing the controller personality all safety features such as ensuring no conflicting movements operated at the same time, appropriate intergreens (amber and red) between conflicting movements were maintained, minimum green times for each movement were retained and that modifications to the fixed time plans or schedules were simple and able to made on site or via the SCATS central computer. Also any time setting that was outside the timing parameters, such as a terminating pulse value greater than the cycle length, was readily identified.

As the correct operation of the roundabout would only occur if the controller was running in Flexilink mode other features were included in the software so that if the control mode was changed the controller would revert to its Fault mode which sent all signals into flashing amber and a Black Out alarm was generated in SCATS to warn the operator.

The Flexilink mode of operation may also be used to provide coordination or “Green Wave” between adjacent sites, even if there is no direct link between each controller. The ability to link or coordinate adjacent intersections was used between the Welcome Bay and Maungatapu sites to ensure that the midblock sections did not become congested and cause queues to form back and block the upstream intersection. It also provided benefits to the north/south traffic flows, which have heavy large vehicle demands, by providing coordination between the sites generally resulting in the north/south flows only being stopped once through both intersections.

Whilst the controller is connected to the SCATS system, SCATS does not have any control on its operation, as it would at a normal intersection. In this case SCATS is used to monitor for faults, such as lamp failures and allow for remote changes to the fixed time plans and schedules.

One disadvantage of the current form of operation is that, unlike standard intersections, the movement/phase times and cycle lengths are predetermined and are not adaptively modified based on current traffic flows. Therefore if traffic flows or patterns change then new fixed time plans and schedules have to be developed. The next challenge is to develop the controller software and background firmware to enable adaptive control.

Paramics Microsimulation also plays its part

The application of microsimulation in the project proved to be particularly useful for a number of reasons. When I first travelled to Welcome Bay in November 2006 the lack of familiarity in the industry to the concept of signalised roundabouts was readily apparent. With the assistance of Angus Bargh, an engineer with Traffic Design Group we were able to quickly develop a microsimulation model of the preliminary LinSig design for Welcome Bay roundabout. This meant that within 3 days of arriving to scope Welcome Bay we had a preliminary 'working' design and sets of optimized timings created using LinSig, basic engineering drawings, and a full visualisation of the scheme using Paramics microsimulation. The scoping visit culminated in a short presentation to Tauranga City mayor in addition to a number of councillors and the local press. All were shown a powerpoint presentation outlining the scheme in tandem with the microsimulation model. This made the task of explaining the scheme immeasurably easier. If a picture paints a thousand words then microsimulation paints 10,000!

As the scheme developed the S-Paramics microsimulation model was used to verify the signal timings for the various time of day plans. It was also used for the economic evaluation process for benefit cost analysis on behalf of NZTA. In addition to the visualisation element, microsimulation now facilitates emulation of the SCATS controllers so that the controller software can be tested prior to implementation on the road. It is fair to say that the testing of the controller software within the S-Paramics microsimulation software gave us an increased level of confidence in the controller operation prior to commissioning of the roundabouts.

Although not essential microsimulation certainly offered all stakeholders an increased level of comfort to what was essentially a new and innovative concept in NZ. Given that microsimulation also offers simple output reporting for economic assessment, development of such models should always be seriously considered.

Acknowledgements: The design and implementing of the first three permanent signal controlled roundabouts in New Zealand has involved valuable contributions from many individuals and organisations. The lead author would especially like to thank Simon Swanston , JCT Consultancy, Martin Parkes and Haydyn Wardley, Tauranga City Council, Mike Tapper, Associate Beca Consultants (project build Consultants), Kevin Reed, New Zealand Transport Agency (project Client), Ulvi Salayev, NZTA, Fulton Hogan Ltd (project Contractors) and Carlin Valenti (public relations).

In Conclusion: The Welcome Bay and Maungatapu Roundabout Signalisation scheme has been submitted for the Ingenium Excellence Award for Public Infrastructure, 2009, by the NZ Transport Agency, Fulton Hogan Ltd and Beca.