



SYDNEY CBD CYCLEWAYS TRAFFIC SIGNALS OPTIMISATION

FOR

ROADS AND MARITIME
SERVICES NSW



BITZIOS
consulting

Gold Coast
Suite 26, 58 Riverwalk Avenue
Robina QLD 4226
P: (07) 5562 5377
W: www.bitziosconsulting.com.au

Brisbane
Level 2, 428 Upper Edward Street
Spring Hill QLD 4000
P: (07) 3831 4442
E: admin@bitziosconsulting.com.au

Sydney
Studio 203, 3 Gladstone Street
Newtown NSW 2042
P: (02) 9557 6202

DOCUMENT CONTROL SHEET

Issue History

Report File Name	Prepared by	Reviewed by	Issued by	Date	Issued to
P0817.001R Sydney CBD Cycleways Traffic Signals Optimisation.doc	A Finlay	D Bitzios	A Finlay	23/11/2011	Matt Faber, RMS
P0817 002R Sydney CBD Cycleways Traffic Signals Optimisation_final.doc	A Finlay	D Bitzios	A Finlay	18/01/2012	Matt Faber, RMS
P0817 003R Sydney CBD Cycleways Traffic Signals Optimisation_final.doc	A Finlay	A Finlay	A Finlay	2/02/2012	Matt Faber, RMS



Quality
ISO 9001



Copyright in the information and data in this document is the property of Bitzios Consulting. This document and its information and data is for the use of the authorised recipient and this document may not be used, copied or reproduced in whole or in part for any purpose other than for which it was supplied by Bitzios Consulting. Bitzios Consulting makes no representation, undertakes no duty and accepts no responsibility to any third party who may use or rely upon this document or its information and data.

CONTENTS

	Page
EXECUTIVE SUMMARY	V
1. BACKGROUND.....	1
2. METHODOLOGY	2
3. DESIGN OPERATION.....	3
3.1 TCS 283 – KING AND KENT STREETS, SYDNEY CBD	3
3.2 TCS 26 – ALBION AND BOURKE STREETS, SURRY HILLS	7
3.3 TSC 3202 – UNION AND EDWARD STREETS, PYRMONT	11
4. ACTUAL OPERATION.....	15
4.1 TCS 283 – KING AND KENT STREETS, SYDNEY CBD	15
4.1.1 SCATS Detector Counts	15
4.1.2 SCATS Intersection Diagnostic Monitor (IDM)	16
4.1.3 Live SCATS Monitoring on Site	16
4.1.4 Observations of Road User Behaviour	17
4.2 TCS 26 – ALBION AND BOURKE STREETS, SURRY HILLS	17
4.2.1 SCATS Detector Counts	17
4.2.2 SCATS Intersection Diagnostic Monitor (IDM)	18
4.2.3 Live SCATS Monitoring on Site	18
4.2.4 Observations of Road User Behaviour	19
4.3 TSC 3202 – UNION AND EDWARD STREETS, PYRMONT	20
4.3.1 SCATS Detector Counts	20
4.3.2 SCATS Intersection Diagnostic Monitor (IDM)	21
4.3.3 Live SCATS Monitoring on Site	21
4.3.4 Observations of Road User Behaviour	21
5. ISF-UTS CYCLIST BEHAVIOURAL STUDY.....	23
5.1 METHODOLOGY	23
5.2 SIGNAL DISPLAYS ON CYCLISTS' APPROACH	23
5.3 CYCLISTS' STOPPING POSITIONS	24
5.4 CYCLISTS' REACTION TO RED SIGNALS	25
5.5 RED LIGHT CROSSINGS	26
5.6 SUMMARY OF CYCLISTS' BEHAVIOUR	26
6. BICYCLE DETECTOR TECHNOLOGY STUDY	27
6.1 DETECTOR TECHNOLOGY BACKGROUND	27
6.2 RMS AND COUNCIL INFORMATION	27
6.3 BICYCLE DETECTION IMPROVEMENT OPPORTUNITIES	28
7. DISCUSSION.....	30
7.1 GENERAL	30
7.2 TCS 283 – KING AND KENT STREETS, SYDNEY CBD	31
7.3 TCS 26 – ALBION AND BOURKE STREETS, SURRY HILLS	32
7.4 TCS 3202 – UNION AND EDWARD STREETS, PYRMONT	33
8. RECOMMENDATIONS.....	34
8.1 CYCLEWAYS IN GENERAL	34
8.2 TCS 283 – KING AND KENT STREETS, SYDNEY CBD	34
8.3 TCS 26 – ALBION AND BOURKE STREETS, SURRY HILLS	34
8.4 TCS 3202 – UNION AND EDWARD STREETS, PYRMONT	34

Tables

Table 3.1:	Intended Operation of King and Kent Streets Traffic Signals
Table 3.2:	Intended Operation of Albion and Bourke Streets Traffic Signals
Table 3.3:	Intended Operation of Union and Edward Streets Traffic Signals

Table 4.1:	Traffic Volumes at King and Kent Streets on 16 August 2011
Table 4.2:	Traffic Volumes at Albion and Bourke Streets on 26 July 2011
Table 4.3:	Traffic Volumes at Union and Edward Streets on 27 July 2011

Figures

Figure 1.1:	Location of Study Intersections
Figure 3.1:	King and Kent Streets Layout
Figure 3.2:	Kent Street looking north
Figure 3.3:	Kent Street looking south
Figure 3.4:	King Street 'hook' turn bay (looking west)
Figure 3.5:	King and Kent Streets Phasing
Figure 3.6:	Albion and Bourke Streets Layout
Figure 3.7:	Bourke Street looking north
Figure 3.8:	Bourke Street looking south
Figure 3.9:	Albion and Bourke Streets Phasing
Figure 3.10:	Union and Edward Streets Layout
Figure 3.11:	Union Street looking east
Figure 3.12:	Union Street looking west
Figure 3.13:	Union Street 'hook' turn bays (looking west)
Figure 3.14:	Union and Edward Streets Phasing
Figure 4.1:	Cyclist waiting beyond cycleway stop line at Albion and Bourke Streets
Figure 7.1:	Proposed Phasing Arrangement at King and Kent Streets

Appendices

Appendix A:	Glossary of Terms
Appendix B:	Signal Design Plans for Study Intersections

EXECUTIVE SUMMARY

Bitzios Consulting was engaged by the then Roads and Traffic Authority of NSW (RTA), now Roads and Maritime Services NSW (RMS), to analyse thoroughly the operation of the special bicycle signals at signalised intersections on dedicated cycleways within and close to the Sydney Central Business District (CBD). The study included but was not limited to the following issues:

- *accurate and efficient detection of bicycles;*
- *duration of bicycle phases in relation to cyclist demand, and to other vehicle and pedestrian demands; and*
- *delays to cyclists, compared to delays to other road users.*

At the same time as the above study, the then RTA engaged the Institute for Sustainable Futures at the University of Technology, Sydney (ISF-UTS) to conduct a study of cyclist behaviour at traffic signals on cycleways.

For both studies, the same three intersections were chosen by RMS and City of Sydney Council. The study intersections were:

- *King Street and Kent Street, Sydney, where two cycleways intersect;*
- *Bourke Street and Albion Street, Surry Hills, on the Bourke Street cycleway; and*
- *Union Street and Edward Street, Pyrmont, on the Union Street cycleway.*

All three intersections are connected to the Sydney Coordinated Adaptive Traffic System (SCATS). Bitzios Consulting and ISF-UTS coordinated their on-site observations so that data and information could be shared and correlated.

The methodology for the Bitzios Consulting study included:

- *reviewing all available data and information supplied by RMS and Council;*
- *analysing traffic signal design plans, controller information sheets, timing cards and SCATS data to determine the intended operation under varying conditions;*
- *undertaking site inspections to observe signal operation and road user behaviour, especially cyclists;*
- *analysing SCATS operation monitors (Intersection Diagnostic Monitors, Strategic Monitors and detector counts) collected on the same day as the site observations;*
- *studying actual live SCATS operation using a SCATS-enabled laptop computer on-site;*
- *reviewing and commenting on the ISF-UTS behavioural study results;*
- *reviewing and commenting on a separate RMS/Council study of bicycle detector technology;*
- *participating in RMS/Council working group meetings; and*
- *reporting results of all components of the study.*

In general, the study found that the bicycle signals and bicycle detectors on the cycleways were operating as designed. The detection of cyclists was reliable so long as the cyclist stopped behind the cycleway stop line and remained in the detection zone until the bicycle signal turned green. The green times allocated for cyclists were generally sufficient for the cyclist volumes, but there were occasions when cyclist volumes exceeded the capacity of the bicycle phase. These were notable in the AM and PM peak periods on the King Street cycleway eastbound at Kent Street and on the Union Street cycleway. In such cases, cyclists often rode against the red bicycle signal, but at the same time as the parallel motor vehicle green signal. Where there was very light conflicting traffic, some cyclists rode against both the red bicycle signal and the red motor vehicle signal.

Our observations of cyclist behaviour revealed that cyclists generally:

- *do not appear to be aware of the bicycle detection zone and prefer to wait beyond the cycleway stop line;*
- *have a low tolerance for delay at red signals, especially if conflicting traffic appears light; and*
- *appear frustrated at delays at successive, closely spaced intersections along a cycleway (because there is currently no coordination of bicycle green signals).*

To address the bicycle detection zone awareness issue, we suggest the application of diamond dot pavement markings on all cycleway approaches, and the trial installation of cyclist handrails at several intersections where it is

feasible. These handrails would provide a welcome facility for cyclists while also encouraging them to stop and wait in the correct location for successful detection.

From our analysis of cyclist volume data provided by Council, we note that on some cycleways the number of cyclists has doubled in 12 months. This suggests that the original set up of the bicycle signal timing, in relation to other signal timing, may need revision to ensure that there is more equitable allocation. There may also be opportunities to better coordinate adjacent signalised intersections for heavy cyclist movements.

Bitzios Consulting submits six recommendations for cycleways generally and a further six recommendations for specific improvements at the three study intersections.

1. BACKGROUND

Roads and Maritime Services NSW (RMS), formerly the Roads and Traffic Authority of NSW (RTA), has been working closely with City of Sydney Council (Council) to maximise the attraction and utilisation of dedicated cycle ways within and close to the Sydney Central Business District (CBD). Some issues have been identified by Council and some cyclists in relation to the operation of special bicycle phases (dedicated bicycle signals) at signalised intersections along the cycle ways.

Bitzios Consulting was engaged by the then RTA to analyse thoroughly the operation of the bicycle phases, including but not limited to the following issues:

- accurate and efficient detection of bicycles;
- duration of bicycle phases in relation to cyclist demand, and to other vehicle and pedestrian demands; and
- delays to cyclists, compared to delays to other road users.

At the same time as the above study, the then RTA engaged the Institute for Sustainable Futures at the University of Technology, Sydney (ISF-UTS) to conduct a study of cyclist behaviour at traffic signals on cycleways.

For both studies, the same three intersections were chosen by RMS and Council. The study intersections, as shown in Figure 1.1 below, were:

1. King Street and Kent Street, Sydney (TCS* number 283), where two cycleways intersect;
2. Bourke Street and Albion Street, Surry Hills (TCS number 26), on the Bourke Street cycleway; and
3. Union Street and Edward Street, Pyrmont (TCS number 3202), on the Union Street cycleway.

*Traffic Control Signal

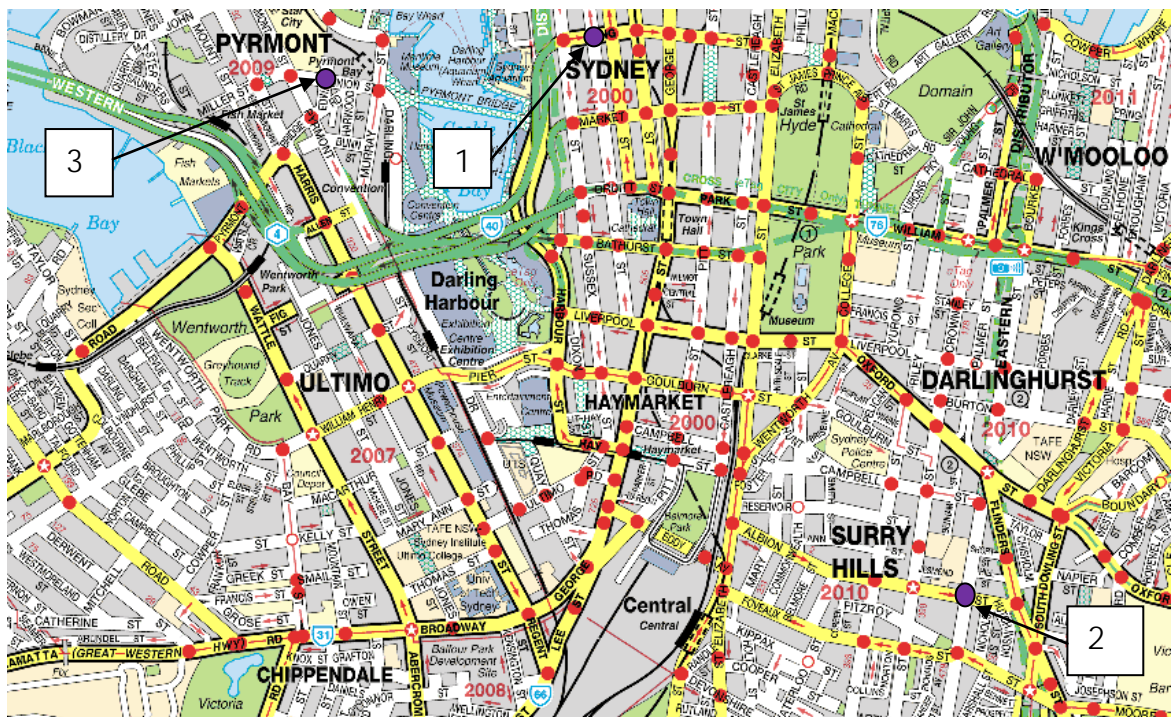


Figure 1.1: Location of Study Intersections

All three intersections are connected to the Sydney Coordinated Adaptive Traffic System (SCATS).

Bitzios Consulting and ISF-UTS coordinated their on-site observations so that data and information could be shared and correlated.

2. METHODOLOGY

The methodology for this study included:

- reviewing all available data and information supplied by RMS and Council;
- analysing traffic signal design plans, controller information sheets, timing cards and SCATS data to determine the intended operation under varying conditions;
- undertaking site inspections to observe signal operation and road user behaviour, especially cyclists;
- analysing SCATS operation monitors (Intersection Diagnostic Monitors, Strategic Monitors and detector counts) collected on the same day as the site observations;
- studying actual live SCATS operation using a SCATS-enabled laptop computer on-site;
- reviewing and commenting on the ISF-UTS behavioural study results;
- reviewing and commenting on a separate RMS/Council study of bicycle detector technology;
- participating in RMS/Council working group meetings; and
- reporting results of all components of the study.

3. DESIGN OPERATION

Bitzios Consulting received a package of information from RMS for each of the study intersections. This package included:

- the traffic signal design plan, showing the layout, phasing, signal groups, and detector logic;
- the Controller Information Sheet (CIS) containing detailed information about the operation of the signal controller under different operating modes;
- the controller timing card showing all time settings; and
- SCATS 'LX' data showing the settings that determine the operation under coordinated conditions.

We analysed this information and where there appeared to be gaps or anomalies we asked RMS Network Operations staff to clarify or to provide additional data. Based on our analysis of the data and information, the intended operation of the study intersections is described in the following sections.

3.1 TCS 283 – KING AND KENT STREETS, SYDNEY CBD

Two cycle ways intersect at this busy CBD intersection of two one-way streets. King Street is one-way eastbound and has a two-way cycleway on its northern side. Kent Street is one-way northbound and has a two-way cycleway on its eastern side. The extract from the design plan in Figure 3.1 shows the details of the intersection.

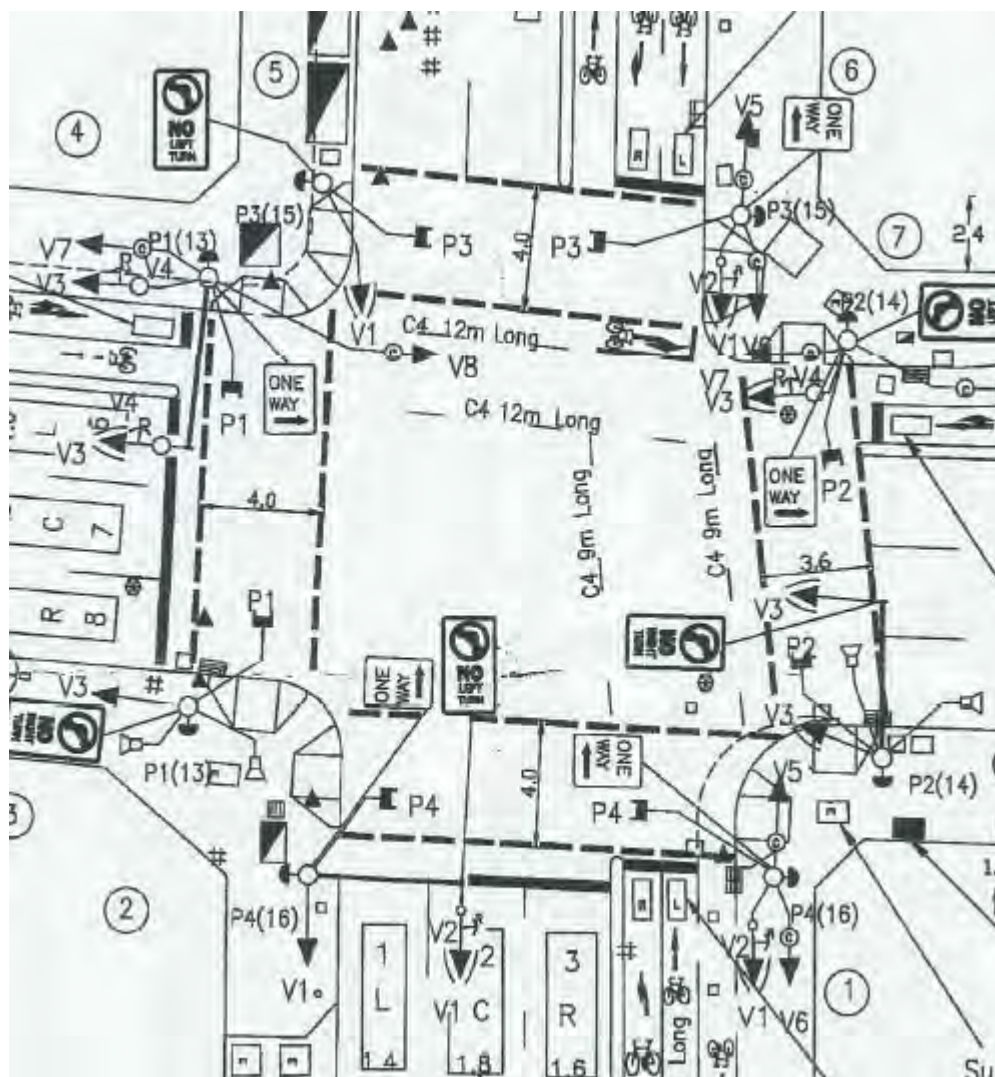


Figure 3.1 King and Kent Streets Layout

The Kent Street cycleway has short storage bays at the intersection for northbound left turns and southbound right turns (see Figures 3.2 and 3.3), and there is a 'hook' turn storage bay for eastbound cyclists turning right to Kent Street (see Figure 3.4). This hook turn involves cyclists moving to the left of the cycleway and waiting for the green bicycle signal on the Kent Street cycleway.



Figure 3.2 Kent Street looking north



Figure 3.3 Kent Street looking south



Figure 3.4 King Street 'hook' turn bay (looking west)

Signalised pedestrian crossings are provided on all four approaches.

The traffic signal phasing is shown in Figure 3.5 below.

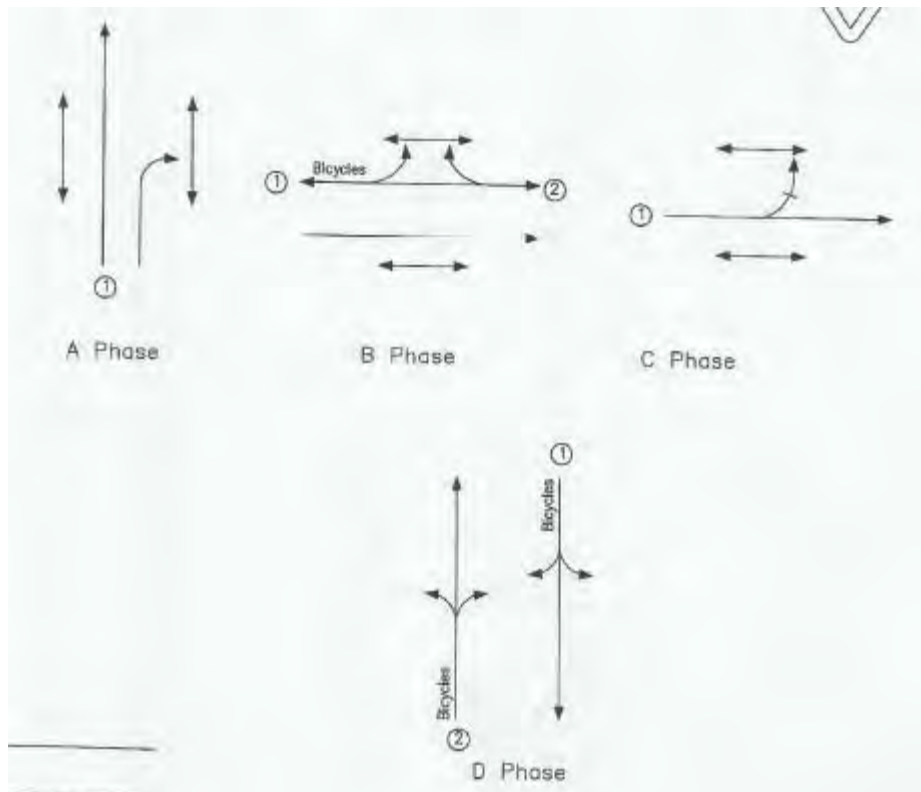


Figure 3.5 King and Kent Streets Phasing

The intended operation of this intersection is summarised in Table 3.1.

Table 3.1: Intended Operation of King and Kent Streets Traffic Signals

Phase	Motor Vehicle Movements	Cyclist Movements	Pedestrian Movements	Remarks
A	Northbound through and right	Nil	Northbound and southbound	10s right turn red arrow protection for eastern pedestrian crossing
B	Eastbound through	Eastbound and westbound	Eastbound and westbound	10s left turn red arrow protection for northern pedestrian crossing
C	Eastbound through and left	Nil	Eastbound and westbound, on southern crossing	Northern crossing red after clearance period (B/C clearance overlap)
D	Nil	Northbound and southbound	Nil	Exclusive bicycle phase allows non-conflicting turns

This intersection operates in SCATS 'Masterlink' mode and is tightly coordinated with other signals along King Street. The Sydney CBD core intersections (including King Street) typically operate at the maximum SCATS cycle length of 110 seconds during all daylight hours of a normal weekday. Phase durations are determined by the dynamic SCATS phase split plan in operation at the time, but only A and C phases vary according to vehicle demand. B phase is allocated 15% of the cycle length (=17s) and D phase is allocated 11% (=12s). Subtracting the 6s inter-green times, these equate to 11s and 6s green times, respectively.

In common with other intersections in the Sydney CBD that have heavy pedestrian movements during weekday daylight hours, this intersection has automatic introduction of all pedestrian features (controlled by SCATS settings). During the same periods, both bicycle phases (B and D) are also introduced automatically. Again, this is controlled by a SCATS setting. This means that the bicycle detectors are used for demanding the bicycle phases during night time and weekend periods only. The detectors could, however, extend the bicycle phases (up to the SCATS-imposed maximum) at any time.

All of the bicycle detectors are the 'Presence Timed' type. This means that, when the bicycle signal is red, a bicycle must be on the detector for a pre-set duration (the presence time) in order for a demand to be placed for the bicycle phase. Should the bicycle move off the detector before the presence time is expired, the demand would be cancelled. The presence time setting, however, is zero so there is no delay between the bicycle being on the detector and the demand being placed.

3.2 TCS 26 – ALBION AND BOURKE STREETS, SURRY HILLS

The Bourke Street cycleway crosses Albion Street at this intersection. Albion Street is one-way eastbound, while Bourke Street is two-way and has a two-way cycleway on its western side. The extract from the design plan in Figure 3.6 shows the details of the intersection.



Figure 3.6 Albion and Bourke Streets Layout

The Bourke Street cycleway has no storage bays at the intersection and because of Albion Street's one-way eastbound direction, cyclists are limited to southbound left turns and northbound right turns (see Figures 3.7 and 3.8).



Figure 3.7 Bourke Street looking north



Figure 3.8 Bourke Street looking south

Signalised pedestrian crossings are provided on all four approaches.

The traffic signal phasing is shown in Figure 3.9 below.

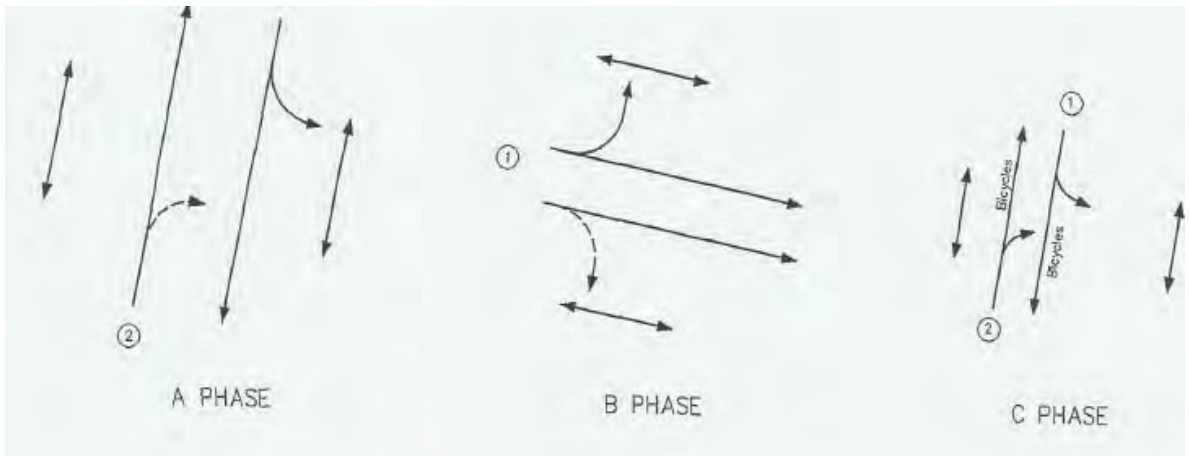


Figure 3.9 Albion and Bourke Streets Phasing

The intended operation of this intersection is summarised in Table 3.2.

Table 3.2: Intended Operation of Albion and Bourke Streets Traffic Signals

Phase	Motor Vehicle Movements	Cyclist Movements	Pedestrian Movements	Remarks
A	Northbound and southbound	Nil	Northbound and southbound	8s right turn red arrow protection for eastern pedestrian crossing
B	Eastbound	Nil	Eastbound and westbound	8s right turn red arrow protection for southern pedestrian crossing
C	Nil	Northbound and southbound	Northbound and southbound	C/A clearance overlap

This intersection operates in SCATS “Masterlink” mode and, depending on eastbound traffic volumes, is coordinated with the signals at Albion and Flinders Streets. Albion Street is an important east-west sub-arterial road linking Elizabeth Street with Flinders Street (and then to Moore Park). Foveaux Street serves as the westbound one-way street to complement Albion Street. By comparison, Bourke Street is a local road and is lightly trafficked. Since Albion Street traffic volumes can vary, the SCATS settings allow the study intersection to ‘marry’ (or link) to the Albion/Flinders Streets intersection when the equivalent average hourly volume of eastbound traffic exceeds 800 vehicles. Under light Albion Street traffic flows, this arrangement allows the study intersection to operate at a lower cycle length and thus reduce delays on the minor approaches.

A further technique to reduce delays to Bourke Street traffic (including pedestrians and cyclists) is employed. The study intersection ‘double cycles’ when the sub-system cycle length exceeds 74s. Given that the medium off-peak cycle length (‘SCL’) is set at 76s, this means the intersection will always double cycle except when operating at minimum cycle length (‘LCL’). Double Cycling means that the study intersection will cycle twice for each cycle of its sub-system. For example, if the sub-system cycle length is 100s, the Albion/Bourke signals will cycle through all demanded phases within 50s. If the study intersection were married to Albion/Flinders, there would be effective eastbound coordination (in B phase) on one of the 50s cycles, but not the other. Such an arrangement is a reasonable compromise between minimising stops on the coordinated route (Albion Street) and minimising delays on the minor approaches (Bourke Street).

The Albion/Bourke sub-system typically operates at the maximum SCATS cycle length of 120 seconds during AM and PM peak periods (meaning two cycles of 60s each). Phase durations are determined by the dynamic SCATS split plan in operation at the time, but only A and B phases vary according to vehicle demand. C phase is allocated 12% of the sub-system cycle length (=14s, or two phases of 7s). Subtracting the 6s inter-green time, this equates to 8s green time. In practice, the bicycle phase green signal duration is governed by the minimum controller time setting of 5s.

Both of the bicycle detectors are the ‘Presence Timed’ type. This means that, when the bicycle signal is red, a bicycle must be on the detector for a pre-set duration (the presence time) in order for a demand to be placed for the bicycle phase. Should the bicycle move off the detector before the presence time is expired, the demand would be cancelled. The presence time setting, however, is zero so there is no delay between the bicycle being on the detector and the demand being placed.



Figure 3.11 Union Street looking east



Figure 3.12 Union Street looking west



Figure 3.13 Union Street 'hook' turn bays (looking west)

Signalised pedestrian crossings are provided on all four approaches.

The traffic signal phasing is shown in Figure 3.14 below.

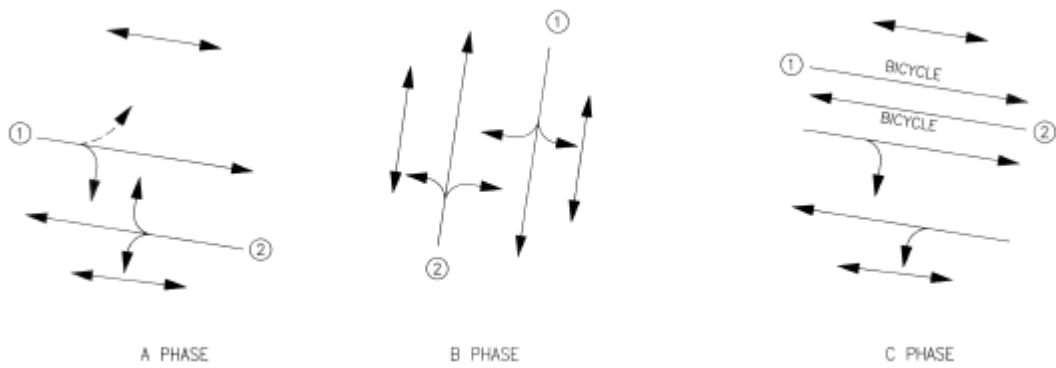


Figure 3.14 Union and Edward Streets Phasing

The intended operation of this intersection is summarised in Table 3.3.

Table 3.3: Intended Operation of Union and Edward Streets Traffic Signals

Phase	Motor Vehicle Movements	Cyclist Movements	Pedestrian Movements	Remarks
A	Eastbound and westbound	Nil	Eastbound and westbound	C/A clearance overlap
B	Northbound and southbound	Nil	Northbound and southbound	
C	Eastbound and westbound	Eastbound and westbound	Eastbound and westbound	8s right turn red arrow protection for cyclists and northern pedestrian crossing 8s left turn red arrow protection for cyclists and northern pedestrian crossing

This intersection operates at all times in SCATS 'Masterlink Isolated' mode, that is the operation is monitored by SCATS but the phase actuations and durations are determined by traffic, pedestrian and cyclist volumes. The study intersection is thus not coordinated with any of the adjacent signalised intersections.

The bicycle phase (C phase) has a minimum green of 5s, and a maximum green of 15s. The actual green time would vary between 5s and 15s according to the number of cyclists detected after the minimum green has expired. If there were a gap of 3s between bicycle detector actuations, the phase would terminate. It would also terminate if the accumulated 'Waste' time (the summed differences between ideal headways and actual headways) exceeded 4s.

In the absence of any detector demands, the signal controller would rest in A phase due to a 'software arterial' on A phase. The A phase minimum and maximum green times are 8s and 40s, respectively. The B phase minimum and maximum green times are 5s and 30s, respectively. The actual duration of A and B phases would depend on vehicular traffic flows.

Both of the bicycle detectors are the 'Presence Timed' type. This means that, when the bicycle signal is red, a bicycle must be on the detector for a pre-set duration (the presence time) in order for a demand to be placed for the bicycle phase. Should the bicycle move off the detector before the presence time is expired, the demand would be cancelled. The presence time setting, however, is zero so there is no delay between the bicycle being on the detector and the demand being placed.

4. ACTUAL OPERATION

The actual operation of the three study intersections was determined by a combination of:

- (a) On-site observations of signal displays and road user behaviour over three one-hour time periods in the AM and PM peak periods, and an off peak period;
- (b) Analysis of SCATS monitor data which was to be collected on the same days as the on-site observations; and
- (c) Live monitoring of SCATS operation (during the same time periods in (a) but on different days) using a SCATS enabled lap top computer at the intersection.

Importantly, the AM and PM peak periods were chosen on the basis of cyclist, not vehicle, volumes because we wanted to capture the busiest times for cyclists. The cyclist volumes were made available by Council from manual counts taken either at the study intersections or at the closest adjacent locations.

The ITS-UTS cyclist behavioural study was conducted at the same time as item (a) above, and involved recording video images of the cyclists using the cycleway, and of the bicycle signal displays, for later desktop analysis. In order to accurately correlate cyclist 'events' (such as correctly demanding and using a bicycle phase), Bitzios Consulting and ISF-UTS devised a method of 'synchronising' the video run time with the SCATS operational time.

4.1 TCS 283 – KING AND KENT STREETS, SYDNEY CBD

The on-site behavioural observations at King and Kent Streets took place on Tuesday 16 August from 0730 to 0830, 1100 to 1200, and 1730 to 1830. The live on-site SCATS monitoring took place at the same time periods, but on Friday 21 October. The actual SCATS operation followed the intended operation, except that there were faulty vehicle loop detectors in the centre and right lanes of Kent Street. This meant that A phase always operated to the maximum time allowed under the SCATS operational plan.

As explained in Section 3.1, the bicycle phases are automatically demanded at this intersection during weekday daylight hours and were thus not dependent on a cyclist stopping and remaining within the detection zone in the approach bicycle lane. The duration of the bicycle phases was in accordance with the SCATS operational timing plan, i.e. 11s for B phase green, and 6s for D phase green.

4.1.1 SCATS Detector Counts

Table 4.1 shows the SCATS traffic counts based on detectors in each lane. Actual directional counts are only possible from lanes dedicated to one movement. Counts from bicycle lanes could be inaccurate if cyclists do not observe the lane direction. For example, if a departing cyclist rides in the wrong direction over an approach detector, that would still be counted because the loop detectors are not unidirectional. In this table "vehicles" includes all types of vehicles (cars, trucks, buses, cycles) counted by the detectors in the traffic lanes.

Table 4.1: Traffic Volumes at King and Kent Streets on 16 August 2011

Approach	Detector No.	AM peak period (0730 to 0830)	Off peak period (1100 to 1200)	PM peak period (1730 to 1830)
Kent St vehicles (left lane only due to faulty detectors in centre and right lanes)	1	140	201	233
Kent St cyclists Northbound left	11	16	2	29
Kent St cyclists Northbound through and right	12	31	12	41
Kent St cyclists Southbound left and through	9	36	8	65
Kent St cyclists Southbound right	10	33	6	93
King St vehicles Left lane (left and through)	6	550	315	321
King St vehicles Centre lane	7	643	337	375
King St vehicles Right lane	8	133	87	132
King St cyclists Eastbound	4	219	19	147
King St cyclists Westbound	5	34	6	96

It can be seen that the cyclist volumes decreased dramatically outside the peak periods, and that the King Street cycleway is more heavily used than the Kent Street cycleway.

4.1.2 SCATS Intersection Diagnostic Monitor (IDM)

Unfortunately, the IDM for this intersection was collected on the wrong day (15 August), and so it was not possible to analyse the SCATS operation in detail on the day of the on-site observations.

4.1.3 Live SCATS Monitoring on Site

The live SCATS monitoring undertaken on 21 October showed that this intersection operated at its maximum cycle length of 110s in all three observation time periods. Due to the faulty A phase detectors in Kent Street, there was very little variation in the phase times for A and B phases. We observed intermittent 'locking on' (detector output staying on after the cyclist had left the detection zone) of cycleway detectors 10 and 11 in the AM peak period, and cycleway detector 9 in the PM peak period. This might have been due to the increased sensitivity settings adopted for cycleway detectors, as part of the bicycle detector technology study.

4.1.4 Observations of Road User Behaviour

The following observations, in no particular order, were made on 16 August:

Most eastbound cyclists did not observe the red bicycle signal. During C phase (King Street vehicles) the eastbound cyclists looked over their right shoulder to see if eastbound vehicles were turning left. If not, the cyclists proceeded.

- The same behaviour was observed for northbound cyclists turning left (except they looked over their left shoulder).
- On several occasions in the AM peak period, there was a queue of up to eight (8) eastbound cyclists in the cycleway. Under these conditions, if all cyclists obeyed the bicycle signals, there would be insufficient green time to clear the bicycle queue.
- Some eastbound cyclists struggled with the significant uphill grade between Sussex Street and Kent Street, and the bicycle signals were not coordinated (unlike the vehicle signals). This means that there was almost guaranteed stopping for cyclists at both intersections.
- Pedestrians on the northern crossing often did not wait for the Walk signal and conflicted with the Kent Street bicycle phase (D phase).
- On several occasions, northbound cyclists were seen to leave the cycleway, use the Kent Street general lanes on the Kent Street vehicle green signal, and then re-join the cycleway north of King Street.
- There was a greater extent of eastbound vehicle queuing through the intersection during off peak and PM peak periods.
- There was much better pedestrian observance of pedestrian signals during off peak periods, but many cyclists did not observe the correct direction on the cycleway (for example, riding southbound over the northbound detector).
- The Kent Street bicycle phase (D phase) was very much underutilised in the off peak period, making the automatic introduction appear illogical.
- In the PM peak period, there was much pedestrian jaywalking and ringing of cyclist bells.
- Only two uses of the 'hook' turn bay were observed.

4.2 TCS 26 – ALBION AND BOURKE STREETS, SURRY HILLS

The on-site behavioural observations at Albion and Burke Streets took place on Tuesday 26 July from 0800 to 0900, 1100 to 1200, and 1715 to 1815. The live on-site SCATS monitoring took place at the same time periods, but on Thursday 13 October. The actual SCATS operation followed the intended operation, except that on 26 July, very occasionally the bicycle phase was not successfully demanded by a correctly positioned cyclist in the northbound cycleway lane. (It is understood from RMS and Council that both bicycle detectors were re-installed in August 2011, following tests that showed their sensitivity was below acceptable limits.)

4.2.1 SCATS Detector Counts

Table 4.2 shows the SCATS traffic counts based on detectors in each lane. Actual directional counts are only possible from lanes dedicated to one movement. Counts from bicycle lanes could be inaccurate if cyclists do not observe the lane direction. For example, if a departing cyclist rides in the wrong direction over an approach detector, that would still be counted because the loop detectors are not unidirectional. In this table "vehicles" includes all types of vehicles (cars, trucks, buses, cycles) counted by the detectors in the traffic lanes.

Table 4.2: Traffic Volumes at Albion and Bourke Streets on 26 July 2011

Approach	Detector No.	AM peak period (0800 to 0900)	Off peak period (1100 to 1200)	PM peak period (1715 to 1815)
Bourke St vehicles Northbound through and right	2	102	81	115
Bourke St vehicles Southbound left and through	1	158	183	234
Bourke St cyclists Northbound through and right	8	109	17	71
Bourke St cyclists Southbound left and through	7	52	27	89
Albion St vehicles Left lane (left and through)	3	46	36	75
Albion St vehicles Centre left lane (through)	4	284	303	463
Albion St vehicles Centre right lane (through)	5	288	221	513
Albion St vehicles Right lane (through and right)	6	18	28	98

It can be seen that the cyclist volumes decreased dramatically outside the peak periods.

4.2.2 SCATS Intersection Diagnostic Monitor (IDM)

The SCATS IDM was analysed to determine the extent to which C phase (the Bourke Street cycleway phase) operated compared to the other phases. The percentage of signal cycles when C phase operated was 19% in the AM peak period, 8% in the off peak period, and 61% in the PM peak period. Noting that the combined cycleway volumes are approximately the same in the AM and PM peak periods (161 and 160), it would be expected that C phase would operate as frequently in each. The lower frequency of operation in the AM peak period could be explained by the sub-optimal operation of the northbound detector (as occasionally observed on site on 26 July).

4.2.3 Live SCATS Monitoring on Site

The live SCATS monitoring undertaken on 13 October showed that this intersection generally operated correctly in 'double cycle' mode, and the sub-system 'married' or 'divorced' from the adjacent intersection (Albion and Flinders Street) as eastbound traffic volumes in Albion Street increased and decreased, respectively.

In the AM peak period we observed intermittent 'sticking' of Albion Street detector number 6 (right lane). That is, the detector output stayed on after a vehicle had departed from the detection zone. This caused some inaccurate Degree of Saturation and Average Volume calculations in SCATS, which in turn caused inappropriately short A phase times and unnecessary 'marrying' to the Albion and Flinders Streets

intersection. In the company of an RMS employee and after approval from the Transport Management Centre, we turned the input switch for detector 6 on and off several times, and this cleared the fault.

The off peak period monitoring showed appropriate operation for the conditions. The bicycle phase was rarely demanded because the few cyclists present did not wait behind the cycleway stop line. There were minimal overall delays, with the intersection operating at 76s cycle length ('SCL') and double cycling as designed (see Section 3.2 for details).

In the PM peak period, we observed intermittent 'locking on' of cycleway detectors 7 and 8. Detector 7 then operated correctly after a cyclist stopped correctly in the detection zone, but detector 8 required re-setting using the same process we had used in the AM peak period for detector 6. Otherwise the SCATS operation was appropriate for the prevailing conditions. We noted that cyclists were less likely to proceed on a red Bourke Street vehicle signal because of the very heavy eastbound traffic in Albion Street. However, most were not stopping behind the cycleway stop line.

4.2.4 Observations of Road User Behaviour

The following observations, in no particular order, were made on 26 July:

- many cyclists rode against the bicycle red signal, but during the Bourke Street green vehicle signal;
- many cyclists stopped beyond the stop line of the cycleway (see Figure 4.1 below);
- several cyclists were seen using the Bourke Street general lanes, rather than the cycleway; and
- in almost all cases, when cyclists stopped correctly behind the cycleway stop line, the bicycle phase (C phase) was successfully demanded and introduced. Occasionally, the cyclist arrived too late in the signal cycle for C phase to be introduced at that time. If the cyclist remained on the detector, however, C phase was introduced on the next signal cycle.



Figure 4.1 Cyclist waiting beyond cycleway stop line at Albion and Bourke Streets

4.3 TSC 3202 – UNION AND EDWARD STREETS, PYRMONT

The on-site behavioural observations at Union and Edward Streets took place on Wednesday 27 July from 0745 to 0845, 1100 to 1200, and 1715 to 1815. There was no live on-site SCATS monitoring undertaken at this intersection because its SCATS operating mode is 'Master Isolated' and so the phase times are not governed by SCATS. The actual SCATS operation followed the intended operation, except that very occasionally the bicycle phase was not successfully demanded by a correctly positioned cyclist in the eastbound cycleway lane.

4.3.1 SCATS Detector Counts

Table 4.3 shows the SCATS traffic counts based on detectors in each lane. Actual directional counts are only possible from lanes dedicated to one movement. Counts from bicycle lanes could be inaccurate if cyclists do not observe the lane direction. For example, if a departing cyclist rides in the wrong direction over an approach detector, that would still be counted because the loop detectors are not unidirectional. In this table "vehicles" includes all types of vehicles (cars, trucks, buses, cycles) counted by the detectors in the traffic lanes.

Table 4.3: Traffic Volumes at Union and Edward Streets on 27 July 2011

Approach	Detector No.	AM peak period (0745 to 0845)	Off peak period (1100 to 1200)	PM peak period (1715 to 1815)
Union St vehicles Eastbound	1	100	138	97
Union St vehicles Westbound	2	49	30	89
Union St cyclists Eastbound	7	94	7	15
Union St cyclists Westbound	8	64	16	131
Edward St vehicles Southbound left lane (left and through)	3	18	24	25
Edward St vehicles Southbound right lane (through and right)	4	77	72	103
Edward St vehicles Northbound left lane (left and through)	5	12	27	12
Edward St vehicles Northbound right lane (through and right)	6	79	127	87

It can be seen that the cyclist volumes decreased dramatically outside the peak periods, indicating that the Union Street cycleway is very important for commuters. Further, the combined AM peak period cyclist volume (158) was greater than the combined vehicle volume (149). Overall, there was more vehicle traffic on the Edward Street approaches than on the Union Street approaches.

4.3.2 SCATS Intersection Diagnostic Monitor (IDM)

The SCATS IDM was analysed to determine the extent to which C phase (the Union Street cycleway phase) operated compared to the other phases. The percentage of signal cycles when C phase operated was 15% in the AM peak period, 4% in the off peak period, and 19% in the PM peak period. Noting that the combined cycleway volumes are approximately the same as the Union Street combined vehicle volumes in the AM and PM peak periods, it would be expected that C phase would operate as frequently in each.

4.3.3 Live SCATS Monitoring on Site

As explained at the start of Section 4.3, there was no live on-site SCATS monitoring undertaken at this intersection because its SCATS operating mode is 'Master Isolated' and so the phase times are not governed by SCATS.

4.3.4 Observations of Road User Behaviour

The following observations, in no particular order, were made on 27 July:

- the vast majority of cyclists rode against the bicycle red signal, but during the Union Street green vehicle signal;
- because of the low conflicting traffic in Edward Street, many cyclists rode against the Union Street vehicle red signal;
- many cyclists stopped beyond the stop line of the cycleway;

- many cyclists were seen using the Union Street general lanes, rather than the cycleway;
- in almost all cases, when cyclists stopped correctly behind the cycleway stop line, the bicycle phase (C phase) was successfully demanded and introduced. Occasionally, the cyclist arrived too late in the signal cycle for C phase to be introduced at that time. If the cyclist remained on the detector, however, C phase was introduced on the next signal cycle;
- the traffic signals were cycling quickly and efficiently in response to detector and push button demands;
- several joggers and walkers were seen using the cycleway, perhaps due to the narrow footpath near the building construction hoarding on the north western corner (see Figure 3.11);
- in the AM and PM peak periods, there was a constant stream of pedestrians on the northern side of Union Street. On many signal cycles, none of the pedestrians activated the push buttons for the northern crossing of Edward Street, and so the pedestrian signal did not operate. When this occurred, there was some pedestrian confusion but most just crossed on the red signal if there was no conflicting traffic in Edward Street. It was noted that the push buttons are located on posts somewhat remote from the most direct pedestrian path;
- we did not see even one use of the 'hook' turn bays in any of the observation periods;
- in the PM peak period, it was clear that westbound cyclists were arriving in platoons at about 120s intervals, from the busy intersection of Pyrmont Bridge Road, Murray Street and Darling Drive situated at the western end of Pyrmont Bridge; and
- to a lesser extent, the same effect occurred in the AM peak for eastbound cyclists travelling from the intersection of Union Street and Pyrmont Street.

5. ISF-UTS CYCLIST BEHAVIOURAL STUDY

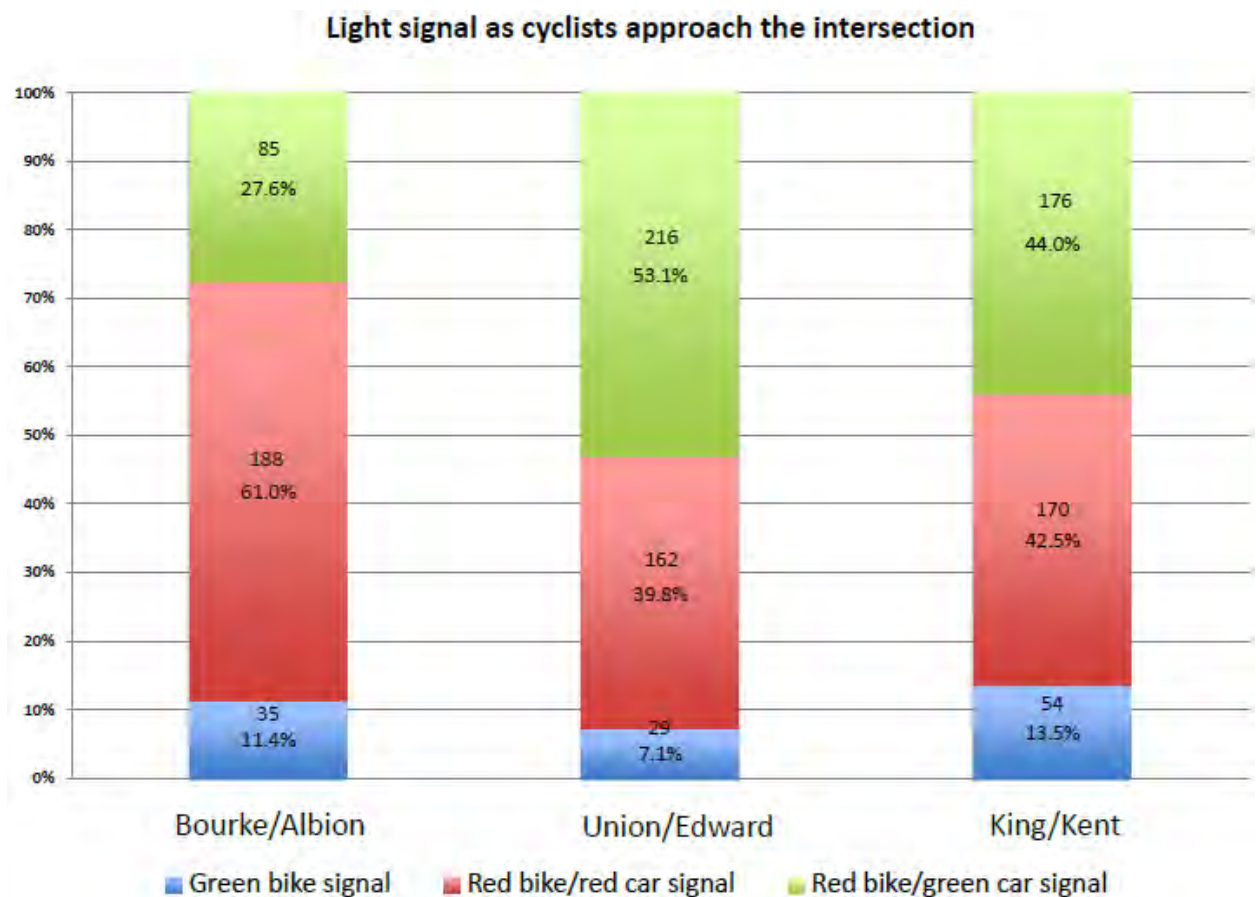
The preliminary results of the ISF-UTS Cyclist Behavioural Study were presented at a Stakeholder Workshop on 10 November 2011. In the absence of a written report on the behavioural study, the following material has been extracted from the workshop presentation.

5.1 METHODOLOGY

The three study intersections were filmed once each in the morning peak, middle of day and evening peak periods, using small video cameras mounted on tripods. One camera was aimed at the adjacent bicycle detection zone, while the other was aimed at the cycleway and the distant bicycle signal. The images could then be displayed on the same screen so that the cyclist's behaviour in the detection zone could be compared with the bicycle signal and vehicle signal. Four cameras were used at Bourke/Albion and Union/Edward, and eight cameras were used at King/Kent.

A series of 24 codes were identified to cover the vast majority of cyclist behaviours. The video footage was then coded by volunteers and ISF-UTS staff, and analysis of the coding results was then undertaken.

5.2 SIGNAL DISPLAYS ON CYCLISTS' APPROACH

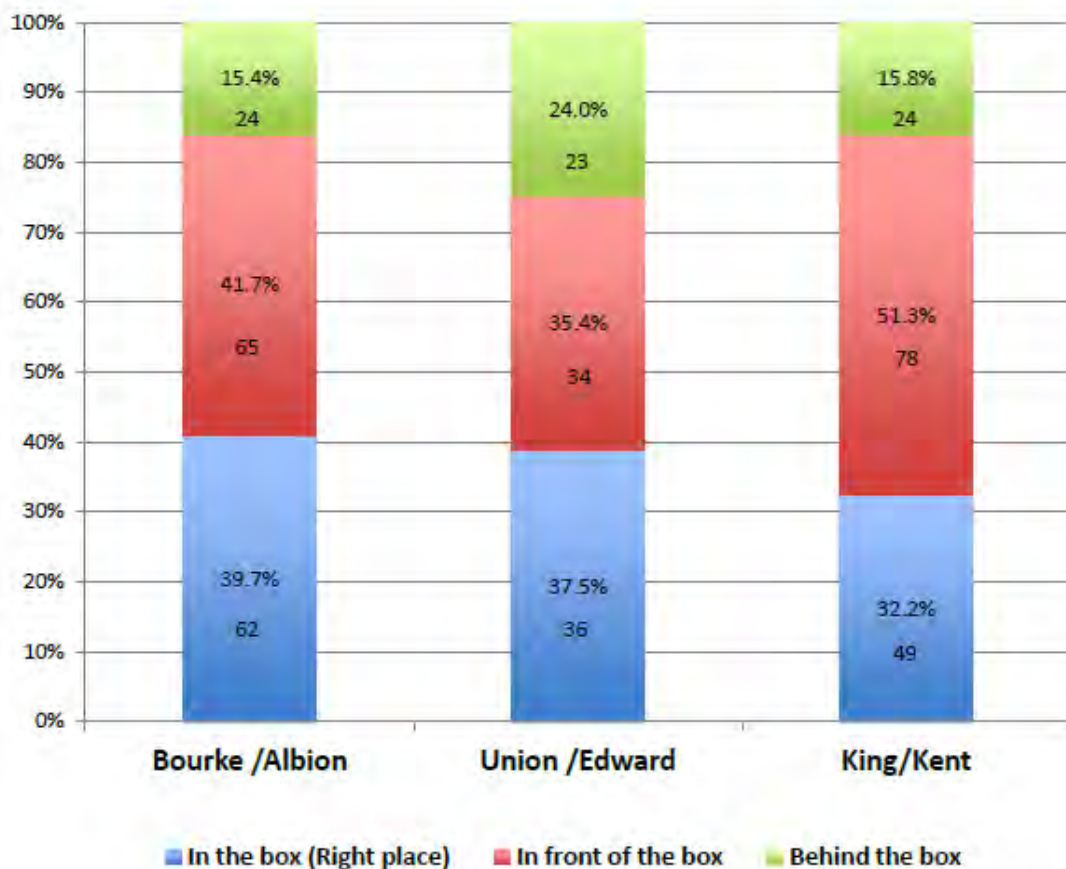


- sample: total cyclists approaching the intersection over three study periods (AM, Off Peak, and PM);
- a very small percentage of cyclists are encountering green bicycle signals when they approach the intersection; and
- approximately 30 – 50% encounter green vehicle signals when they approach the intersection.

It should be noted that other road users (including pedestrians) on 'minor' approaches would typically encounter red signals as they approach the intersection. Only motor vehicle drivers on the coordinated approaches (King Street or Albion Street) could expect a green signal.

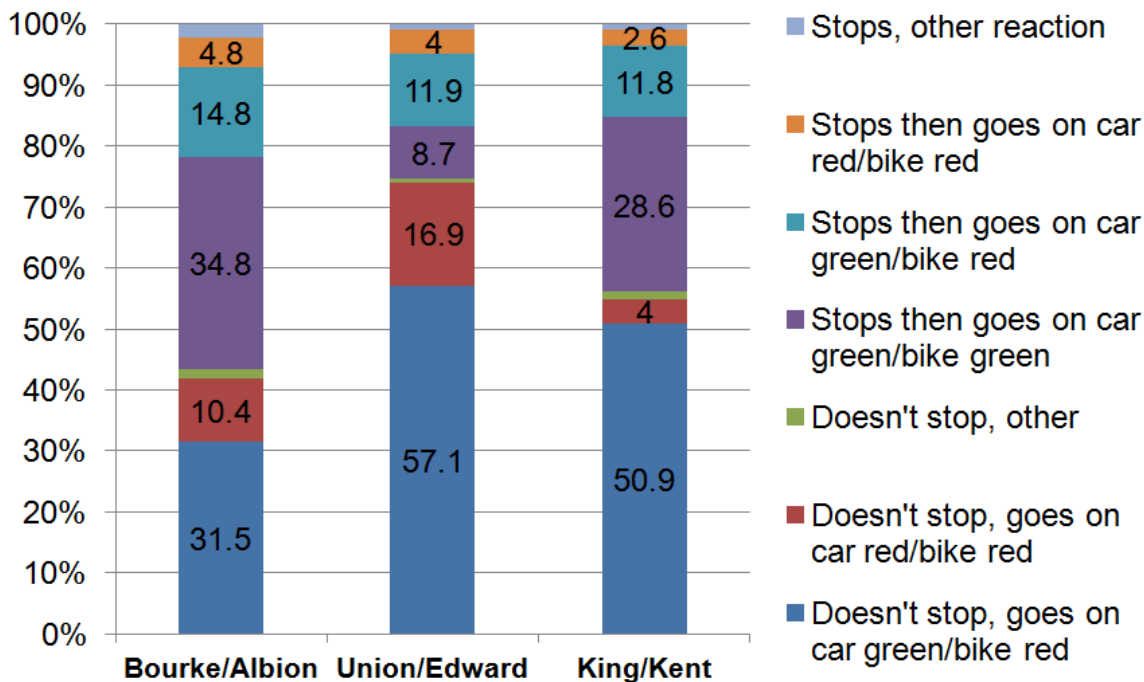
5.3 CYCLISTS' STOPPING POSITIONS

Where in relation to the detection box do cyclists stop?



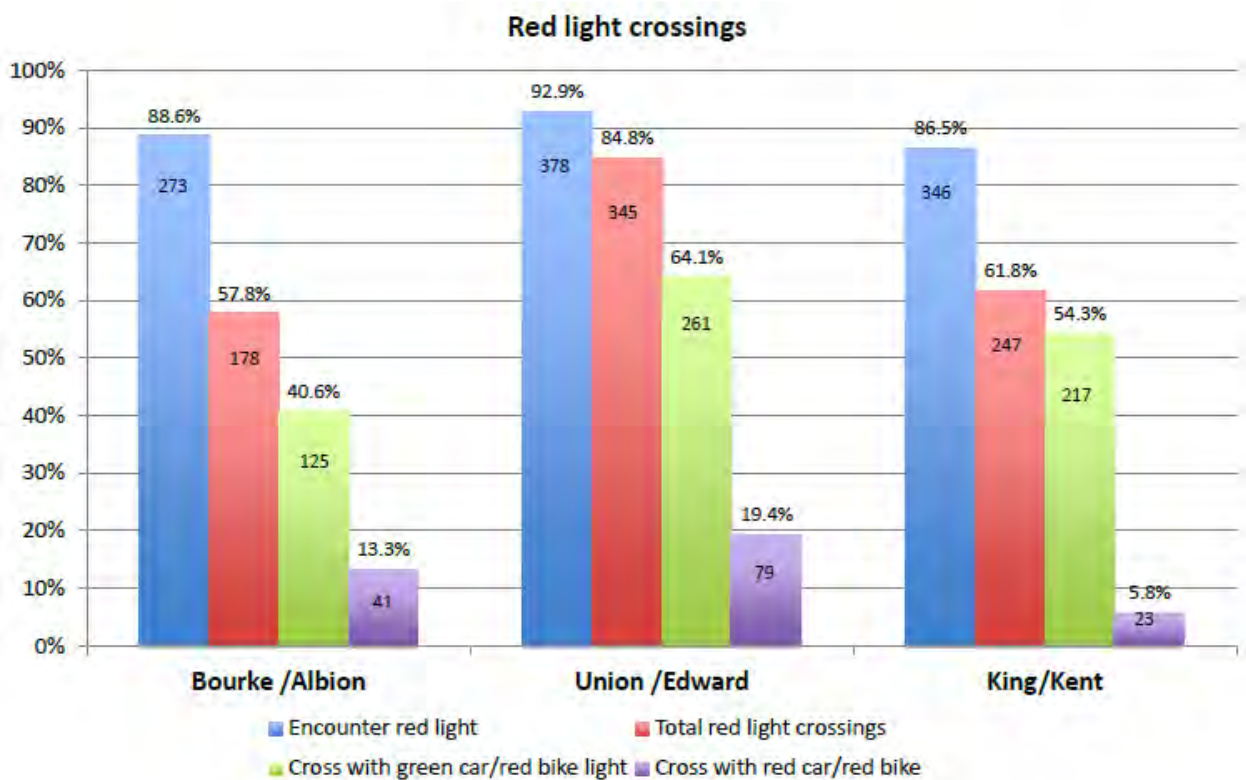
- sample: stopping cyclists over three study periods (AM, Off Peak, and PM);
- only 32 – 40% of cyclists are stopping in the detection zone ('box'); and
- suggests little knowledge of how the detector works and also means they may be facing long waits for a green bicycle signal (except at King and Kent Streets where the bicycle phases are automatically introduced).

5.4 CYCLISTS' REACTION TO RED SIGNALS



- many cyclists do not stop when faced with red bicycle signal;
 - Bourke/Albion ~ 45%;
 - King/Kent ~ 55%; and
 - Union/Edward ~75%.
- King and Kent Streets one way streets and low traffic on Union and Edward Streets may contribute to red light running;
- once stopped, most common reaction at King/Kent and Bourke/Albion is to cross with green bicycle signal; and
- at Union/Edward, even after stopping more cyclists go with green vehicle/bicycle red signal than green bicycle signal.

5.5 RED LIGHT CROSSINGS



5.6 SUMMARY OF CYCLISTS' BEHAVIOUR

- cyclists dislike stopping - unlike cars they require physical effort to regain momentum;
- cyclists rarely (~10%) encounter green bicycle signals when approaching intersection;
- cyclists are used to non-cycleway behaviour, where they follow the car signals;
- signals are prioritised for cars so no 'green wave' for bikes;
- lack of knowledge regarding detector zones; and
- cyclists are not adhering to the dedicated bicycle signals. Instead they appear to be relying on the vehicle signals and their own assessment of intersection safety.

6. BICYCLE DETECTOR TECHNOLOGY STUDY

6.1 DETECTOR TECHNOLOGY BACKGROUND

The bicycle detectors currently used in the cycle ways are inductive loop detectors. They are a smaller version of the same detectors used for motor vehicle detection, and rely on a metallic object passing through an induced electromagnetic field and so causing a frequency change in a tuned electronic circuit. The frequency change is converted to a switched output that is 'on' when a vehicle is within the detection zone and 'off' when there is no vehicle present. The sensor technology for such loop detectors has been continually improved over the last 40 years and they have proven very reliable for motor vehicles. The SCATS system relies heavily on accurate motor vehicle detection for both local vehicle actuation and for strategic traffic flow information. The loop detectors are always used in 'Presence' mode; that is, the duration of the 'on' signal is dependent on the time the vehicle stays in the detection zone. The weakness of loop detectors is the dependence on a firm, stable road pavement. Should the pavement break up or be damaged by excavation, the loop wire breaks and the failsafe design means that the detector output is then always 'on'. In turn, this means that the associated phase is always demanded and extended, regardless of traffic flow.

Bicycles have less metallic content than motor vehicles but, subject to appropriate sensitivity settings and correct location of bicycles within the detection zone, the smaller dimension loop detectors should reliably detect the vast majority of bicycles. So far, the bicycle detectors have not been used as SCATS 'strategic' detectors (able to influence cycle length, phase splits and offsets), but this could possibly occur in future and so it is important that they operate in the same way as motor vehicle loop detectors.

6.2 RMS AND COUNCIL INFORMATION

Bitzios Consulting attended regular meetings of the joint RMS-Council working group on bicycle detector technology, and we received copies of reports on studies undertaken by both RMS and Council. These included literature searches on relevant detector technology, and trials of some alternatives to the current inductive loop detectors. The trial alternatives included:

1. A pressure pad that produces an electrical pulse in response to the bicycle passing over the pad
2. Two different video camera technologies that used pre-defined detection zones in the video image and analysis of pixels to detect a bicycle passing through the zone
3. A digital vision camera system using 'stereoscopic' vision from above the cycleway lanes to define a detection zone (trial still in progress at King and Kent Streets)

The scope of this study does not allow for detailed reporting of all of the bicycle detector technology issues, but from our understanding of the results so far, system 1 has proven to be unreliable (undercounting) and non-durable (the pad has quickly deteriorated and lifted from the road surface). The video camera based systems in item 2 have been shown to have questionable accuracy and reliability in variable ambient light levels (especially at night) and one of them had an unacceptable long and complicated restarting process after a power failure.

Council and RMS staff have jointly mapped out detection zones for different sensitivity settings of the existing cycleway loop detectors. In general this work has shown that:

- the detection zone increases in size with increased sensitivity settings, and there do not appear to be any 'cross talk' issues with vehicles in adjacent lanes;
- the probability and reliability of detection increases when both the front and rear rims of the bicycle fall onto the loop area;
- the detection zone increases in size if the wire of the loop is installed closer to the road pavement surface; and
- sometimes detection zones cannot be placed in the ideal location because of drainage grates or pits close to the cycleway stop line.

Other issues discussed at the working group meetings relate to cyclists' perceptions that the bicycle detectors do not work properly. Having gained this perception, many cyclists think that there is no point waiting for the green bicycle signal and so proceed during either the parallel vehicle green signal (less safe) or even the opposing flow vehicle green signal (least safe).

Ideas have been canvassed on how to improve cyclists' trust of bicycle signals on cycle ways. These include:

- (a) providing a 'call recorded' indicator light to confirm that their demand has been registered and that a green signal will be provided;
- (b) providing diamond dot pavement markings to indicate to cyclists the most sensitive area of the detection zone;
- (c) providing a push button (in addition to the loop detector) as an additional way of placing a demand; and
- (d) providing a hand rail (resting rail) to reduce the need to unclip from pedals or rest one foot on the kerb (if available).

Another issue discussed in the working group meetings is the bicycle detector logic. As explained in Section 3, the current bicycle detectors are timed presence detectors. They place a demand for the bicycle phase after a pre-set period (currently zero seconds), but the demand is cancelled if the bicycle moves out of the detection zone. In this sense, they are 'non-locking' detectors, whereas most vehicle detectors are 'locking' detectors – the demand remains even if the vehicle moves off the detector. Council has suggested that all cycleway detectors should have 'locking' detector logic so that the likelihood of the bicycle phase operating is maximised.

In our view, the key difference is the degree of compliance with red traffic signals. Motor vehicle drivers are largely very compliant with red signals, whereas cyclists are largely not. If the bicycle detector logic were 'locking', there would be many traffic signal cycles when the bicycle phase operated for no reason (as a result of the cyclist riding through the red signal and not being present at the start of the bicycle phase). Cyclists riding in the opposite direction over the detector (i.e. on the wrong side of the cycleway) would also unnecessarily demand the bicycle phase (unless the presence timer was set to, say, two seconds). This would add unnecessary delay to other road users (including pedestrians) and could create complaints about 'faulty' or inefficient traffic signal operation. Until cyclists' compliance with bicycle signals and lane discipline improves, we support the current bicycle detector logic arrangements.

6.3 BICYCLE DETECTION IMPROVEMENT OPPORTUNITIES

Regarding item (a) above, there are significant challenges in providing a suitable display, as well as suitable cabling and power supply. For a number of reasons, NSW traffic signals moved away from 'call recorded' pedestrian push buttons many years ago, and the associated electrical equipment is no longer installed in controllers or signal posts.

We support the use of diamond dot markings (item (b) above) to enhance cyclists' understanding of the best place to stop in order to maximise the probability of successful detection. There should be continuing education campaigns about the meaning of these markings. RMS road marking specialist staff have advised that the most cost-effective method of applying diamond dot markings would be paint with a crushed aggregate (glass or quartz). A 1-2mm aggregate would provide the required skid resistance while offering protection for the cycleway green paint underneath. A longer lasting option would be application of the diamonds using thermoplastic, with an anti-skid coating added during the application.

Cyclist push buttons (item (c)) would need to be located within easy reach of a cyclist when correctly positioned in the cycleway lane. Existing traffic signals posts are located very close to the stop line and if the bicycle push buttons were located on these, it would place the cyclist partly beyond the cycleway stop line, usually inside the pedestrian crossing lines. Again, special electrical equipment would need to be installed, and in some locations (for example very narrow median strips separating the cycleway from other traffic lanes) it would not be safe to install a special post for the cyclist push button, nor is there likely to be any cabling in this location. See Figure 3.2, for example.

Regarding item (d) above, handrails are a very simple device that could serve dual purposes – (i) they would provide a welcome resting facility for cyclists and, more importantly, (ii) they would encourage cyclists to stop in the correct location within the detection zone. They require no electrical infrastructure and can be more slender than a signal post, thus increasing the opportunity to install them in narrow median strips. Each location would need to be assessed, however, for hazards to other road users and for ease of maintenance if struck by vehicles.

There also appear to be opportunities to enhance the operation of bicycle loop detectors by installing the wires as close to the kerb (or the left hand side of the cycleway lane) as possible. This would take into account cyclists' tendency to rest a foot on the kerb while waiting for the green signal.

7. DISCUSSION

7.1 GENERAL

From our analysis of the SCATS operation of the three study intersections, and our observations of cyclist behaviour, Bitzios Consulting concludes that the current cycleway detectors work with sufficient reliability so long as the sensitivity setting is high and the cyclist rides within the detection zone and remains behind the cycleway stop line when the bicycle signal is red. Most of the alleged faulty detection issues can be attributed to 'incorrect' cyclist behaviour.

In considering why many cyclists do not comply with bicycle signals, we suggest the following:

- (e) cyclists behave this way because of their approach to conventional signalised intersections. For example they like to get out ahead of vehicles so that they can be seen and so they can see conflicting traffic;
- (f) cyclists do not like stopping because of the effort required to regain cruising speed (and in some cases, the need to unclip from pedals), and they go to considerable (and sometimes risky) lengths to avoid stopping. Hence the high incidence of red light running;
- (g) cyclists need to learn new behaviours on cycle ways where dedicated signals and detectors are provided, but perhaps there is ingrained distrust of traffic signals;
- (h) another problem is the short green periods provided for cyclists on cycle ways, compared to relatively long green periods for vehicles and long clearance periods for pedestrians. If cyclists comply with bicycle signals, usually (but not always) they must wait a long time for next bicycle phase in the signal cycle. This is perceived as unfair, especially if the apparent conflicting traffic is light; and
- (i) cyclists don't understand RMS's strict approach to separating them from conflicting traffic. They are treated more like pedestrians than a vehicle (albeit a vulnerable one).

Cyclists might react favourably and sensibly to a flashing yellow bicycle signal, displayed after the bicycle green and when the only conflicting traffic is running parallel. This could be compared to the use of flashing yellow signals for vehicles (Pelican crossings) and flashing yellow arrow signals for vehicles turning through pedestrian crossings. Flashing yellow signals are generally interpreted as "proceed with caution". The legal, technical and policy implications of a flashing yellow bicycle signal would, however, need to be carefully assessed.

Diamond dot markings, to indicate the most sensitive area of the cycleway detection zone, are a simple, low cost measure and should be installed on all cycle ways. The meaning of the markings might not be widely understood, however. A Google search in late 2011 revealed very few sources of information about the markings, and none included any photos or diagrams. The markings should be included in a suitable education campaign (see below).

Handrails (where feasible) appear to be a low cost way to assist cyclists (good for resting and no need to unclip from pedals) and if the handrails were cleverly located they could help keep the cyclists behind the cycleway stop line and thus in the detection zone.

It would appear there is a need for an education and awareness campaign targeted at cyclists likely to use cycleway signals. Such a campaign should explain the benefits of the cycle ways but also the cyclist's responsibilities and the different riding techniques required to get the best experience.

The design of the bicycle features at the three study intersections appears to have been predicated on very low cyclist volumes compared to motor vehicle volumes, and would have been a reasonable basis at the time. This explains the short green times for the bicycle phases (compared to other phases) and the lack of coordination of bicycle phases with those at adjacent intersections. Over time, however, as cyclist volumes have grown (in some cases by as much as 152% in 12 months according to Council data), it would be prudent to revisit the design and SCATS operation of the bicycle signal phasing. If the cyclist volumes match or exceed motor vehicle volumes, it would seem reasonable to either allocate more green time to bicycle phases or (subject to other constraints) provide some degree of coordination of bicycle phases at adjacent intersections.

7.2 TCS 283 – KING AND KENT STREETS, SYDNEY CBD

At this intersection, the issue is not so much about effective detection of cyclists, because the automatic introduction of the bicycle phases during busy periods ensures that there are no skipped phases. The more important issue is the allocation of time within the signal cycle, and the lack of coordination of the King Street cycleway green signals. As outlined in Section 4.1.4, eastbound cyclists starting at King and Sussex Streets face a steep uphill climb to Kent Street. The signal coordination along King Street is designed around cars, which travel much faster up the hill in free flow conditions. By the time the eastbound cyclists arrive at Kent Street, the bicycle phase has already terminated, and the cyclists must wait almost 110s for the next bicycle green signal.

It would not be feasible to provide a longer bicycle green signal, due to the need for full protection from eastbound left turning traffic (left turn red arrow) and in any case, there would be very few cyclists able to use the first part of a longer green signal, thus making it inefficient.

A suggested solution to consider and (possibly trial) is to add another phase (say E phase) and modify the phase sequence. The additional phase would be for eastbound vehicles only and would provide a left turn green signal and a green through signal. (Pedestrians and cyclists would be held on red signals.) This phase would be the one to coordinate for eastbound cars from Sussex Street. At the end of this phase (exact duration to be determined but possibly around 15 seconds green time), a left turn yellow arrow would bring left turning traffic to a halt and a left turn red arrow would hold such traffic, while the existing B phase (the bicycle phase) was introduced. The remaining sequence would remain as currently operates, with the E phase time taken from the existing C phase. So the sequence would be A-E-B-C-D. The proposed phasing arrangement is shown in Figure 7.1 overleaf.

In the longer term, if a flashing yellow bicycle signal becomes available, it could be applied in A phase and C phase.

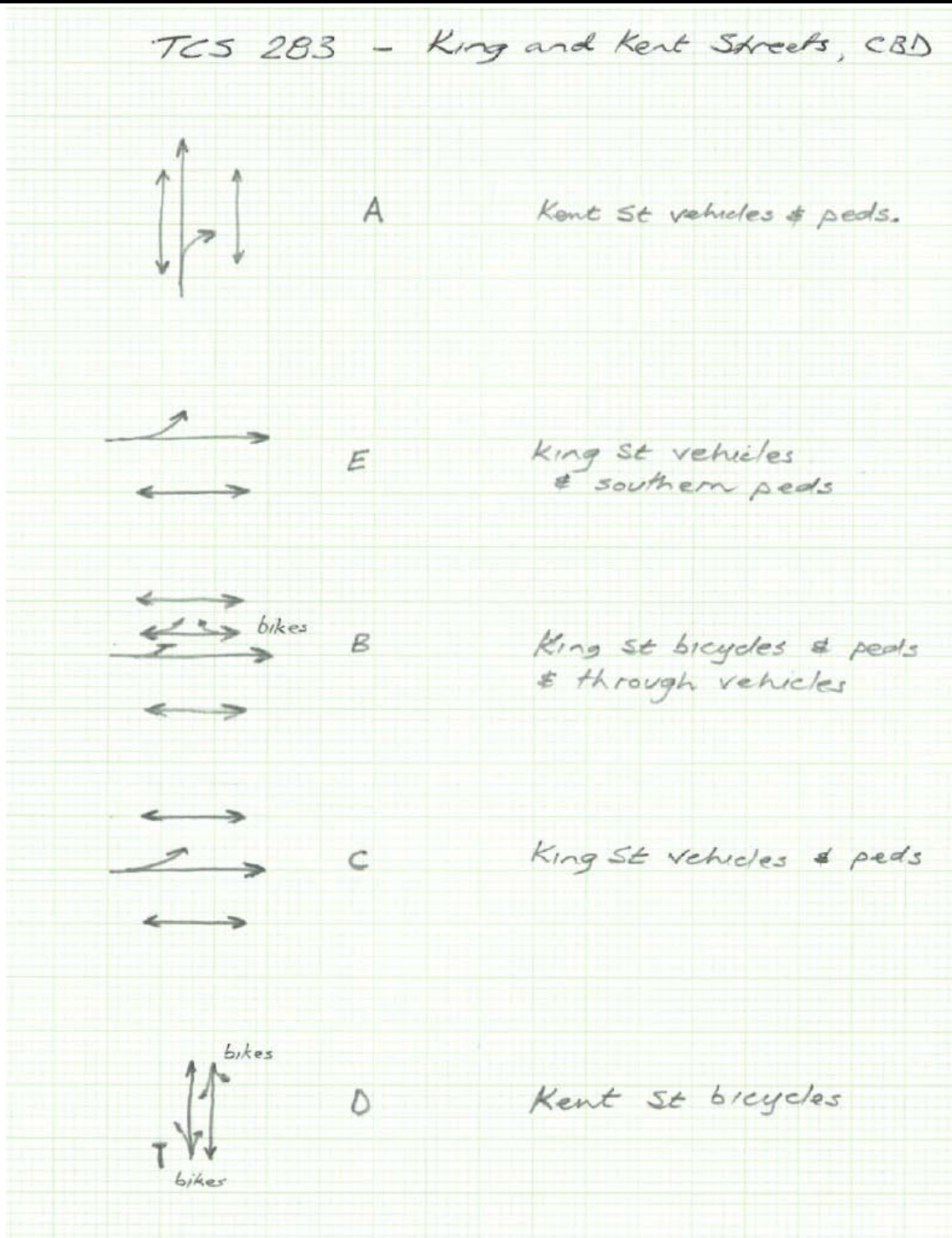


Figure 7.1 Proposed Phasing Arrangement at King and Kent Streets

7.3 TCS 26 – ALBION AND BOURKE STREETS, SURRY HILLS

At this intersection, the main issue appears to be cyclists not stopping and remaining in the detection zone, causing the bicycle phase to be skipped. The delays to cyclists (and indeed all road users) are quite reasonable due to the 'double cycling' feature and the ability to 'divorce' from the busier adjacent intersection when traffic volumes on Albion Street decrease.

In the short term, we suggest the trial installation of hand rails next to the bicycle detection zone to encourage cyclists to accurately activate bicycle detectors.

In the longer term, if a flashing yellow bicycle signal becomes available; it could be applied in A phase.

7.4 TCS 3202 – UNION AND EDWARD STREETS, PYRMONT

Peak period bicycle volumes at this intersection are almost the same as motor vehicle volumes, so it should be possible to provide better for cyclists. Although delays are minimal due to the current SCATS 'Master Isolated' operation, bicycle phases are often skipped due to cyclists not stopping and remaining in the detection zone. Further, there appear to be some opportunities to coordinate the bicycle phase with those at adjacent intersections and thus reduce the need for peak direction cyclists to stop.

The other issue observed was the heavy pedestrian flow along the northern footpaths and the occasional skipping of the northern pedestrian crossing signal.

The following improvements could be considered for trial:

- (j) automatic introduction of the bicycle phase (C phase) during the periods of peak cyclist flows (typically 0730 to 0900 and 1630 to 1930 on weekdays);
- (k) installation of hand rails next to the bicycle detection zone to encourage cyclists to accurately activate the bicycle detectors;
- (l) automatic introduction of the P1 pedestrian feature during the AM and PM pedestrian peak periods;
- (m) coordination of this intersection with the Union and Pyrmont Streets intersection in the AM peak, and with the Pyrmont Bridge Road/Murray Street/Darling Drive intersection in the PM peak period – for eastbound and westbound cyclists, respectively. This would need to consider the differences in required cycle lengths, especially in the PM peak period. It may be necessary to consider 'double cycling' Union and Edward Streets in order to minimise delays to other road users; and
- (n) in the longer term, if a flashing yellow bicycle signal becomes available, it could be applied in A phase.

8. RECOMMENDATIONS

As a result of this study, Bitzios Consulting submits the following recommendations.

8.1 CYCLEWAYS IN GENERAL

1. The specification for the installation of bicycle loop detectors should be modified to ensure that the loop wires are installed as close as possible to the kerb (or the left hand side of the cycleway lane) and are installed at the minimum feasible depth. Detector sensitivity settings should be as high as possible.
2. RMS and Council should arrange for the installation of diamond dot pavement markings (to indicate to cyclists the most sensitive area) in all cycleway detection zones.
3. RMS and Council should conduct a trial of cyclist handrails at several intersections where there is currently no automatic introduction of bicycle phases, to assess the effectiveness of handrails in encouraging cyclists to stop and remain within the bicycle detection zone.
4. RMS and Council should jointly develop and deploy an education and awareness campaign targeted at cyclists likely to use cycleway signals. Such a campaign should explain the benefits of the cycle ways but also the cyclist's responsibilities and the different riding techniques required to get the best experience.
5. RMS should investigate the legal, technical and policy issues associated with flashing yellow bicycle signals for potential use in situations where there is minimal conflict with cyclist movements.
6. RMS and Council should jointly analyse the relative volumes of cyclists and motor vehicles at all of the cycleway intersections, with a view to exploring the potential for providing either more green time for the bicycle phase or better coordination for major cyclist movements between adjacent intersections.

8.2 TCS 283 – KING AND KENT STREETS, SYDNEY CBD

7. RMS, in consultation with Council, should consider, and possibly trial, an additional phase in order to adjust the timing of the King Street bicycle phase and provide eastbound coordination for cyclists (as described in detail in Section 7.2 and Figure 7.1).

8.3 TCS 26 – ALBION AND BOURKE STREETS, SURRY HILLS

8. RMS and Council should conduct a trial of cyclist handrails at this intersection.

8.4 TCS 3202 – UNION AND EDWARD STREETS, PYRMONT

9. RMS should trial the automatic introduction of the bicycle phase (C phase) during the periods of peak cyclist flows (typically 0730 to 0900 and 1630 to 1930 on weekdays)
10. RMS and Council should conduct a trial of cyclist handrails at this intersection.
11. RMS should trial the automatic introduction of the 'P1' pedestrian feature (on the northern side of the intersection) during the AM and PM pedestrian peak periods.
12. RMS should investigate the potential for coordination of this intersection with the Union and Pyrmont Streets intersection in the AM peak, and with the Pyrmont Bridge Road/Murray Street/Darling Drive intersection in the PM peak period – for eastbound and westbound cyclists, respectively.

APPENDIX A

GLOSSARY OF TERMS

Sydney CBD Cycleways Traffic Signals Optimisation

Glossary of Terms

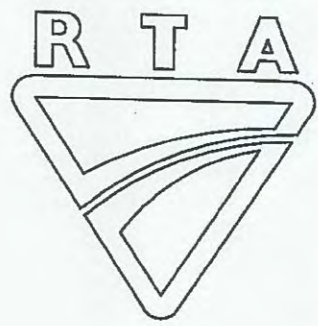
Cycle Length	The time taken to complete one whole cycle of all phases of signalised intersection
Detector	Device used to detect the presence of a vehicle at a signalised intersection
Divorce	Term used to describe the un-linking of SCATS sub-systems
Gap Time	Controller time setting used for measuring large gaps in traffic flow during green time
Headway Time	Controller time setting used for comparing ideal gaps in traffic flow during green time
HCL	SCATS maximum cycle length
ISF-UTS	Institute for Sustainable Futures at University of Technology Sydney
Inter-green	The period between the green times of successive signal phases, typically the Yellow plus All Red periods
IDM	SCATS Intersection Diagnostic Monitor – a summary of SCATS signal operation
Isolated	Isolated operation of traffic signals, that is not coordinated with other signals
LCL	SCATS minimum cycle length
Marry	Term used to describe the linking of SCATS sub-systems
Masterlink	Coordinated operation of traffic signals under SCATS control
Phase	A group of traffic movements that operate simultaneously at traffic signals
Phase split	The proportion of the cycle length allocated to a phase
Presence time	The duration required for occupancy of a detector before a demand is placed for a phase
RMS	NSW Roads and Maritime Services
RTA	NSW Roads and Traffic Authority
SCATS	Sydney Coordinated Adaptive Traffic System
SCL	SCATS medium off peak cycle length
Software arterial	A permanent demand for a traffic signal phase applied via controller software
Sub-system	A group of one or more intersections operating at the same cycle length and phase split plan in SCATS
Waste Time	Controller time setting used for measuring accumulated small gaps in traffic flow during green time

APPENDIX B

SIGNAL DESIGN PLANS FOR STUDY INTERSECTIONS

DRAWN BY CADD
DO NOT AMEND MANUALLY

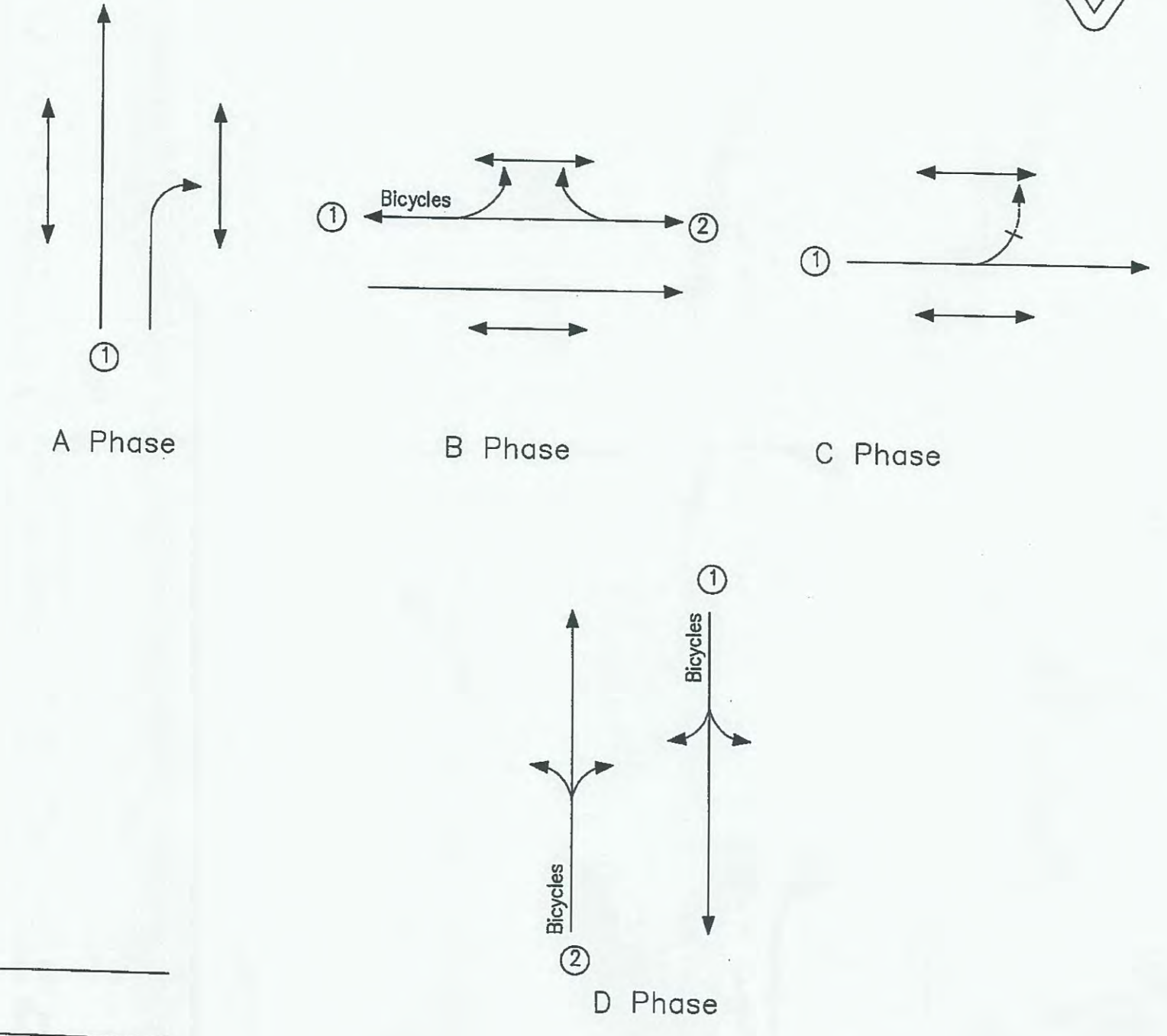
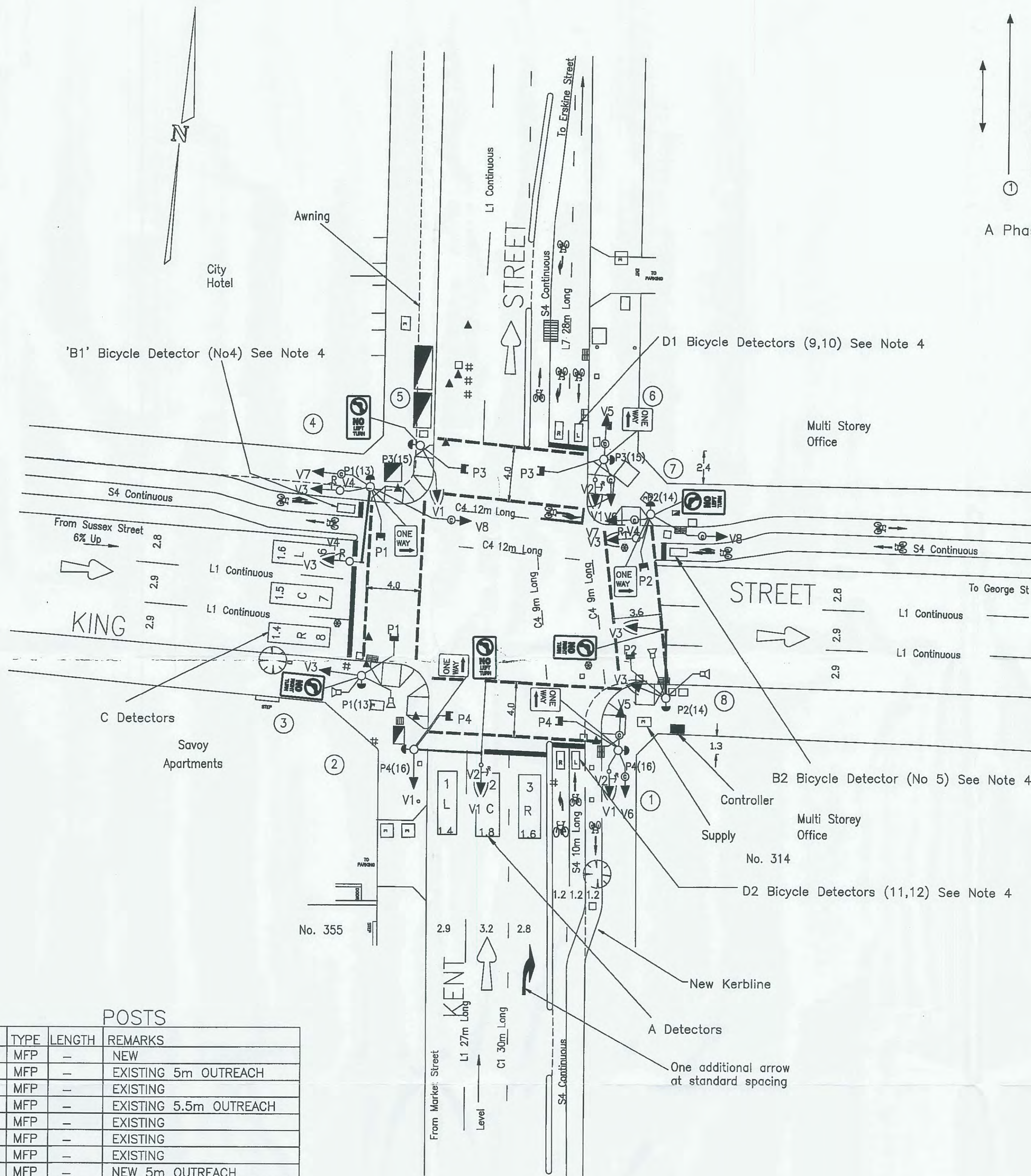
DATE IN SERVICE : 19/12/38



7000.412.W.0283

SIGNAL GROUP PHASE CHART

SIGNAL GROUP	PHASE DURING WHICH GREEN DISPLAYED				GROUP TABLE	CHART REMARKS
	A	B	C	D		
V1	X				1	
V2					44 83	TIMED R.A. PROTECTION FOR P2 PED
V3		X	X		4	B→C Only
V4					44	TIMED R.A. PROTECTION FOR P3 PED
V5				X	1	
V6				X	1	
V7	X				1	
V8	X				1	
P1	X				1	
P2	X				1	
P3		X	X		22	OVERLAP B→C Only
P4		X	X		22.6	OVERLAP B→C Only



MOVEMENTS

NOTES:

- This site is SCATS linked.
- All push buttons are audio-tactile type.
- Special stop signs (R1-4) placed on posts 1, 2 and post 6 facing south bound cycle lane.
- Bicycle detectors to be:
 - 0.6 x 2.0 and installed as figure 8 single loop.
 - Road markings to be provided over detector as shown in Austroads 1999 publication Part 14 Bicycles, figures 5.8 and 5.9.
 - Bicycle logos to be 1800 x 1100.
- All kerb ramps to be constructed in accordance with Model Drawing MD.R173.B01.A.1.
- In Masterlink and Flexilink:
 - Bicycle phase 'B' to be auto introduced in presence of XSF14.
 - Bicycle phase 'D' to be auto introduced in presence of XSF15.
- Bike lantern to be 200mm with square visors and no target board.
- Roadworks in accordance with City of Sydney construction drawings 209009 L/D CD 306 and 307.
- CBD Evacuation Speakers mounted on posts 3 & 8.

DETECTOR SPECIFICATION

Detector	Specifications			
	FN	A(L)	A(E1)	
A	SG/PS	A	A	
	DS	-	-	
B1 (Bike)	FN	B(PR)	B(E1)	
	SG/PS	B	B	
B2 (Bike)	FN	B(PR)	B(E2)	
	SG/PS	B	B	
C	FN	C(PR)	C(PR)	C(E1)
	SG/PS	B,C	B	C
D1 (Bike)	FN	D(PR)	D(E1)	
	SG/PS	D	D	
D2 (Bike)	FN	D(PR)	D(E2)	
	SG/PS	D	D	
P1 (Ped)	FN	A(PB)	C(L)	
	SG/PS	P1(WALK)	A,P1(WALK)	
P2 (Ped)	FN	A(PB)	C(L)	
	SG/PS	P2(WALK)	A,P2(WALK)	
P3 (Ped)	FN	C(PB)	A(L)	
	SG/PS	P3(WALK)	B,C,P3(WALK)	
P4 (Ped)	FN	C(PB)	A(L)	
	SG/PS	P4(WALK)	B,C,P4(WALK)	

POSTS

POST	TYPE	LENGTH	REMARKS
1	MFP	-	NEW
2	MFP	-	EXISTING 5m OUTREACH
3	MFP	-	EXISTING
4	MFP	-	EXISTING 5.5m OUTREACH
5	MFP	-	EXISTING
6	MFP	-	EXISTING
7	MFP	-	EXISTING
8	MFP	-	NEW 5m OUTREACH

A ORIGINAL ISSUE	PUBLIC UTILITY LEGEND	REFERENCE PLANS	U.B.D. Ref. 2009 Mop3 E2	DESIGN APPROVAL	RTA ACCEPTANCE	Roads and Traffic Authority, N.S.W	EXISTING <input type="checkbox"/>	PROPOSED <input checked="" type="checkbox"/>
	SYMBOLS/ABBS	SYMBOLS/ABBS	S.G. E1: 318 823	APPROVED	RECOMMENDED	SYDNEY CITY COUNCIL AREA	CADD FILE: VV02B3_12A.dgn	ISSUE
	DESIGNED	DESIGNED	CO-ORDS: N: 1 250 909	RNETTLE	RECOMMENDED	TRAFFIC SIGNALS AT THE INTERSECTION OF KING STREET AND KENT STREET	SCALE: 5 0 (1:200) 5 10	A
	CHECKED	CHECKED	DATE: August 2006	DATE: 7/5/2010	ACCEPTED	SYDNEY	FILE: 412TS 312	SUPERSEDES SHEET/ISSUE: 11B
				DATE: 11/8/2008		REGN. 7000.412.W.0283	SHEET: 12	

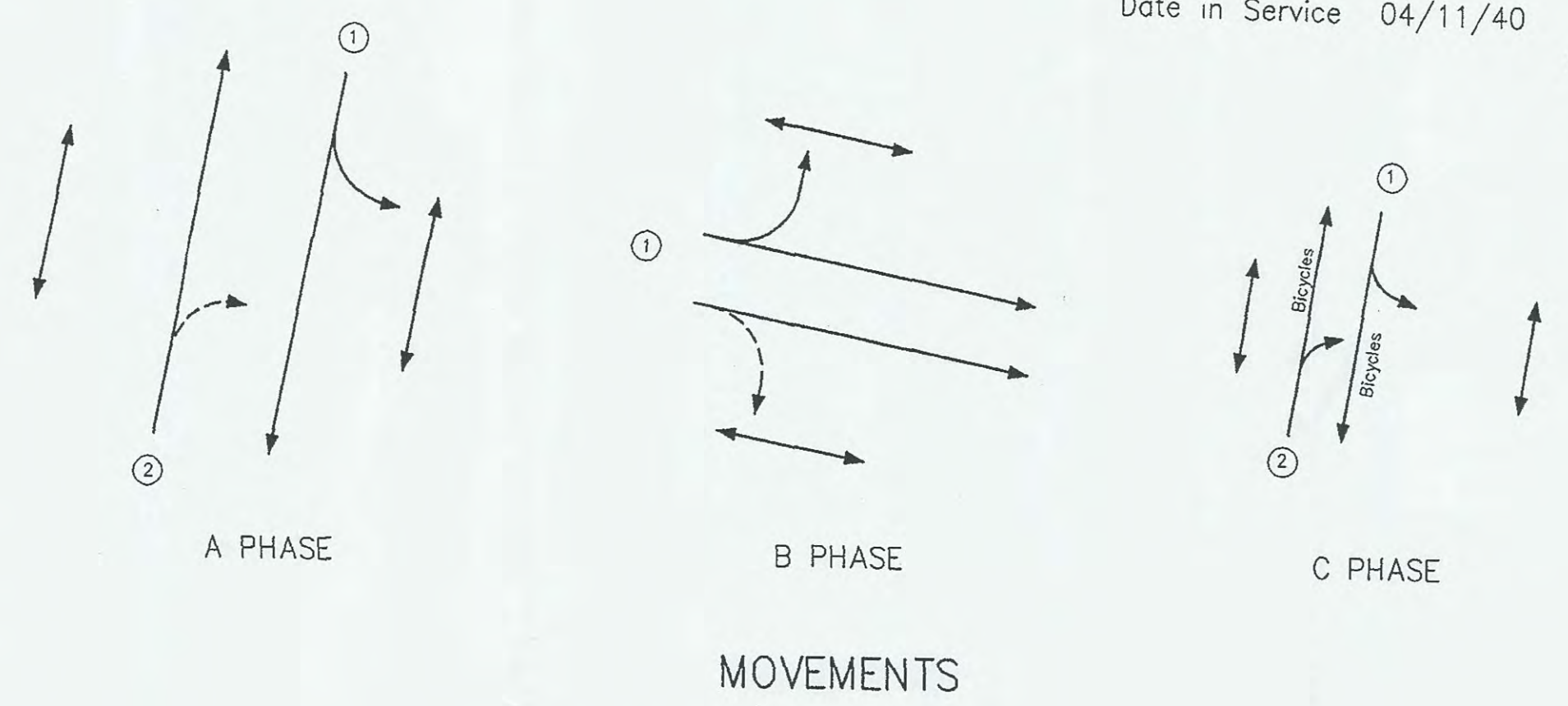
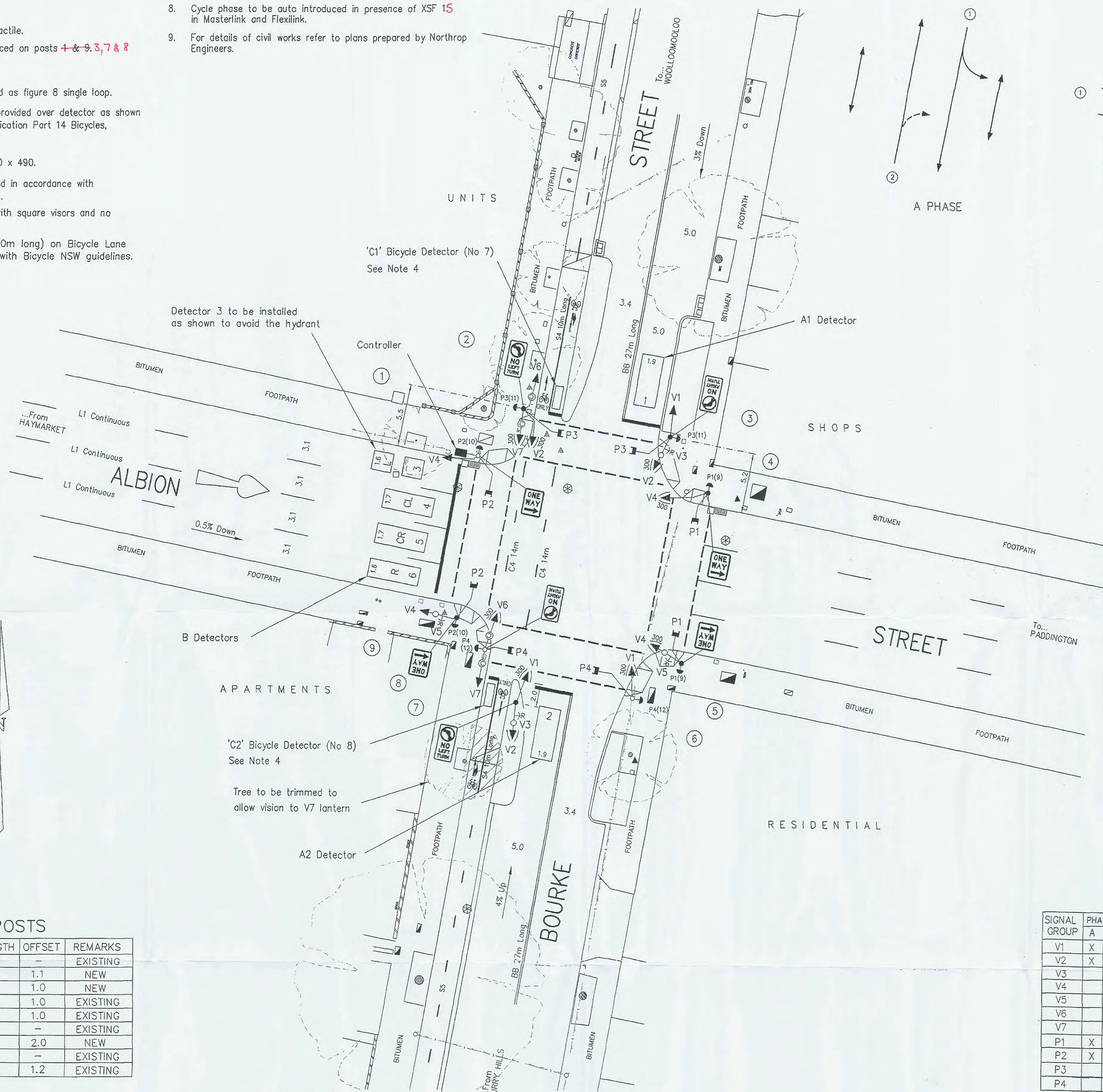
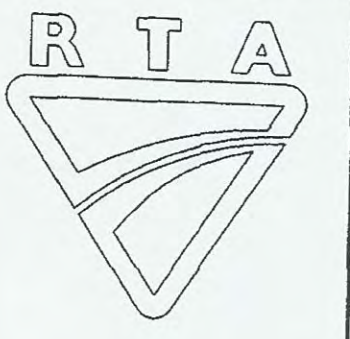
7000.412.W.0026

DRAWN BY CADD
DO NOT AMEND MANUALLY

NOTES:

- This site is SCATS linked.
- All push buttons are audio-tactile.
- Special stop signs (R1-4) placed on posts 4 & 9, 3, 7 & 8
- Bicycle detectors to be:
 - 0.6 x 2.0 and installed as figure 8 single loop.
 - Road markings to be provided over detector as shown in Austroads 1999 publication Part 14 Bicycles, figures 5.8 and 5.9.
 - Bicycle logos to be 800 x 490.
- All kerb ramps are constructed in accordance with Model Drawing MD.R173.B01.A.1.
- Bicycle lanterns are 200mm with square visors and no target board.
- Green coloured pavement (10m long) on Bicycle Lane to be provided accordance with Bicycle NSW guidelines.
- Cycle phase to be auto introduced in presence of XSF 15 in Masterlink and Flexilink.
- For details of civil works refer to plans prepared by Northrop Engineers.

Date in Service 04/11/40



DETECTOR SPECIFICATION

DETECTOR	SPECIFICATION		
	FN	A(L)	A(E1)
A1	SG/PS	A	A
	DS	-	-
A2	FN	A(L)	A(E2)
	SG/PS	A	A
B	FN	B(L)	B(E1)
	SG/PS	B	B
C1 Bike	FN	C(NL)	C(E1)
	SG/PS	C	C
C2 Bike	FN	C(NL)	C(E2)
	SG/PS	C	C
P1 P.B.	FN	A(PB)	B(L)
	SG/PS	A.C. V1.P1(WALK)	[A+C] V1.P1(WALK)
	DS	B	B
P2 P.B.	FN	A(PB)	B(L)
	SG/PS	A.C. V2.P2(WALK)	[A+C] V2.P2(WALK)
	DS	B	B
P3 P.B.	FN	B(PB)	A(L)
	SG/PS	P3(WALK)	B.P3(WALK)
	DS	-	A.C
P4 P.B.	FN	B(PB)	A(L)
	SG/PS	P4(WALK)	B.P4(WALK)
	DS	-	A.C

POSTS

POST	TYPE	LENGTH	OFFSET	REMARKS
1	ELP	-	-	EXISTING
2	2	4.1	1.1	NEW
3	2	4.1	1.0	NEW
4	2	4.1	1.0	EXISTING
5	2	4.1	1.0	EXISTING
6	ELP	-	-	EXISTING
7	2	4.1	2.0	NEW
8	ELP	-	-	EXISTING
9	2	4.1	1.2	EXISTING

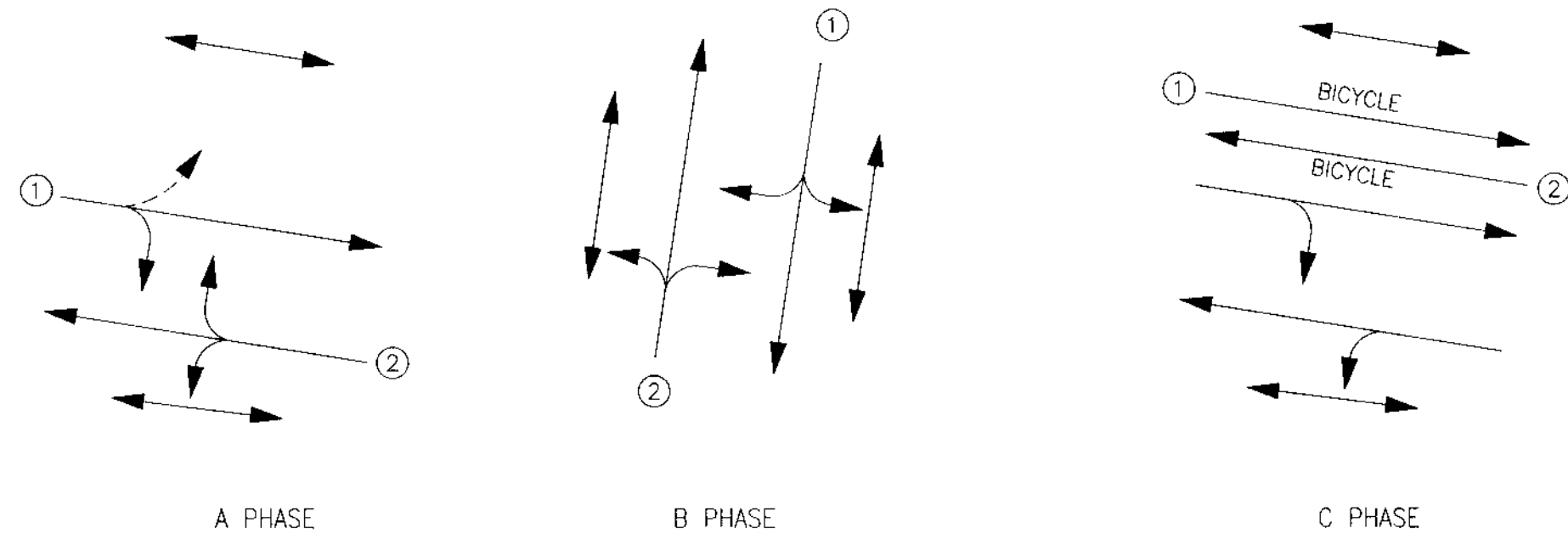
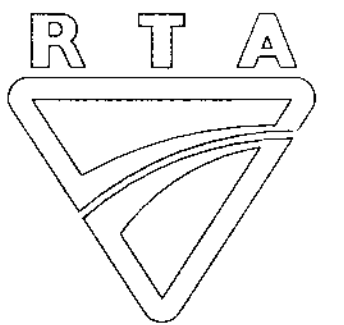
SIGNAL GROUP PHASE CHART

SIGNAL GROUP	PHASE GREEN			TABLE TYPE	REMARKS
	A	B	C		
V1	X			1	
V2	X			1	
V3				29	Timed RA protection for 'P1' pedestrians.
V4		X		1	
V5				29	Timed RA protection for 'P4' pedestrians.
V6			X		Auto introduced in presence of XSF 15 under master & flexilink
V7			X		Auto introduced in presence of XSF 15 under master & flexilink
P1	X		X	22	No A->C overlap permitted
P2	X		X	22	No A->C overlap permitted
P3		X		1	
P4		X		1	

A ORIGINAL ISSUE	PUBLIC UTILITY LEGEND	REFERENCE PLANS	U.B.D. Ref. Map 3, P16	DESIGN APPROVAL	RTA ACCEPTANCE	Roads and Traffic Authority, N.S.W. CITY OF SYDNEY COUNCIL AREA TRAFFIC SIGNALS AT THE INTERSECTION OF BOURKE STREET AND ALBION STREET SURRY HILLS TCS No 26	EXISTING <input type="checkbox"/> PROPOSED <input checked="" type="checkbox"/>
	HYDRANT	SYMBOLS/ABBS. V0003-6	I.S.G. E. 319 811	APPROVED	RECOMMENDED		CADD FILE: W0026_9A.dgn
	STOP VALVE	STD POSIT V0001-5	CO-ORDS N. 1 249 239	DESIGNED J BATES	POSITION DATE 17/11/2010		SCALE 5 0 (1:200) 5 10
	GAS VALVE	DET SCHED EXP V0018-10	CHECKED	J BATES	ACCEPTED		FILE 412 TS 134
SEWER MANHOLE	PRES. DETECT V0005-17		"SITE" CHECKED	DATE 28/03/10	REGN. 7000.412.W.0026	SUPERSEDES SHEET/ISSUE 8B	
TELECOM PIT	SSG DIS. SEQ. V0018-8			DATE 28/03/10	RECOMMENDED	ISSUE A	
ELECT LIGHT POLE						SHEET 9	
POWER POLE							
STAY POLE							
TELEPHONE BOX	SURVEYOR: City of Sydney						
TELECOM PILLAR	DATE: 2008						

DRAWN BY CADD
DO NOT AMEND MANUALLY

DATE IN SERVICE : 23/5/1997



MOVEMENTS

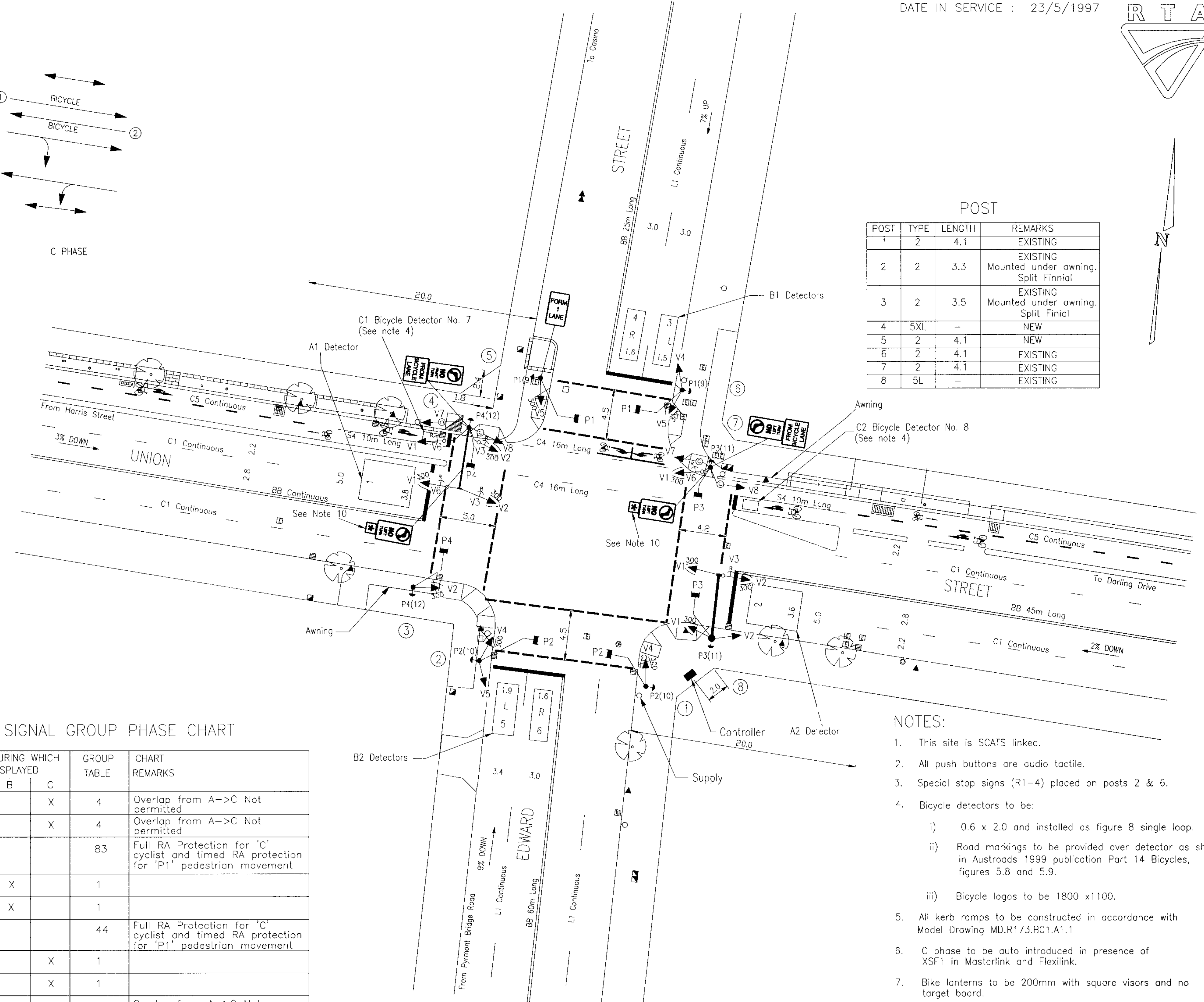
DETECTOR SPECIFICATION

Detector	Specifications			
	FN	A(PR)	A(PR)	A(E1)
A1	SG/PS	A	C	A
	DS	-	A(NG)	-
A2	FN	A(PR)	A(PR)	A(E2)
	SG/PS	A	C	A
B1	FN	B(L)	B(E1)	
	SG/PS	B	B	
B2	FN	B(L)	B(E2)	
	SG/PS	B	B	
C1 (Bike)	FN	C(PR)	C(E1)	
	SG/PS	C	C	
C2 (Bike)	FN	C(PR)	C(E2)	
	SG/PS	C	C	
P1	FN	A(PB)	B(L)	
	SG/PS	P1(WALK)	A/C.P1(WALK)	
P2	FN	A(PB)	B(L)	
	SG/PS	P2(WALK)	A/C.P2(WALK)	
P3	FN	B(PB)	A(L)	
	SG/PS	P3(WALK)	B.P3(WALK)	
P4	FN	B(PB)	A(L)	
	SG/PS	P4(WALK)	B.P4(WALK)	

SIGNAL GROUP PHASE CHART

SIGNAL GROUP	PHASE DURING WHICH GREEN DISPLAYED			GROUP TABLE	CHART REMARKS
	A	B	C		
V1	X		X	4	Overlap from A->C Not permitted
V2	X		X	4	Overlap from A->C Not permitted
V3				83	Full RA Protection for 'C' cyclist and timed RA protection for 'P1' pedestrian movement
V4		X		1	
V5		X		1	
V6				44	Full RA Protection for 'C' cyclist and timed RA protection for 'P1' pedestrian movement
V7			X	1	
V8			X	1	
P1	X		X	-	Overlap from A->C Not permitted
P2	X		X	-	Overlap from A->C Not permitted
P3		X		1	
P4		X		1	

POST	TYPE	LENGTH	REMARKS
1	2	4.1	EXISTING
2	2	3.3	EXISTING Mounted under awning. Split Finial
3	2	3.5	EXISTING Mounted under awning. Split Finial
4	5XL	-	NEW
5	2	4.1	NEW
6	2	4.1	EXISTING
7	2	4.1	EXISTING
8	5L	-	EXISTING



NOTES:

- This site is SCATS linked.
- All push buttons are audio tactile.
- Special stop signs (R1-4) placed on posts 2 & 6.
- Bicycle detectors to be:
 - 0.6 x 2.0 and installed as figure 8 single loop.
 - Road markings to be provided over detector as shown in Austroads 1999 publication Part 14 Bicycles, figures 5.8 and 5.9.
 - Bicycle logos to be 1800 x 1100.
- All kerb ramps to be constructed in accordance with Model Drawing MD.R173.B01.A1.1
- C phase to be auto introduced in presence of XSF1 in Masterlink and Flexilink.
- Bike lanterns to be 200mm with square visors and no target board.
- Roadworks in accordance with City of Sydney construction drawing 208008 LD CD.
- BICYCLE LANE to be coloured green over the full width and for a distance of 10 metres on the approach to each 'Bicycle' Stop line.
- No Left Turn vehicles under 10m long excepted.

A ORIGINAL ISSUE

PUBLIC UTILITY LEGEND		REFERENCE PLANS		U.B.D. Ref. 1996 Map 12 P3	
HYDRANT	□	SYMBOLS/ABBS	VD003-6	I.S.G. E:	318 040
STOP VALVE	▲	STD. POSIT.	VD001-5	CO-ORDS N:	1 250 810
GAS VALVE	⊕	DET. SCHED. EXP.	VD018-10	DESIGNED JS	
SEWER MANHOLE	⊙	PRES. DETECT	VC005-17	CHECKED AM	
TELECOM PIT	⊕	SSG DIS. SEQ.	VD018-8		
ELECT LIGHT POLE	○				
POWER POLE	○				
STAY POLE	○				
TELEPHONE BOX	⊕	SURVEYOR: HARD & FORESTER			
TELECOM PILLAR	⊕	DATE: MAY 1995			

DESIGN APPROVAL		RTA ACCEPTANCE	
APPROVED		RECOMMENDED	
POSITION DATE	18.12.09	POSITION DATE	18.12.09
DESIGN PREPARED BY	TRANSPORT AND TRAFFIC PLANNING ASSOCIATES	POSITION DATE	

Roads and Traffic Authority, N.S.W.
SYDNEY CITY COUNCIL AREA
TRAFFIC SIGNALS AT THE INTERSECTION OF
EDWARD STREET AND UNION STREET
PYRMONT
DESIGN LAYOUT TCS No 3202

EXISTING <input type="checkbox"/>		PROPOSED <input checked="" type="checkbox"/>	
CADD FILE:	W3202-5A.DGN	SCALE	1:200
FILE	412 TS 584	SUPERSEDES SHEET/ISSUE	1B
REGN.	7000.412.W.3202	SHEET	5