18

Chapter 18

Traffic Signals

18

Table of Contents

18

18

Chapter 18 Amendments - October 2001

Revision Register

Issue/ Rev No.	Reference Section	Description of Revision	Authorised by	Date
1		First Issue.	Steering Committee	May 2000
2	18.6.3	Modifications to the second paragraph and Figures 18.8 and 18.9.	Steering Committee	Aug 2000
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	18.4.9	Reference to Standard Drawings 1446 and 1447 added.		
	18.5.3	Figure 18.6 modified to cater for visually impaired.		
	18.5.8	New Section - ‘Marking for Cyclists’.		
	18.10.4.1	Push Button access for disabled - changed to 1m above the surface.		
	18.14.3	Minimum width of median changed to 2.0m.		
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	18.4.4	Modifications to Figure 18.1		
	18.4.5	Modifications to Figure 18.2		
	18.4.10	Modifications to Figure 18.5		
	18.8.3	Additional text to last paragraph		
	18.11.2	Additional text		
	18.14.3	Additional text and modifications to Figure 18.18		

Chapter 18
Traffic Signals

18.1 Introduction

18.1.1 Purpose

The purpose of this chapter is to provide guidelines for the provision of a signalised intersection and requirements for the intersection design.

18.1.2 Investigation

Requests for the installation of traffic signals may come from many sources. These requests usually arise because of an existing problem such as lane blockages, long queues, excessive delays or a poor accident record. In many cases these requests are well founded, but in others they may arise because of an ignorance of basic traffic engineering principles. An investigation should always be carried out to determine whether or not traffic signals can solve the problem and whether or not they are the most appropriate solution.

18.1.3 Associated Australian Standards

This chapter is complementary to AS1742 Part 14 "Manual of Uniform Traffic Control Devices - Traffic Signals" and other associated Australian Standards.

18.1.4 Associated AUSTROADS Guides

AUSTROADS has issued a number of publications relevant to signalised intersections, in particular Guide to Traffic Engineering Practice - Part 7: Traffic Signals.

18.2 Warrants

18.2.1 General

This section describes the general warrants for the installation of traffic signals. It must be emphasised that these are only a guide. If a site satisfies the warrants it does not necessarily mean that traffic signals are the best solution. All traffic data should be analysed and alternative treatments considered to determine the optimum solution.

18.2.2 Factors Influencing the Provision of Traffic Signals

Traffic signals are usually installed at an intersection:

- to provide traffic control at a site with a traffic capacity or road safety problem;
- to control conflicting movements with high traffic flows;
- to facilitate access to and from local areas in a major/minor road system;
- as part of an area wide system of traffic management.

A side effect of signalisation is that the traffic flow on a major road is broken up into platoons. This assists nearby pedestrians to cross the major roads and allows vehicles in nearby streets to cross or enter the major road.

Factors influencing the provision of traffic signals include:

- traffic flows
- traffic conflicts
- traffic accidents

- pedestrian requirements
- access to major roads
- cost of installation

General warrants for traffic signals are given in the Main Roads Manual of Uniform Traffic Control Devices Part 14 Section 5.

18

18.2.3 Mid-Block Pedestrian Crossings

The need for a signalised mid-block pedestrian crossing is a function of the probability of a pedestrian being able to find a suitable gap in vehicular traffic. Finding such a gap depends on the speed, concentration and flow of vehicles not just the flow of pedestrians. Therefore factors such as randomness, number of lanes and upstream influences need to be taken into account as well as the proportion of children, elderly or handicapped pedestrians and pedestrian desire lines.

Provision for a signalised mid-block pedestrian crossing should consider that the facility might attract extra pedestrians to the site. Therefore justification should be based on the potential pedestrian flow rather than the existing or actual flow.

General warrants for pedestrian traffic signals are given in the Main Roads Manual of Uniform Traffic Control Devices Part 10 Section 6.4.2.

18.3 Preliminary Design

18.3.1 General

Preliminary design data is used to assess the adequacy of geometric layouts, the location of signal equipment, the signal phasing and time settings. This data can be divided into three categories:

- physical layout;
- traffic data; and
- planning information regarding future developments.

Where data is estimated or predicted, the effects of its accuracy on the design should also be considered.

18.3.2 Physical Layout

The following features of the site covering 50m on each approach should be shown on the base plan (preferably drawn to 1:250 scale):

- relevant property boundaries and building lines;
- location of shoulders and kerbs and channels including gully pits, driveway crossings and kerb ramps;
- bicycle lanes;
- edges of medians and islands;
- paved footpaths and driveways;
- parking, bus bays or taxi zones;
- location of all poles and aerial cables;
- location of all service manholes;
- position, type and size of any signs or other roadside furniture eg bus shelters, guardrail, etc;
- location and nature of road lighting;
- position of any overhead obstructions eg power lines, shop awning, etc;
- location of trees with diameter of trunk, height and spread of foliage; and
- location of bridge decks, parapets (incl. height) abutments and relieving slabs.

Additional information required should include:

- vertical geometry of the intersection and approaches;
- location of any nearby fire station, ambulance or railway level crossing that may influence the design;
- condition of pavement;

- one way traffic movements;
- photographs taken from each approach to show a clear vision of the intersection and additional photographs showing problem utilities or obstructions; and
- any other features that may affect the design.

18.3.3 Traffic Data

Traffic signals should operate over a wide variety of traffic conditions. While designs are based on peak traffic conditions, efficient operations at peak and lower volumes are provided by the use of traffic actuated controllers.

Traffic volumes are expressed in hourly flow rates including turning movements and proportion of commercial vehicles. Usually 15 minutes summation intervals are used so the peak flow rates can be identified. Traffic counts may vary by day of the week, weather conditions, school or public holidays or other abnormal conditions. The circumstances of the count should be adjusted or a recount taken before determining the volumes for the design.

Counts should identify the pedestrian volumes crossing each vehicle approach and the proportion of children, aged or disadvantaged pedestrians should be included. These are required to enable specific features to be designed where necessary.

Bicycle volumes should also be counted both along and across each vehicle approach to identify the need for special features in the design.

Accident data should be obtained to identify hazard problems for which the signals should cater. Accident data for this purpose are best shown as collision diagrams and it is usual to show at least three years of data.

18.3.4 Bicycles

The needs of cyclists must be incorporated into the design. Details of possible treatments are discussed in Austroads (1999) and in Queensland Transport's Bicycle Notes.

18.3.5 Future Developments

During the design of traffic signal installations it is necessary to consider future developments as these may indicate the need for additional features and/or equipment eg controller location, ducts and cabling that may become necessary. Where appropriate these should be included in the design.

18.4 Geometric Requirements

18.4.1 General

This section deals with the aspects of intersection geometry that are specific to signalised intersections. A complete treatment of geometric requirements is given in Chapter 13 of this Manual.

When designing for traffic signals at an intersection it is important to identify and rectify deficiencies in the geometric layout to ensure safe and efficient operation and hence obtain the maximum benefit from signalisation.

The design of the intersection should provide for:

- optimum location of traffic signal hardware;
- clearance to traffic signal hardware;
- clearly defined vehicle turning paths;
- adequate sight distances;
- storage requirements;
- minimising the distance between stop lines;
- pedestrian requirements;
- minimising the length of pedestrian crossings;
- medians and left-turn islands (where required);
- exclusive bus or transit lanes;
- auxiliary lanes (where required).

Any changes in the geometry should be in accordance with Chapter 13 of this Manual but care should be taken in applying these principles. The combined effect of horizontal and vertical alignment should be considered at all times.

18.4.2 Intersection Configuration

The installation of traffic signals and associated islands may restrict the movement of larger vehicles and it is necessary to choose a suitable 'design vehicle'. The turning path characteristics of the 'design vehicle' are used to ensure that pavement widths, alignments, kerb locations and roadside furniture positions are suitable.

Because of these requirements larger turning radii may be considered. The following problems are associated with the use of larger radii especially for left turning movements:

- hazard to pedestrians by increased turning speed;
- delays because of increased clearance times as the stop lines are located further from the intersection;
- longer pedestrian crossing distances or deviations from their direct route;
- difficulty of achieving optimum lantern positioning and aiming.

Use of smaller radii may require large vehicles to encroach on other traffic lanes but this may be acceptable if occurring infrequently.

Refer to Chapter 13 dor details of geometric design.

18.4.3 Traffic Lanes

The number of traffic lanes to be provided on a particular approach depends on the traffic flow, available width and scope for future widening.

To increase the capacity of a particular intersection approach the number of lanes on that approach or on other approaches may need to be increased. This can be achieved by either reducing the width of existing lanes or by widening the approach and departure carriageways and providing appropriate tapers to allow proper usage of the lanes.

Through lanes across an intersection should be aligned to achieve clear definition of vehicle paths. When it is desired to store vehicles in separate turning lanes adjacent to through traffic lanes it is important to ensure that adequate storage length is provided. Where adequate storage length cannot be provided the signal phasing may need to be modified.

18.4.4 Sight Distance

Sight distance requirements for a signalised intersection should be in accordance with Chapter 13. The combined effect of horizontal and vertical alignment on sight lines and stopping distances must be considered at all times. In addition stopping sight distance (refer Figure 18.1) should be the minimum available to:

- provide clear sight of primary, overhead primary or dual primary lanterns as applicable;
- the rear end of a stored vehicle or stationary queue.

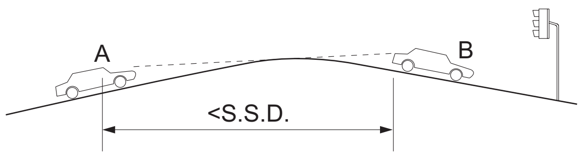

Figure 18.1 Stopping Sight Distance

If stopping sight distance to primary or dual primary lanterns is inadequate then overhead primary lanterns will be required if regrading is not carried out.

If stopping sight distance to the rear of a stored vehicle or stationary queue is insufficient the probability of a rear end collision is high. If vehicle B is a through vehicle there is no simple solution to the problem of inadequate stopping sight distance other than regrading. If vehicle B is waiting to make a turn then possible solutions are to:

- provide an exclusive turn bay;
- ban the turn;
- split the approach phasing;
- regrade.

If the road alignment does not provide sufficient sight distance and the existing geometry cannot be adjusted, provision of advance warning signs (W3-3) or advance warning signals eg flashing yellow lights will be necessary.

18.4.5 Medians and Islands

The following criteria should be observed when designing median islands at signalised intersections:

- a minimum clearance from face of kerb to the signal lantern target board of 0.5m is desirable refer (Table 18.1);

*Table 18.1 Minimum Widths of Raised Medians**

Situation	Desirable (m)	Absolute (m)
No posts	1.2	0.9
Post with single 200mm lanterns	2.4	1.2
Post with dual 200mm lanterns	2.4	1.5
Two-stage mid-block pedestrian crossing	4.0	4.0

* Residual median at the signals.

- where pedestrians are likely to accumulate on medians or islands the width should be a minimum of 1.5m to 2.0m (refer AS1742);
- if a protected right turn lane is provided, the residual median width should satisfy the above two dot points;
- the use of wide medians reduces capacity because of increased clearance times. Wide medians may cause the problem of interlocking opposing right turn vehicles and therefore should be avoided;
- the ends of medians and islands should be set back a minimum 0.6m behind the prolongation of the kerb lines or full shoulder width unless a pedestrian crossing is provided;
- when a pedestrian crossing is provided the median should preferably terminate at the crossing unless a gap in the median as wide as the crossing is provided and the median continued for at least 2m beyond the crossing (refer Figure 18.2).

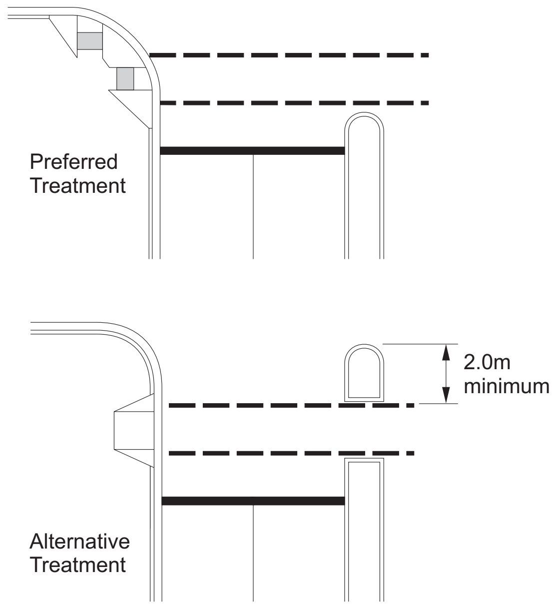

Figure 18.2 Treatment at Pedestrian Crossings

While the minimum width of median is stated as 0.9m (no posts) in Table 18.1, lesser widths of painted median may be used. The use of back-to-back median kerb is not recommended as it is:

- not readily observable by approaching drivers particularly in bad weather;
- a hazard for errant vehicles straddling it;
- not wide enough to provide adequate refuge for pedestrians.

Where a two-stage signalised pedestrian crossing is used, the median must be a minimum of 2m (2.5m to 4.0m desirable) wide to allow for pedestrian storage.

Median islands for minor channelisation should be at least 10m long to ensure adequate conspicuity. If a signal post is provided it should be at least 1.2m wide.

Painted medians or islands may be used where there is not sufficient carriageway to construct a kerbed median or island or where it is desirable to permit vehicles to cross the median.

Traffic signal posts should always be located behind raised kerbing and must not be placed in the painted areas.

18.4.6 Left Turn Islands

Left turn islands for slip lanes may be used as shown in Figure 18.3 to:

- reduce the distance between stop lines;
- reduce the length of pedestrian crossings;
- enable the free flow of left turn vehicles where this would benefit capacity without endangering pedestrians.

Left turn islands should be designed to accommodate traffic signal equipment, storage of pedestrians and the ends of any stop lines and pedestrian crossings including tactile indicators. Providing for all of the needs of users, together with the physical space needed to accommodate the equipment requires an island of sufficient size to avoid congestion and clutter. A minimum size of 25m² should be provided (see Chapter 13).

To minimise the consequences of a possible pedestrian/vehicle conflict, kerb radii in excess of 20m should be avoided, keeping design speeds to approximately 30km/h or less. The preferred treatment is to reduce the left turn speed by redesigning the kerb line as shown in Figure 18.4(b). The side street phase pedestrian movement may be protected if required. (See also Chapter 13, Sections 13.8.6, 13.8.7, 13.8.8.)

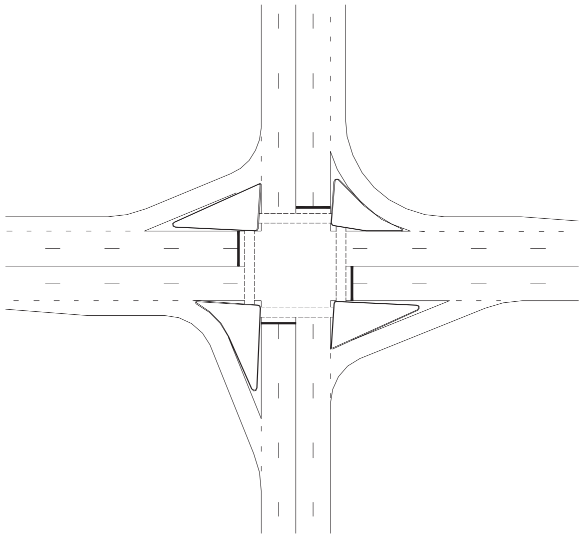

Figure 18.3 Left Turn Island Treatments

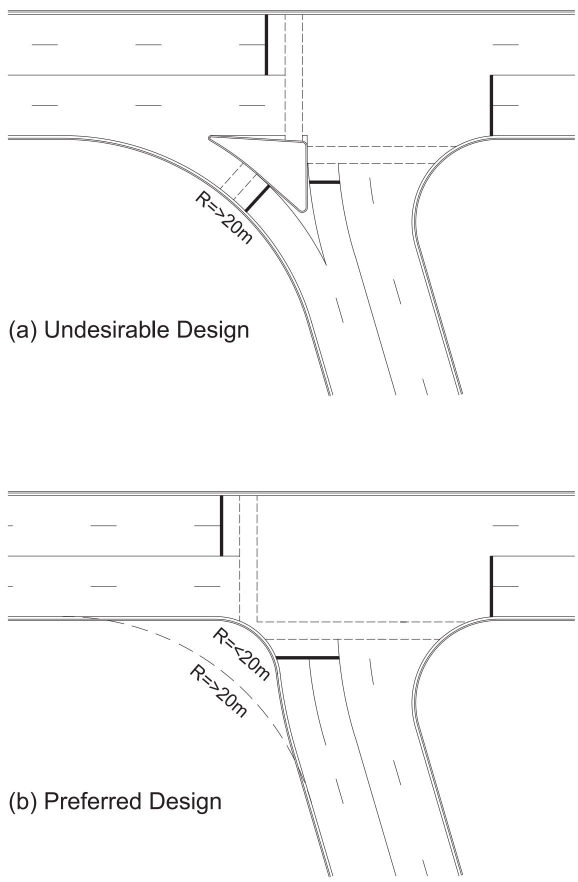

Figure 18.4 Reduction of Left Turn Speed

18.4.7 Right Turn Lanes

Where through and right turn vehicles share a lane the following may occur:

- hazardous situations created by a right turning vehicle stationary in a through lane;
- blocking a through lane increasing intersection delays;
- inefficient use of any right turn phase.

Exclusive right turn lanes are therefore desirable on all intersection approaches where traffic volumes are sufficiently high (see Chapter 13, Figure 13.21). A correctly designed right turn lane will provide a deceleration length and a storage length long enough to accommodate the maximum expected queue of right turn vehicles. If the deceleration length cannot be achieved (as is often the case in urban areas) the lane should be at least long enough to accommodate the stored right turn vehicles so they do not overflow and block the adjacent through lane. They should also be long enough to allow the right turn vehicles to enter the right turn lane without being blocked by the queue of vehicles in the adjacent through lane.

The calculation of the expected queue lengths can be carried out by computer analysis eg SIDRA (Simulated Intersection Design Research Aid). (Refer also to Chapter 13, Appendix A13.3.1).

18.4.8 Diamond Turns

Designs should provide sufficient clearance for diamond turns ie opposing right turns operating concurrently and be in accordance with Chapter 13, Section 13.8.4.8. Where there is insufficient width for a diamond turn either one of the turns must be banned or the phasing altered so that the right turns operate during different parts of the cycle eg split approach phasing.

18.4.9 Ramped Pedestrian Crossings

Ramped pedestrian crossings should be provided at all pedestrian crossings whether signalised or not. The number and position of ramps are determined by considering the general movement of pedestrians, the location of pedestrian crossings and any obstacles such as traffic signal posts and utilities. Wherever practical ramps should be located downstream of adjacent gully pits.

Ramps should be installed so that they guide pedestrians (particularly the visually handicapped) across the road by the most direct route. Detailed requirements are shown in Standard Drawings 1446 and 1447.

See Chapter 7 for details of this type of crossing (kerb types 18, 19, 20, 21).

18.4.10 Service Roads

Service roads should not generally be carried through signalised intersections because they cause:

- reduction in safety due to the greater number of conflict points, the larger intersection conflict area and the difficulty for the right turning motorist to select appropriately sized gaps in opposing traffic on two carriageways;
- reduction in intersection capacity because of increased pedestrian and vehicle clearance times.

Therefore where service roads are provided problems can be minimised by terminating the service road or by carrying it around the corner as a left turn movement only. See Figure 18.5 for typical examples.

Alternatively, if space is available, the service road can be "bulbed" to intersect the cross road at a distance from the intersection sufficient to form a separate intersection. This distance will be longer than the expected queue at the intersection or a minimum of 20 m (allows a semi trailer to do a U-turn between inside lanes).

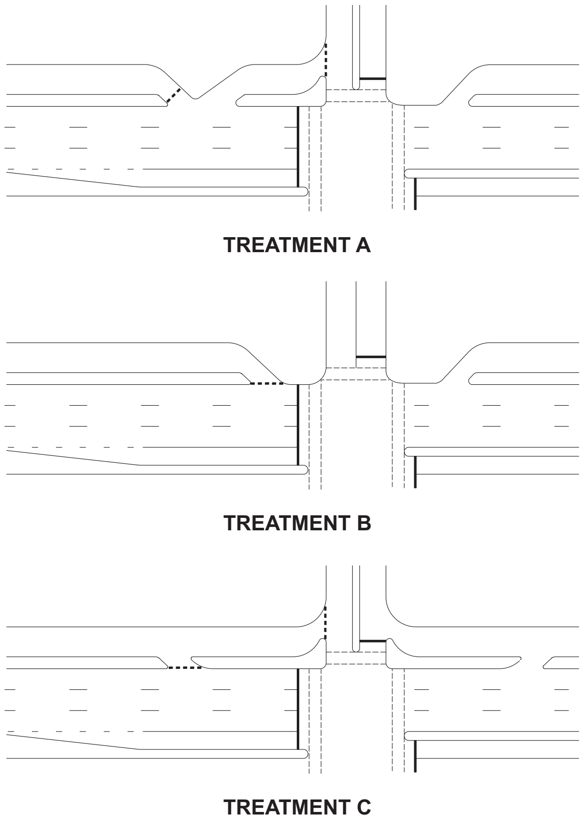

Figure 18.5 Typical Service Road Treatments

18.4.11 Parking

Vehicles parked near an intersection can cause the following:

- reduction in the numbers of effective lanes on an approach ;
- reduction in the numbers of effective departure lanes;
- misleading activations of the traffic detectors;
- obstruction of signal displays and other control devices;
- reduced sight distances for vehicle or pedestrian traffic;
- delays as vehicles manoeuvre into parking spaces.

Where statutory restrictions are not adequate parking prohibitions and restrictions are necessary to reduce these difficulties.

18.4.12 Bus Zones

The effect of bus bays or zones close to an intersection is similar to that of short term parking. Bus stops on the approaches cause detection difficulties if placed between the loops and the stop bar and when designing bus priority schemes. Bus stops on the departure sides can cause platoons of vehicles to queue through the intersection and the use of bus bays should be considered.

18.5 Pavement Markings

18.5.1 General

This section discusses some of the pavement marking requirements specific to signalised intersections. General requirements for pavement markings are given in the Main Roads Manual of Uniform Traffic Control Devices Part 2 Section 4.

18.5.2 Stop Lines

Stop lines should be located:

- so as to minimise intergreen times and clearance times;
- not less than 3m from conflicting vehicle movements;
- clear of the swept path of vehicles turning from other approaches;
- a minimum of 1.0m from parallel pedestrian crossings at intersections;
- a minimum of 3m from signalised mid-block pedestrian crossings;
- at a desirable 10m in advance of the starting (secondary) lantern for that approach except for mid block pedestrian crossings; and
- at a maximum skew of 70 degrees to the direction of travel (over 70°, stop line may be stepped).

18.5.3 Pedestrian Crosswalks

The pedestrian crosswalk widths should be at least 2m wide. This should be increased when there are heavy pedestrian volumes.

Pedestrian crossings should be located:

- as near as possible to the desire lines of pedestrians;
- as near as possible to and no greater than 20 degrees from the shortest path across the carriageway to minimise clearance times;
- as close to, but at least 0.6m clear of, parallel vehicle movements.

Where two pedestrian crossings meet the intersection point of the outside edges should be no more than 1m from the face of the kerb (Figure 18.6). This is to minimise conflicts by pedestrians in separate phases and to deter pedestrians from waiting on the road pavement.

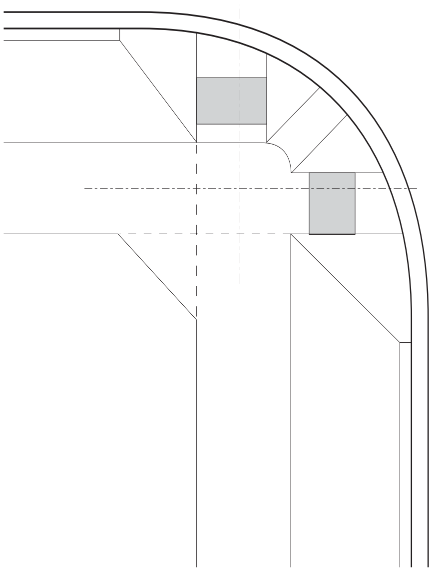

Figure 18.6 Intersection of Pedestrian Crossings

Where a pedestrian crossing is provided to a left turn island the crossing ends at the kerb not at the painted chevron. This is to discourage pedestrians from standing on the road pavement (Figure 18.7).

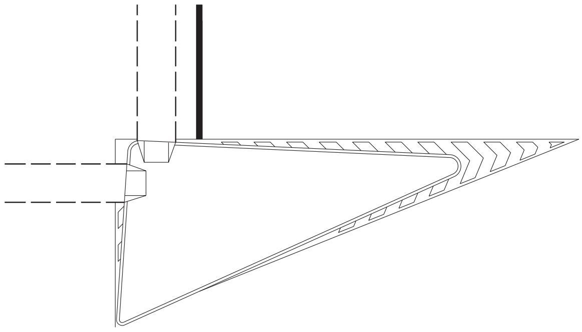

Figure 18.7 Pedestrian Crossings at Left Turn Islands

18.5.4 Longitudinal Lines

To control overtaking in the vicinity of the intersection and the position from which right turns are made, a median island, barrier lines or a single unbroken line may be used. The length of barrier line should be 27m minimum from the stop line and further extended if required. Requirements for kerbside parking and access to property entrances adjacent to the barrier line should be considered.

Broken lane lines should be provided where possible for at least 51m on the approach and 27m on the depart side of an intersection. Where necessary to improve lane discipline lane lines may be marked as unbroken lines.

18.5.5 Turn Lines

Turn lines may be used to provide delineation to guide two or more streams of traffic which turn simultaneously in the same direction or provide guidance through intersections with unusual geometry, skewed approaches or lanes not aligned across the intersection.

Turn lines should not be carried through pedestrian crosswalks.

18

18.5.6 Pavement Arrows

Pavement arrows should be used:

- in auxiliary lanes (left or right) to avoid inadvertent use by through vehicles;
- to allow movements that would not otherwise be allowed under traffic regulations;
- to prohibit movements that would otherwise be allowed under traffic regulations.

Pavement arrows should not be used to reinforce lane usage that is regulated by traffic regulations. If drivers are breaking the law relating to lane usage it may indicate that the existing lane distribution is inappropriate and may need to be changed.

A minimum of three arrows in any lane should be provided.

18.5.7 Painted Islands

Where painted islands are used at signalised intersections traffic signal hardware must not be mounted on them.

18.5.8 Marking for Cyclists

The special needs of cyclists at intersections can be accommodated in a range of ways, depending on the circumstances involved. Details of the marking systems for cyclists at intersections are provided in Austroads (1999), Queensland Transport's Bicycle Notes and Part 14 of the MUTCD.

18.6 Signs

18.6.1 General

This section refers to signs that are uniquely associated with traffic signals. General requirements for signs are given in the Main Roads Manual of Uniform Traffic Control Devices.

18.6.2 Parking

Signs controlling or prohibiting parking or standing are used extensively in the vicinity of signalised intersections to improve capacity and to reinforce statutory no standing requirements associated with traffic signals.

18.6.3 One Way (R2-2), No Entry (R2-4) and No Left/Right Turn (R2-6)

Traffic signals at the intersection of one or more one-way streets need to be signposted to eliminate the possibility of confusion to motorists.

When a right turn movement is banned to deny wrong-way entry to a one-way street a No Right Turn sign should be placed on the post carrying the primary lantern and a One Way sign on the post carrying the tertiary lantern (Figure 18.8).

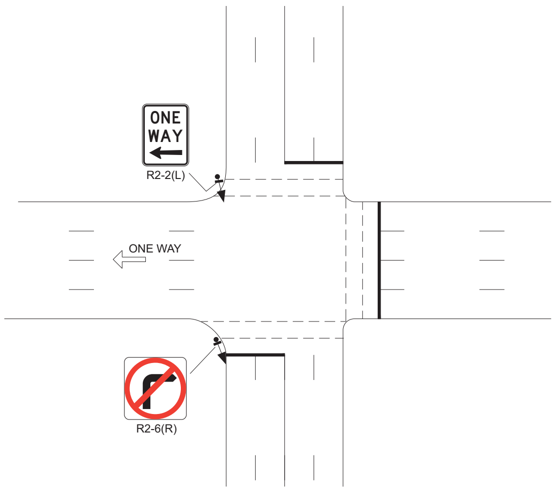

Figure 18.8 Left Turn Movement

When a left turn movement is banned to deny wrong-way entry to a one-way street a No Left Turn sign should be placed on the post carrying the dual primary, overhead primary and primary lantern and a One Way sign on the post carrying the secondary lantern (Figure 18.9).

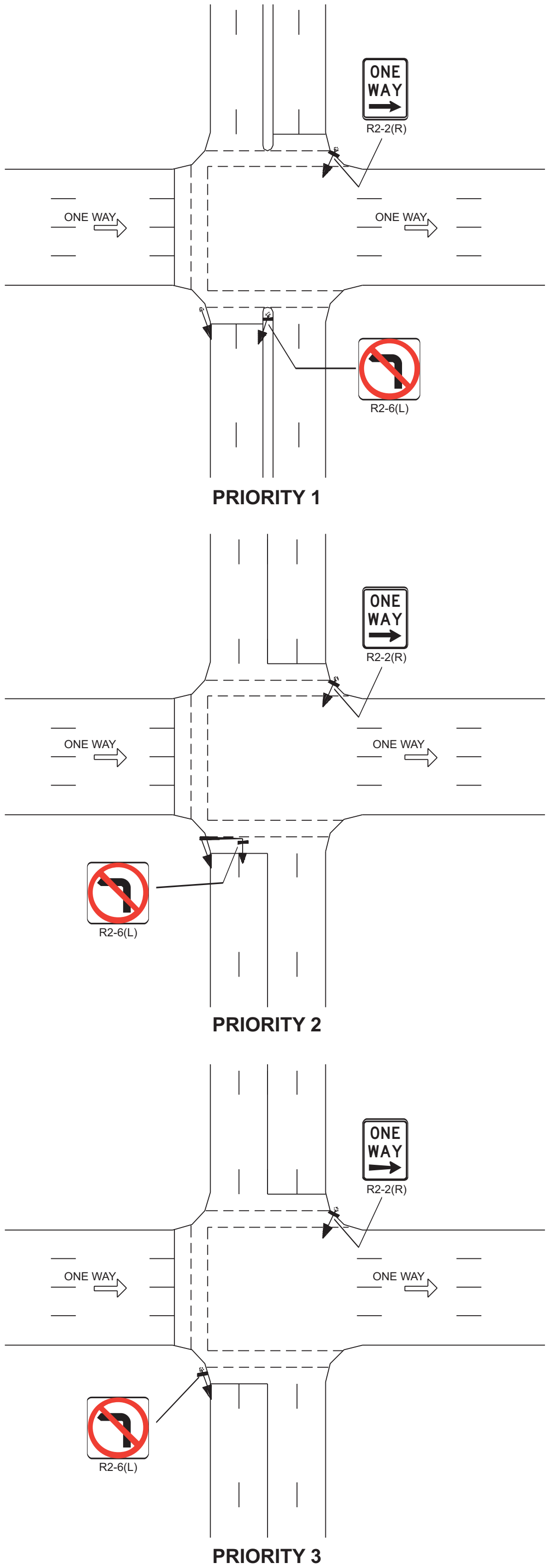

Figure 18.9 Right Turn Movement

When a through movement is banned to deny wrong-way entry to a one-way street a No Entry sign should be placed on the posts carrying the secondary and tertiary lanterns (Figure 18.10).

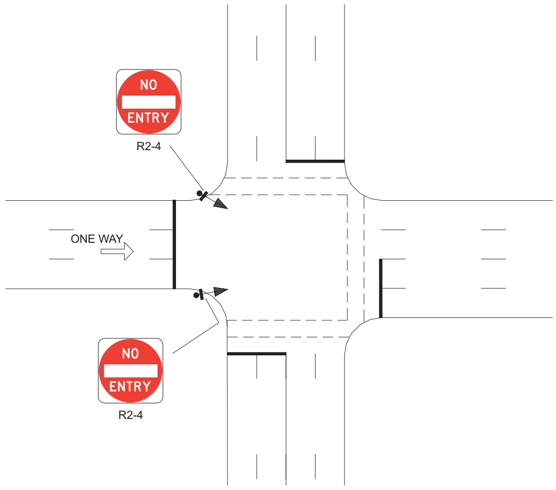

Figure 18.10 Through Movement

18.6.4 Give Way to Pedestrians (R2-10)

This sign is only used at signalised intersections where there is a need to remind drivers of right or left turning vehicles that although they are still under the control of the intersection signals they must give way to pedestrians.

The sign should not be used except in special circumstances because indiscriminate use would reduce the effectiveness of the general regulation applying to signalised intersections.

18.6.5 U-Turns Permitted (R2-15)

U-turns are prohibited by regulation at all intersections controlled by traffic signals. Therefore signs prohibiting U-turns should not be installed.

Where it is considered desirable and safe to relax this rule the U-Turn Permitted sign is used. As a general rule the sign should only be used on intersection approaches with medians and preferably with right turn auxiliary lanes.

U-turns should only be permitted where:

- geometry is sufficient to allow the U-turn to be made in one manoeuvre by vehicles of the type likely to U-turn;

- there are no more than two lanes of opposing through traffic;
- there is adequate visibility of approaching vehicles;
- there would be no danger to pedestrians.

18

18.6.6 Left Turn At Any Time With Care (R2-16)

The sign Left Turn At Any Time With Care should only be used at an intersection controlled by traffic signals where there is a slip lane for the left turn movement not required to comply with the traffic signals and falls clearly within the boundary of the intersection.

It should be mounted on the left hand side at the beginning of or within the slip lane but may be located on the right hand side so that it faces only the traffic approaching and using the slip lane.

18.6.7 Stop Here on Red Signal (R6-6)

This sign is not intended for routine use at signalised intersections. Its use is generally limited to situations where signals might be unexpected such as fire station or ambulance signals which are only in use in an emergency.

18.6.8 Signals Ahead (W3-3)

This sign is required where signals are located in an unexpected position eg restricted visibility on the approach to lanterns or end of queue, or temporary signals.

Where there is a high risk of rear-end collisions with vehicles stopped against a red signal the use of Advance Warning Signals incorporating the Signals Ahead sign should be considered. A device of this type should be located at not less than the stopping distance in advance of the probable end of queue.

18.7 Signal System and Components

18.7.1 System Purpose

Signal control is provided to:

- reduce traffic conflicts and delays;
- share times between conflicting movements;
- reduce accidents.

18.7.2 System Process

Demands for traffic movements are identified through vehicle detectors, pedestrian push buttons and externally supplied data from area control masters. The signal system transforms traffic demands in a manner determined by the controller algorithms and operational settings into a sequence of signal displays.

18.7.3 Components

18.7.3.1 Vehicular Lanterns

These lanterns convey the control signals to vehicular traffic. They include 200mm and 300mm diameter red, yellow and green aspects and may have arrow masks or other qualifying symbols.

18.7.3.2 Pedestrian Lanterns

These lanterns are provided for the control of pedestrians. Red and green symbolic displays are used.

18.7.3.3 Associated Equipment

Visors are used to minimise sunphantom effects and to reduce the possibility of a signal being seen by traffic for which it is not intended.

Louvres may be used to minimise sunphantom effects when oriented horizontally or to reduce the possibility of a signal being seen by traffic for which it is not intended. As louvres constrict light distribution their use should be restricted to essential locations.

Target Boards surround the signal lantern in order to improve the visibility of the signal. Black target boards provide the best signal conspicuity.

Symbolic displays (masks) such as arrows can be used to mask signal aspects. These displays are used to dedicate the aspect for a particular movement or vehicle type.

18.7.3.4 Lantern Supports

Posts, poles, brackets and straps are used to support the signal lanterns at the required height. Posts may be up to 5.1m in height. Joint use poles or mast arms may be up to 12m in height with up to 6.5m outreach. Joint use poles are used to reduce the number of poles at a particular site. Typical examples are illustrated in Standard Drawing 1420.

18.7.3.5 Power Reticulation

The supply of power throughout the signal installation is made via traffic signal cable that is laid underground in ducting. Changes of direction in the ducting are made at junction pits. Junction pits are provided adjacent to the controller cabinet and each signal post or pole. Junction pits and terminal assemblies provide for the connection of the cable to the signal equipment.

The signal cable provides 240 volt (nominal) 50Hz power to the signal lanterns and other traffic demands and 32 volt circuits for the pedestrian push buttons. This is a low voltage installation and must be installed to the requirements of Standard Drawing 1149 and AS/NZS 3000 - Wiring Rules.

18.7.3.6 Traffic Signal Controller

The traffic signal controller regulates the sequence and duration of aspects and intervals.

Main features of this equipment include:

- circuit breakers for the signal lanterns; controls for safe display of lanterns by interlocking or solid state switching; monitoring by current and voltage feedback to green and red aspects;
- provision for display of minimum green periods and safe clearance periods between conflicting movements;
- storage of detector and push button information to determine the sequence and duration of green displays;
- facilities for traffic personnel to monitor or alter its operation;
- communication and other facilities to allow control by a remote master controller or computer.

18

18.7.3.7 Detection

The most common form of vehicle detector is the inductive loop sensor. Several turns of wire (see Standard Drawing 1424) are placed in a slot cut in the road pavement. The wire is connected via a feed cable to a detector sensor unit mounted in the controller cabinet. A vehicle (ie a large mass of metal) presence or movement over a loop reduces the loop inductance and causes a detector output. This output is the closure of a relay contact or the equivalent operation of a semiconductor.

Pedestrian demands are recorded when a pedestrian presses a push button mounted on the side of the signal post or pole.

Detection of bicycles and light motor cycles is difficult but may be achieved by using special loop designs and sensitive detectors. Refer to Austroads (1999), Part 5.4.1.

Priority vehicles may also be detected if special detector systems are used.

18.7.4 Component Selection

The selection of the components to be used for a signal installation will be determined by the signal design. Consideration should also be given to practical restrictions such as availability of components, maintenance requirements, stock holdings, price and standardisation of installation.

18

Some modifications to design may be required in order to achieve overall economic efficiency for the supply, installation and maintenance of the system.

18.8 Phasing

18.8.1 General

The choice of phasing for a particular intersection depends primarily on the flows of vehicles and pedestrians for each movement. Phasing can also depend on geometry. Design strategies should be to:

- minimise the number of phases to make best use of the available time;
- minimise the cycle time;
- run as many compatible movements as possible during each phase;
- restrict each phase to non-conflicting movements;
- allow each movement to run in as many phases as possible.

Design objectives are:

- promote safety, efficiency, consistency and simplicity;
- optimise capacity and reliability;
- minimise operation costs and driver frustration.

In practice it may not be possible to achieve all these objectives simultaneously so a compromise may be necessary. Safety is the foremost consideration when determining compromise.

A signal group is a set of lanterns that share the same colour sequence within each phase and for each phase sequence. A signal group may control one movement or a number of movements.

This section provides guidelines to the selection of phasing and discusses techniques for ensuring that the signal group display sequences are safe and efficient.

18.8.2 Phasing Elements

The simplest form of phasing at an intersection is two phases which allocates Phase A to the main street and Phase B to the cross street as shown in Figure 18.11.

This phasing leaves four crossing conflicts (between right turn vehicles and through vehicles), four merge conflicts (between right turn vehicles and left turn vehicles) and eight vehicle/pedestrian conflicts (between left/right turn vehicles and pedestrians.

Nevertheless this phasing will usually work quite adequately for a site with geometry and sight distance which meets the required design standards, no record of severe accidents and low vehicle and pedestrian flows because the priority for each conflict is determined by the traffic regulations.

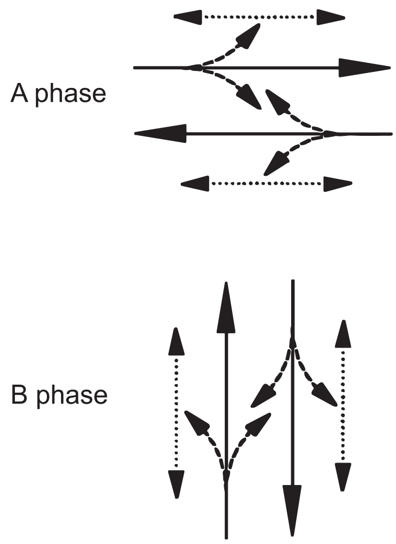

Figure 18.11 Two Phase Design

As the potential safety and efficiency of an intersection declines due to poorer geometry, inadequate sight distance, reduced capacity or increased vehicle or pedestrian flows it becomes necessary to increase the number of phases and use more complex phasing by using additional signal groups to control certain movements.

Phases for protecting right turns are the most commonly added phases. The basic sequences that accommodate right turn movements include:

- ***Protected Right Turn.*** This is a right turning movement in which only one approach is protected and moves on the arrow indication. If preceding the opposing through movement it is termed a 'leading right turn' and if following a 'lagging right turn'.
- ***Diamond Turn.*** This is a right turning movement where the opposing right turns move simultaneously in a phase of their own.
- ***Diamond Overlap Turn.*** In this operation the opposing right turns start simultaneously. When one terminates the through movement in the same direction as the extending right movement is started. When the extending right turn is terminated the other through movement is started. It is usually used in preference to a diamond turn.
- ***Lead-Lag Turn.*** This phasing is the combination of a protected leading right turn in one direction followed by the through movements then by a lagging right turn in the opposing direction. It is usually used in systems to provide a wider two-way through band.
- ***Split Phase.*** This phase is where the movements of opposing traffic flow in totally separate phases. The right turn and associated through movements flow at the same time whilst all opposing movements are stopped.

Although there are no limitations to the number of phases that can be utilised they should be held to a minimum. Movements that run in more than one phase should preferably be allowed to overlap to reduce delays and improve safety. However, there are situations where this is not possible because other more dangerous conflicts would result. In this case it is necessary to stop the relevant movements and restart them following a suitable delay.

18.8.3 Right Turn Movements

There is no formal warrant or guideline available to determine whether or not a protected right turn phase is required. It will depend upon site conditions, traffic flows and signal timings. As a general rule it should be considered when two or more vehicles turn right each cycle.

The protected phase is required if motorists attempting to make a right turn have insufficient opportunities to filter during the through phase and intergreen period and generally when three through lanes are being crossed. This results in the right turn movement being delayed or motorists taking unnecessary risks.

For existing intersections the need for a protected right turn phase can usually be determined by observing the operation of the intersection. If the right turn queue regularly does not clear in a cycle and the intersection is operating at a relatively high cycle time then a protected right turn phase is needed. At signals operating on short cycle times extending the through phase green time will increase the opportunity for vehicles to turn right. This can be accomplished by utilising presence loops to detect vehicles waiting to turn right and extending the through phase with this detection.

Where traffic conditions are changing or a new intersection is being designed, it is not possible to observe traffic operations. The need for a protected right turn phase must be based on traffic volumes. In general a protected phase will be required if there are more than 200 vehicles/hour turning against more than 600 vehicles/hour. A protected right turn phase would not be required where the right turn volumes are less than 60 vehicles/hour depending on the opposing volume and alternative access arrangements.

18.8.3.1 Right Turn Ban

Banning the right turn should be avoided unless the right turn flows are low and a suitable alternative route is available.

18.8.3.2 Right Turn Filter

A right turn filter is where right turn vehicles select gaps in the opposing vehicle flow. The flow rate of a filter right turn is affected by:

- the rate of the opposing flow;
- the speed of the opposing flow;

- the number of lanes (or width of the road) that the right turn vehicles must cross;
- the length of phase during which the filter may take place.

Often one or two vehicles will be able to filter during the intergreen period. Any right turn vehicle that has crossed the stop line during the green interval may legally complete the turn during the intergreen.

A filter right turn should not be permitted on approaches where:

- sight distance is insufficient to filter safely;
- there is more than one right turn lane;
- it is possible for a yellow signal to be displayed to the right turn vehicle when the opposing approach has a green signal, eg the opposing approach has a lagging right turn or the approach with the right turn has an early cut-off;
- the 85th percentile speed of the opposing traffic is greater than 70km/h and the right turn has to filter across more than two lanes;
- there is an adverse traffic accident history involving filtering right turn vehicles;
- the opposing approach is four lanes or more wide.

18.8.3.3 Protected Right Turn

A right turn phase can be provided as the only means by which vehicles are permitted to turn right or it can be provided in addition to a filter right turn permitted in another phase.

A right turn phase can operate as a leading right turn or a lagging right turn. Both the leading and lagging right turns can operate with or without the right turn operating as a filter movement.

A leading right turn occurs when the right turn phase precedes the phase in which the opposing through movement runs as shown in Figure 18.12.

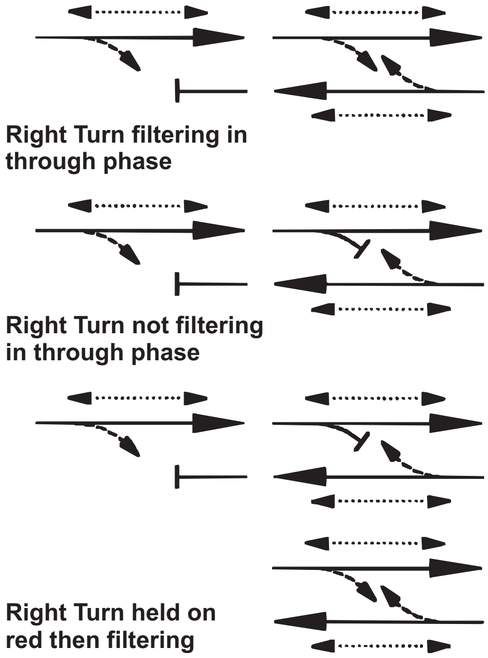

Figure 18.12 Leading Right Turns

A lagging right turn occurs when the right turn phase follows the phase in which the opposing through movement runs as shown in Figure 18.13. This phasing cannot be used at cross roads where the other right turn filters.

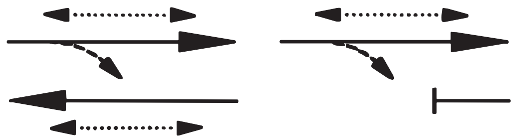

Figure 18.13 Lagging Right Turn

When a right turn movement operates as a phase and filter turn:

- the lagging right turn sequence is normally used when the opposing right turn filter can be banned and is preferred at T junctions;
- the leading right turn sequence is normally used when the opposing right turn filter is light and cannot be banned;
- specific signal groups are required under certain conditions for safety reasons.

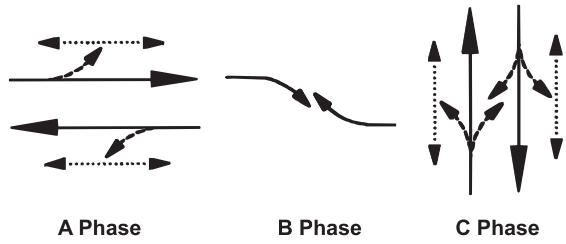

Figure 18.14 Diamond Turn

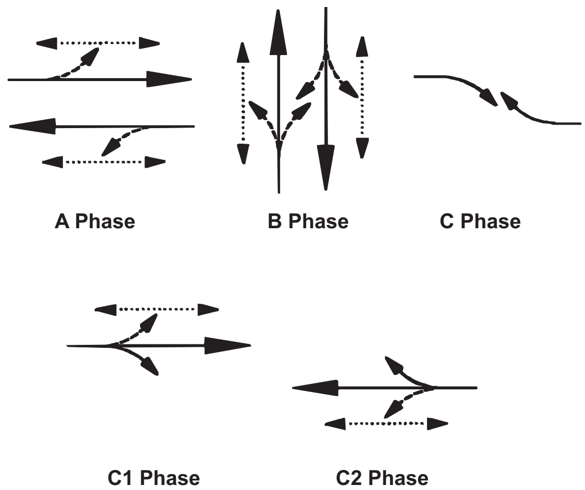

Figure 18.15 Diamond Overlap Phasing

18.8.3.4 Diamond Turn

When it is necessary to signalise opposing right turns and exclusive right turn lanes are available it is possible to allow both right turns to run simultaneously while the through movements are stopped. This is called a diamond turn and is shown in Figure 18.14.

This phasing is inefficient and is not recommended. It should only be considered when both right turn flows are the same under all flow conditions. It is more efficient to use a diamond overlap turn.

Diamond Overlap Turn

Diamond overlap phasing is the combination of a diamond turn with alternative overlaps for one intersecting street as shown in Figure 18.15. This phasing is more flexible and efficient than diamond turn phasing because it can cater for widely varying demands. It is possible to have a filter option in A phase on either or both right turn movements.

Where diamond overlap phasing is required on both intersecting streets a double diamond overlap can be used.

18.8.3.5 Split Phase

Split phase operation as shown in Figure 18.16 is usually only used on side street approaches. It is used where appropriate if both right turn movements require to be protected or where a particularly heavy right turn movement is opposed by a very light movement (the right turn movement may fail to give way to random arrivals on the through movement).

If a pedestrian movement is allowed to run concurrently with each of the split approach phases then the combined clearance times may exceed the cycle time required by vehicle actuation alone. Therefore when using split phasing one of the pedestrian crossings should be sacrificed.

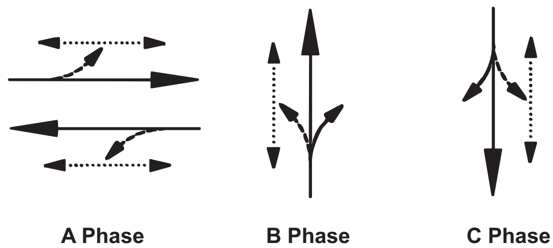

Figure 18.16 Split Phasing

18.8.4 Left Turn Movements

Left turns can be designed in two ways, with or without a corner island. The lane created by using a corner island is called a slip lane. In most cases only one slip lane is required but more lanes can be provided if warranted by traffic flows.

The approach left turn lanes may be shared or exclusive. A shared left turn lane is one where through vehicles use the same lane as the left turn vehicles.

An exclusive lane (dedicated lane) is used solely by left turn vehicles.

18

Signal control of left turns can be complex depending on whether the turn is from a shared lane, an exclusive lane, conflicts with a signal-controlled pedestrian crossing or overlaps from one phase to another.

Depending on site conditions and constraints a left turn movement can be permitted to operate in:

- one phase;
- separate phases (overlapping/non overlapping);
- all phases (exclusive protected depart lane - left turn on red is not permitted in Queensland).

18.8.4.1 Corner Island

If a corner island is provided, ie there is a slip lane, the left turn movement can be allowed to turn:

- left at any time it is safe to do so by providing a Turn Left At Any Time With Care sign (G9-14);
- at any time into an exclusive departure lane;
- when a left turn green aspect is displayed.

The first two options are not controlled by signals.

18.8.4.2 No Corner Island

If a corner island is not provided, ie there is no slip lane, the left turn movement can be:

- banned;
- allowed to run concurrently with other vehicles on the same approach by displaying a full green aspect;
- allowed to run independently of other vehicles on the same approach by displaying a left turn green arrow.

18.8.4.3 Left Turn Bans

Banning a left turn is very rare and should be avoided unless the left turn geometry is so restrictive that vehicles cannot safely negotiate the turn.

18.8.4.4 Arrow Controlled Left Turns

Left turns can be controlled for one phase operation by either a three aspect lantern or four aspect lantern (three roundels plus a green arrow). For more than one phase operation left turns can be controlled by a three plus two aspect lanterns (three roundels plus green and yellow arrows) or two three aspect lanterns (three roundels plus red, yellow and green arrows).

Left turn vehicles can normally be catered for during the same phase as the through vehicles on the same approach. However it is often beneficial to increase the left turn capacity by allowing the left turns to run complementary to a right turn phase as shown in Figure 18.17. At a T junction it may be included to run complementary to the side street movement.

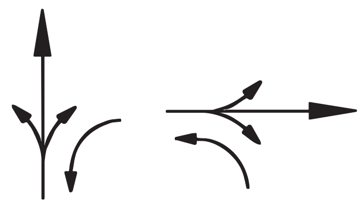

Figure 18.17 Left Turn Green Arrow

There are situations where providing a left turn green arrow does not improve capacity. If the left turn flow is low and the lane is shared with a relatively heavy movement, few vehicles will be able to turn left because they will be blocked by the through vehicles; therefore the left turn arrows should be omitted. A similar situation occurs with shared lanes when a pedestrian movement delays the left turn blocking the passage of the through movement.

The suitability of providing the left turn during the corresponding right turn phase should be tested by computer analysis.

Left turn arrows should only be used when vehicles can turn without conflict with other vehicles or pedestrians.

Left turn arrows can also be used to provide for pedestrian protection. The left turn is stopped using a left turn yellow arrow followed by a left turn red arrow which is held for a predetermined period.

18.8.5 Late Start

Uses for a late start interval are:

- to delay the introduction of the through movement in a trailing right turn when there was an opposing right turn filter in the previous phase;
- to delay the introduction of a right turn filter when it was controlled by a right turn green arrow in the previous phase;
- to delay the introduction of a left turn green arrow when the left turn movement has been held during the intergreen because it is in a shared lane which was controlled by a full green in the previous phase;
- to delay the introduction of a left turn green arrow when the left turn movement has been held during the intergreen because of an opposing right turn filter in the previous phase.

18.8.6 Early Cut-off

The early cut-off interval is used to terminate one movement before another within the same phase. A typical application is at intersections with double stop lines such as staggered T junctions.

18.8.7 Early Start and Green on Yellow

Early start and green on yellow allow some movements to commence earlier than others within the same phase. This is usually associated with the early cut-off interval of another phase.

18.8.8 Pedestrian Movements at Intersections

When a signalised pedestrian crossing is provided at a signalised intersection, the pedestrian movement normally runs in association with the parallel vehicle movement. When this occurs care must be taken to avoid unsafe sequences. For example if a pedestrian demand is received after the parallel vehicle green aspect is displayed, it may be unsafe to introduce the pedestrian movement due to the conflict with the left or right turning traffic.

To avoid such conflicts and where there is no demand for another phase, the pedestrian push button actuation shall first 'call away' to another phase and stop the parallel traffic for a minimum period. The pedestrian and vehicle green aspects are then introduced simultaneously.

Where there are no conflicts between vehicle and pedestrian movements (one way streets or corner islands), the pedestrian movement may be re-introduced or late introduced while the parallel vehicle signal group is green.

When a signalised pedestrian crossing is parallel to an overlap vehicle movement, the pedestrian movement should also be capable of overlapping. In this way the first phase of the overlap does not need to be prolonged in order to terminate the walk and clearance intervals.

Exclusive (scramble) pedestrian phases eliminate all vehicle/pedestrian conflicts and provide the highest level of safety for pedestrians but they have several disadvantages. Pedestrian clearance times need to be longer, reduced vehicle green times may lead to driver frustration, particularly in off peaks when drivers are unable to perceive why they are delayed for the sake of perhaps a single pedestrian crossing an approach parallel to their movement and oversaturation in peak periods.

Despite the disadvantages, exclusive pedestrian phases have been found to be beneficial at certain sites in central business districts and busy shopping centres where heavy, consistent pedestrian movements would otherwise cause excessive conflicts with vehicular traffic.

18.8.9 Pedestrian Protection

Protection for pedestrians should be considered whenever pedestrians are placed at an

18

unnecessarily high risk by the introduction of the pedestrian movement. This includes poorly located crossings, sites with poor visibility, high speed turns, two lane left turns and crossings used by pedestrians with special needs such as children, the aged and the handicapped.

The degree of protection depends on the circumstances and may be:

- no protection;
- timed protection for part of the walk interval;
- timed protection for all of the walk interval;
- full protection for all of the walk and clearance intervals.

As a guide, pedestrian protection is usually unnecessary when all of the following conditions are met:

- the crossing is clearly visible;
- the flow of turning traffic is light;
- the turn only occurs from one lane;
- the speed of the turning traffic is low.

Full protection is necessary when any of the following conditions apply;

- where there is a green arrow controlled conflicting left turn;
- sighting to the pedestrian crossing is restricted;
- the flow of pedestrians is high;
- the speed of the turning traffic is high;
- there is a high proportion of children, aged or handicapped pedestrians;
- there are two or more lanes turning through the pedestrian movement.

Timed protection caters for any other situations. The length of the timed protection depends on the type of pedestrians that are using the crossing, the flow of pedestrians and flow of conflicting vehicles, but it cannot exceed the duration of the walk and clearance display.

18.9 Lanterns

18.9.1 Functions

To be effective, traffic signal lanterns must command attention, convey a simple message and satisfy the functions of:

- warning;
- stopping;
- starting;
- manouvering.

Primary (including dual and overhead) lanterns provide the warning and stopping functions while the secondary and tertiary (including the overhead) lanterns provide the starting and manouvering functions as shown in Standard Drawing 1439.

These four functions are generally satisfied by three lanterns per signal group for undivided approaches and four for divided approaches. The minimum is three per signal group for each approach and two for each supplementary turning movement. Where possible, each lantern should be used to fulfil more than one function, provided that it is fully effective in its main function.

18.9.2 Assemblies

Lantern assemblies should be limited to no more than six aspects (dual three aspect lanterns) per approach on each post.

When a lantern consists solely of left or right turn arrows the lantern must never have all arrows blacked out unless an adjacent three aspect lantern consisting of full roundels is provided in the same dual lantern assembly.

Aspects are available in two sizes ie 200mm and 300mm diameter.

Lanterns using 200mm diameter aspects are usually adequate as a warning or stopping signal on the primary and dual primary posts where the approach speed is 70 km/h or less. Starting and manouvering signals on the secondary and tertiary posts are normally only required to be visible over a little more than the width of the intersection and as this distance rarely exceeds 40m the standard 200mm diameter aspects are usually adequate.

Lanterns using 300mm diameter aspects are used on overhead signals mounted on mast arm outreaches. They may also be used in lieu of 200mm aspects where a greater advance warning then the normal is required.

A four aspect display consisting of red and yellow full aspects and two green (full and arrow or two arrows) in a single column display may be used. This is not permitted for overhead mounted signals. Four aspect columns should not be used in multicolumn displays.

18.9.3 Left Turn Vehicle Displays

18.9.3.1 Six Aspect Left Turn Display

Left turn movements can be controlled by a full column of left turn arrow aspects (adjacent to the standard three aspect column) forming a six aspect display.

The left turn green arrow aspect should be illuminated when no conflicting traffic movements (vehicle or pedestrian) are permitted.

The left turn yellow arrow aspect followed by the left turn red arrow aspect should be illuminated when a conflicting movement must be protected.

The column of left turn aspects should be blacked out when the left turn movement may filter through a parallel walk or other traffic movement ie the full aspect is green.

18.9.3.2 Five Aspect Left Turn Display

(a) Left Turn Yellow/Green Arrow Aspects

The red arrow aspect may be omitted from the six aspect display when it is not required to protect conflicting movements during the display of the full green. The left turn green arrow aspect should be illuminated only when no conflicting traffic movements are permitted.

The left turn yellow aspect provides a termination display to allow the left turn green arrow aspect to be terminated independently of the full green signal.

(b) Left Turn Red/Yellow Arrow Aspects

The yellow/red arrow aspects alone should be provided when the left turn may be stopped during the full green display but the requirements for a left turn green arrow are not met. This occurs infrequently but may be required to stop left turn traffic for trains.

For left turning traffic a period must be assured when the full green aspect is displayed alone.

18.9.3.3 Four Aspect Left Turn Display

(a) Left Turn Green Arrow Aspect

Use of a single aspect left turn green arrow aspect may be used only when the green arrow is always terminated simultaneously with the full green aspect ie when the full yellow aspect is introduced.

(b) Left Turn Red Arrow Aspect

Use of a single aspect left turn red arrow aspect may be used only when its use is restricted to delay a 'filter' turn for protection of pedestrians in which case the red arrow should be switched off at the earliest practicable time eg at the end of the walk period.

18.9.4 Right Turn Vehicle Displays

18.9.4.1 Six Aspect Right Turn Display

Right turn movements can be fully controlled by a full column of right turn arrow aspects (adjacent to the standard three aspect column) forming a six aspect right turn display.

The green right turn arrow aspect should be illuminated only when no conflicting traffic movements (vehicle or pedestrian) are permitted.

The yellow right turn aspect should always be illuminated following the green aspect.

The red right turn aspect should be illuminated following the yellow aspect when the right turn must be protected or when a conflicting movement must be protected.

18.9.4.2 Five Aspect Right Turn Display

(a) Right Turn Yellow/Green Arrow Aspects

This display may be used instead of a six aspect display when:

- the right turn movement may filter at all times when the full aspect is green; and
- there is no conflicting pedestrian movement or special movement which requires protection from the right turning vehicle.

(b) Right Turn Red/Yellow Arrow Aspects

This display is rarely needed. It may be used when there is no requirement for a protected right turn but it must be stopped for its own safety eg by a nearby train movement.

18.9.4.3 Four Aspect Right Turn Display

(a) Right Turn Green Arrow Aspect

This arrangement may only be used when the green arrow is always terminated simultaneously with the full green aspect eg in split phase.

A single column alternative (four aspect) can be used in this arrangement.

(b) Right Turn Red Arrow Aspect

Use of a single right turn red arrow aspect may be used only when its use is restricted to delay a 'filter' turn for the protection of pedestrian or special vehicles.

18.9.5 Lantern Labelling

The labelling of lanterns is necessary to distinguish between different signal groups.

The vehicle signal groups are numbered in ascending order with no gaps in the numbering sequence followed by the pedestrian signal groups in ascending order with no gaps in the numbering sequence.

Individual numbering of signal groups for each approach improves the diagnostic process in determining the cause of a short circuit and open circuit in cables, terminals and lanterns.

All controllers with solid state lamp switching are equipped for lamp monitoring. The benefits of this will only be evident at STREAMS sites but introduction of dial-up fault monitoring facilities to isolated sites is possible.

18.10 Detection

18.10.1 General

Traffic detectors are a primary requisite of actuated signal control as they sense vehicular or pedestrian presence and/or passage and relay the data to the local controller so that the appropriate signal indications may be displayed for their required initiation and duration.

Initial detection by arriving traffic faced by a yellow or red signal registers an initial demand that it requires a green signal.

Subsequent detection by approaching traffic on a green signal registers via the same system that it requires the green signal to continue even though an initial detection may have been made by traffic on another approach.

18.10.2 Detector Types

The types of detectors currently in use are:

- vehicle detectors;
- push button detectors;

- special detectors.

Vehicle detectors are the most common. The two types currently in use are the inductive loop detector and the microwave (radar) detector. The microwave detector cannot detect stationary vehicles and is only used at temporary signal sites ie bridgeworks. Push button detectors are usually provided for the use of pedestrians.

18.10.3 Vehicle Detection

18.10.3.1 Characteristics

The inductive loop has proved to be the most reliable vehicle detector. This consists of two parts - a loop and a sensor unit. The loop consists of turns of wire in a special pattern installed in saw slots in the road surface as shown in Standard Drawing 1424. These loops are connected to the sensor units normally located in the controller.

Traffic signal detection systems operate in two modes:

- *locking* detectors detect the presence of a moving vehicle and are generally located in advance of the intersection;

- *non-locking* detectors detect the presence of a stationary vehicle and are generally located close to the stop line on the approach to the intersection.

Locking detectors should produce a short pulse as each vehicle enters the detection zone. Therefore they allow a headway time. The only additional information which a locking detector could provide is the flow rate. Locking detectors do not provide further pulses if stationary (or very slow moving) traffic occupies the detection zone.

Non-locking detectors should provide a continuous output while part of the vehicle is within the detection zone. Therefore they can provide more information than a locking detector enabling more characteristics of the vehicle stream to be calculated eg besides indicating continuing presence of a vehicle it also allows determination of occupancy times. The non-locking detector is the preferred type of detector for traffic management.

18.10.3.2 Installation and Location

Generally detectors should be located as shown on Standard Drawing 1425.

When locating detectors the following points should be considered in regard to installation:

- does the pavement need resurfacing or reconstructing (loop wire is vulnerable to damage but needs to be close to the road surface for optimum sensitivity);

- loops cannot be installed over any bridges, culverts or similar structures unless there is at least 80mm of covering pavement;

- loops cannot be installed closer than 300mm to any ferrous metal object such as a manhole cover;

- the distance between the loop and the sensor unit is limited to about 300m and is dependent on the number of turns in the loop.

18.10.3.3 Types of Vehicle Detectors

There are several types of vehicle detectors:

- advance
- stop line
- right turn
- counting
- queue
- violation.

18.10.3.4 Advance Detection

Advance detectors are so named because they are located in advance of the stop line. They are only used to detect moving vehicles and are therefore operated in passage mode.

Advance detectors should be used at sites where the approach speed is high and particularly if there is a large proportion of heavy vehicles. Where possible they should be located to suit the stopping distance required for the 85th percentile approach speed.

Under free-flow conditions advance loops have the advantage of being able to terminate phases earlier since assessment of gaps or waste time can be made several seconds before it can be detected at the stop line.

18.10.3.5 Stop Line Detection

Stop line detectors are the most common and are so named because they are located at the stop line. They are always operated in locking mode.

Stop line loops require greater sensitivity as slow moving or stopped vehicles must be detected. The location of the loop in relation to the stop line must be such as to ensure that a vehicle's normal stopping position is in the detection zone.

In addition the detector must have sufficient memory time to monitor waiting traffic even under conditions of extreme congestion.

18.10.3.6 Right Turn Detection

Where a shared or exclusive right turn lane permits filtering and a right turn phase is also provided a right turn detector comprising three loops connected in series and operating in non-locking mode is used. If necessary to achieve a satisfactory detection zone a fourth loop may be added.

18.10.3.7 Counting Detection

Where connected to STREAMS extra loops to count traffic may be provided eg auxiliary lanes with non-locking detection and uncontrolled slip lanes.

These detectors have no effect on the controller operation but use the controller's detector inputs. They are usually operated in locking mode.

18.10.3.8 Queue Detection

Queue detectors are used in special circumstances to detect stationary vehicles for queue detection and strategic purposes and must therefore be operated in non-locking mode.

Typical applications include the detection of:

- traffic blocking an intersection;
- full or overflowing right turn lanes;
- queues on or near a rail level crossing adjacent to a signalised intersection;
- queues in a left turn slip lane with a heavy flow at a T intersection where the right turn flow is light.

18.10.3.9 Violation Detection

Violation detectors are installed in conjunction with a red signal violation camera and flash unit to enable red signal traffic violations to be detected. If a vehicle passes over one of the detectors while facing a red signal the camera and flash are activated.

The camera equipment can accept up to four red inputs. This normally comes from the full red hence violation detectors should only be installed in lanes where all traffic is stopped by the full red. This includes exclusive through and right turn lanes and shared lanes where there is no left or right turn green arrow displayed in conjunction with the full red.

If the stop line is located at an angle then the shape of the loop is a parallelogram as it must be parallel to the stop line. This is the only type of loop where this is permitted.

18.10.4 Pedestrian Push Button Detection

18.10.4.1 General

Pedestrian push button detectors are used to register demands by pedestrians. They should be provided on posts on each approach to a pedestrian crossing.

Where a pedestrian crossing is interrupted by a median they should be provided on any median posts.

The push button should be mounted on the post 1m above the level of the surface on which a wheel chair stands when the occupant is attempting to use it.

Kerbside push buttons are generally oriented so that the face of the assembly is at right angles to the direction of travel. This orientation is important as visually-impaired pedestrians are taught to determine the crossing direction by feeling the face of the push button housing especially audio tactile types. The push button symbol on the drawing must be shown to the correct side of the post.

Mounting two push buttons on the one post should be avoided.

18.10.4.2 Audio Tactile Push Buttons

Audio tactile push buttons should be installed where they are needed by visually-impaired pedestrians. If an audio tactile push button is installed on a short post a note should be added to the drawing to describe where the audio tactile driver is located.

Audio tactile push buttons must not be installed:

- on median posts - except at 2 stage crossings;
- where there are two on the same post;
- within 2m of another audio tactile push button.

If necessary a short push button post may be installed to separate two audio tactile push buttons.

18.10.5 Special Detection

18.10.5.1 Emergency Vehicles

When traffic signals are close to a fire or ambulance facility it may be necessary to take special precautions to ensure that emergency service vehicles are not blocked by stationary vehicles and given right of way when trying to exit in an emergency.

Emergency vehicles are not normally detected by automatic detectors. The appropriate Authority provides the necessary advance warning of the approach of the vehicle and an emergency service phase may be provided. A pedestrian push button is usually used as the detection device.

18.10.5.2 Rail level Crossings

If a traffic signal installation is located close to a rail level crossing special provision should be made to ensure that queues generated by the traffic signals will not extend across the tracks.

If traffic signal linking with the level crossing is justified track switches should be provided by Queensland Rail to enable a special queue clearing sequence to be initiated at a predetermined time before the train is due at the crossing.

18.10.6 Detector Numbering

Traffic signal controllers have detector inputs that are numbered. All detectors (including push buttons) on the drawing are numbered to indicate these inputs.

In general the numbers for vehicle detection loops are in ascending order from 1, starting from the controller and then in a clockwise direction. Counting detectors should follow after traffic signal detectors ie advance, stopline and right turn detectors.

Numbers for pedestrian push button detection are in descending order from 16 or 32 depending on the detector card used starting from the first pedestrian group.

18.10.7 Detector Logic

Vehicles can be detected during two parts of the traffic signal cycle. Traffic waiting for a green signal registers an initial demand that it requires right-of-way (call); and provided advance detectors are no closer than 15m to the stop line, the controller can increment the initial green time. Traffic already given the right-of-way via a green signal registers its continuing requirement for right-of-way so that the green signal can be extended depending on the prevailing traffic conditions (extend).

Detector logic is used to specify the conditions under which an actuation from a detector can call, extend or increment a phase. For example the standard detector logic for a stop line detector is:

- *call* a phase except while it is green;
- *extend* a phase while it is green;

and for an advance detector is:

- *call* a phase except while it is green;
- *extend* a phase while it is green;
- *increment* initial green except while it is green.

In the above logic there is only one phase involved and only one condition for each function. This amount of logic is sufficient for a simple two phase design but for most other types of phasing several conditions may be required and a detector may demand and/or extend more than one phase. When designing detector logic for these situations the basic aim is to minimise the cycle time while satisfying all the traffic and safety needs of the intersection. This is achieved by:

- avoiding the introduction of unnecessary phases by only registering and maintaining demands which are actually required:
- demanding a phase that satisfies the most (or main) vehicle movements;
- minimising the variable initial green time by allowing detectors to increment when a queue is forming;
- avoiding unnecessary extension of a phase eg by ceasing extension by vehicles on a given movement when that movement also runs in the following phase.

18.11 Controller

18.11.1 General

The traffic signal controller is the equipment that switches power to the signal lanterns and controls the duration and sequence of the lantern displays.

Ground mounted interlocked and solid state controllers are utilised with operations 'burned into' an EPROM (Erasable Programmable Read-Only Memory).

18.11.2 Location

Controllers must be located so access can be gained for maintenance purposes.

A ground mounted controller has only one door for access. This type of controller is normally located adjacent to the property boundary with the door opening towards the footway.

The location of the controller is also affected by other conditions. Ideally, the controller should be located so that:

- a continuous 240v single phase power supply can be conveniently obtained (some poles cater for roadway lighting or high voltage supply only);
- a Telstra line is available nearby for STREAMS communications;
- it is clear of high voltage poles and cabinets with electrodes or earth grids as this can affect the electronics in the controller;
- it is clear of future widening proposals;
- the position does not detract significantly from the visual quality of the streetscape (painting in a decorative way may be appropriate);
- there will be an unobstructed view of all approaches to the site for timing and maintenance purposes;
- it does not unduly obstruct the footway;
- it will not be unduly exposed to accidental damage by passing traffic;
- access is available for maintenance personnel to park a vehicle.

If it is located where it is vulnerable to traffic it must be protected by appropriate safety barrier (see Chapter 8). It is preferable to find a less vulnerable location and thus avoid the introduction of another hazard (safety barrier).

18.11.3 Full Actuated Control

In a full actuated application as used throughout Queensland the controller operates on continuously variable cycle lengths. All phase green times are determined by the number of vehicles detected on the various controlled approaches.

The characteristics of full actuated control are:

- detectors on all approaches;
- each phase has preset minimum green interval to provide starting time for standing vehicles;
- green interval is extended by preset passage time for each actuation after the minimum green interval expires, provided a gap greater then the passage time does not occur;
- green extension is limited by preset maximum limit;
- yellow change and all-red intervals are preset for each phase;
- each phase has a recall when
  - both recalls are off, the green will remain on one phase when no demand is indicated on the other phase
  - one recall is on, the green will revert to that phase at every opportunity
  - both recalls are on, the controller will cycle on a fixed-time basis in the absence of demand on either phase (one minimum green interval on each phase).

18.12 Electrical Design

18.12.1 General

Electrical design is required for power and lighting circuits for the interconnection of signal components including controllers, lanterns, detectors and push buttons. Cabling and wiring involved may provide one or more of the following:

- 240V, 50Hz circuits for lamps;
- extra low voltage 50Hz circuits for pedestrian push buttons;
- circuits for vehicle detector outputs;
- digital data links associated with co-ordinated signal systems.

Cable connection charts are required to identify each core of each cable, its function, connection details and cable routing. Such a chart is an essential document for installation and subsequent maintenance.

18.12.2 Installation

All cable systems shall be installed to the requirements of the Local Authority and of AS/NZS 3000 - Wiring Rules. This provides for safety for both electrical workers and the general public. In this regard specific attention must be given to:

- buried depth of cable;
- earthing of signal hardware and equipment for electrical safety;
- adequate separation/isolation/insulation of 240V and other cabling;
- jointing of cables at terminal strips located on the top of signal posts, in junction boxes or within the cavity of joint use columns and mast arms;
- duct and access pit sizes to facilitate installation of cable.

18.12.3 Cables

Cables manufactured to the requirements of AS2276 - Part 1 are used. For Department installations 6, 19, 29 or 39 core cables are used.

For aesthetics and operational benefits cables are installed underground. Multicore cables have core insulation based on a four colour system as follows:

(a) Earth core - Green/Yellow

(b) Neutral core - Black

(c) ELV return - Grey

(d) Other numbered cores - White

The number of circuits required will determine the number of cores required in each cable. Provision must be made for:

- one active cable core for each colour of each signal group;
- one cable core for each pedestrian push button circuit;
- a number of spare cores. Spare cores allow for modifications to the signal control mode without recabling. In the event of core damage it may allow repair to be carried out without the need to replace the cable.

18.12.4 Vehicle Detector Loop Cables

The feeds to vehicle loops should be screened feeder cable manufactured to the requirements of AS2276 - Part 2. Single or three pair twin 7/0.50 cable is used.

The sensor to loop distance should be minimised (300m maximum) since long lengths of feeder cable may have adverse effects on detector sensor operation.

The loop cable should be manufactured to the requirements of AS2276 - Part 3. Single 7/0.50 cable is utilised.

18.12.5 Data Link Cables

Data link cables are leased from Telstra.

18.12.6 Cable Connection Design

The cable connection design determines the size, length and routing of cables. The circuits connecting lanterns, push buttons and wait indicators to the controller may be optimised to produce the most economic solution.

The number of cores in the multicore cable is chosen to provide sufficient circuits for each colour of each signal group and push button. The cores are connected from the post mounted terminal block on each post or terminal strip in each joint use or mast arm to the controller terminals.

The cable connection chart documents the cable connection design. Details of the connection of individual cable cores to the appropriate terminals in the controller and on each terminal block at each post, joint use pole or mast arm are shown.

18.12.7 Adaptive Engineering

The task of configuring of a controller to the specific requirements of a particular site is known as adaptive engineering. It includes the provision of phasing, sequencing signal groups and the prevention of hazardous displays.

Hazardous displays arise from failures in the mechanisms that switch power to the signal lanterns. These hazards can be minimised by interlocked switching and/or conflict monitoring.

Interlocked switching is used with relay switching of lamp circuits eg Philips PTF controller. The general principal is that switching a green to one signal group will open the circuit to conflicting green signal groups and close the circuit to the red of these signal groups.

One method of interlocking signal groups is effected by connecting relay contacts in series to create a ‘chain’ from the lamp active supply to the green feeds of the signal groups. When a signal group is switched to green the green feed to signal groups lower down the chain is open circuited (green interlocking). The groups that are higher in the 'chain' must ensure red is displayed for groups that are lower in the 'chain' (red interlock). Signal groups that are designated to have an “off” display should be in the lowest positions in the 'chain'. They do not require a red interlock as this would override the off display.

Conflict monitoring is mandatory where solid state lamp switching is used eg Tyco PSC or Aldridge ETG controllers. The circuits to the signal group colours should be monitored as close as possible to the controller output terminals. The state of each circuit is compared with the permissible and the unsafe states determined during the adaptive engineering (conflict table) to prevent unsafe operation.

18.13 Co-ordination

18.13.1 General

Traffic signals co-ordination is implemented to improve the level of service of a road or a network of roads where the spacing of signals is such that isolated operation causes excessive delays, stops and loss of capacity.

Co-ordination maintains a time relationship between adjacent sets of signals. This is predetermined to achieve the design objective of minimising overall delay and/or the number of stops. All signals to be co-ordinated must operate at the same cycle time to maintain the required time relationships. An exception to this can sometimes be made when it is found that a cycle time of half the system cycle time at some signals can reduce delay to the side road traffic without unduly affecting main road performance. This is known as double cycling.

Co-ordination is also used to assist in the achievement of other traffic management and environmental objectives such as improving the level of service of arterial roads to reduce the pressure on residential streets.

The benefits of traffic signal co-ordination include:

- improved capacity of closely spaced signalised intersections;
- reduction in travel time and delay;
- reduction in number of stops;
- reduction in intersection accidents;
- reduction in noise levels, air pollution and energy consumption;
- achievement of other area or corridor traffic management goals.

18

18.13.2 The Case for Co-ordination

An isolated intersection is one in which vehicle arrival at each approach is not significantly affected by other intersections. This situation can be managed by traffic actuated controllers with a high degree of efficiency.

The presence of a nearby signalised intersection or a pedestrian crossing upstream of the intersection alters the arrival pattern from random to platoon flow. This enables improved traffic flow to be achieved if the green signal is arranged to coincide with the arrival of the platoon.

The closer the traffic control signals are spaced the less random the arrival patterns become and the greater the opportunities are for improved efficiency afforded by co-ordination. Generally, when traffic signals are provided at successive intersections spaced less than one kilometre apart, benefits result from co-ordination. At spacings of less than 500 metres the reductions in delays and stops usually exceed 20%.

18.13.3 Types of Co-ordination

There are numerous options available for signal co-ordination. These options fall into three basic categories, namely local co-ordination, mains frequency or cableless link co-ordination and centrally controlled co-ordination (STREAMS). Local and mains frequency co-ordination systems are rarely used.

18

18.13.3.1 Local Co-ordination

With this type of co-ordination the local controllers in a system are free within certain constraints to respond to specific traffic demands.

Local co-ordination may be implemented using one or a combination of the following:

(a) Sister Linking - a simple method of achieving vehicle progression between two or three intersections that are less than 300m apart. The main linking mechanism is the establishment of a time relationship between the commencement of the controllers maximum green timers or transfer of detector actuations from each site to the other (repeat pulsing) by a cable connection between the sites.

(b) Master/Slave Link - this is a system in which a number of controllers are interconnected such that one of the controllers takes the role of master determining cycle time and phase times for the group and all other controllers are subservient to the operation of the master controller.

(c) Vehicle/Pedestrian Link - this is used to co-ordinate a closely spaced (generally 200m maximum) mid block pedestrian crossing to an intersection by means of a cable connection. The pedestrian site is inhibited from going to the pedestrian phase until the vehicles from the intersection have cleared the pedestrian site. There are two types of link. One specifies a vehicle phase under which a pedestrian phase should run and the other a vehicle phase under which a pedestrian phase should not run.

18.13.3.2 Mains Frequency Co-ordination

With mains frequency or cableless link co-ordination the controller responds to inputs from vehicle and pedestrian detectors and from pulses generated by the co-ordination software resident in the controller. Co-ordination timing plans are changed by time of day and day of week.

The 50Hz electricity supply provides an accurate time base to maintain fixed time relationships between controllers. Clock times must be regularly checked on site and adjusted if necessary to ensure that clock times are accurate and all clocks are synchronised so that the offsets maintain the correct time relationship for the co-ordinated route.

18.13.3.3 Centrally Controlled Co-ordination

Where sites in a system are all connected to a STREAMS regional computer the local controller may operate under the following conditions:

(a) Isolated - operates as any other isolated site except that it can respond to the STREAMS special facility signals and can be monitored by the regional computer eg monitoring of lamps, changing time settings, vehicle counts and special facilities enabled or disabled.

(b) Flexilink - is the same as cableless link operation except that the clock times in the controller are kept accurate by regular reference to the time obtained from the STREAMS regional computer.

(c) Masterlink - allows full dynamic control by the STREAMS regional computer. The data gathered from strategic detectors are used to optimise the cycle time and the phase splits for each intersection in the sub-system. In the event of a communication fault between the controller and the STREAMS computer or failure of the STREAMS computer the local controllers automatically revert to the fallback mode of operation. The fallback may be isolated or flexilink.

18.13.4 Design Factors

The routes and/or networks to be co-ordinated must be decided and the following factors considered:

(a) Roadway - information is required on the capacities of roads both at and between intersections. This enables an assessment of the manner in which traffic platoons will behave. The effective capacity of the co-ordinated system is determined by the capacities of the critical intersections that must be identified. In addition data on the geometry of the intersections in the network, including the location of existing and planned intersections and pedestrian crossings, and the distances between the stop lines of the intersections is required.

(b) Geometric - examination of intersection and roadway geometry may indicate the need for changes to improve the flow of traffic. Examples of geometric improvements include the provision of protected right turn lanes, free left turn lanes and linemarking alterations to minimise lane changing caused by lack of lane continuity along a road.

(c) Traffic - a complete inventory of traffic movements along a route to be co-ordinated is required. This enables time-distance diagrams and signal timing plans to be prepared. Individual intersections must be assessed first after which appropriate combinations of intersections may be assessed on a co-ordinated basis using common cycle time.

(d) Equipment - an inventory of existing equipment is necessary to identify constraints imposed by this equipment and determine required changes.

18.13.5 Requirements for Signal Design

When undertaking the design of a set of traffic signals it is important to consider the effects which co-ordination will have on the design. The major effects relate to:

(a) Controller Selection - the use of controllers that are compatible with the type of co-ordination adopted.

(b) Detector Loops - consideration of the detection system required which in many cases will be specified by the type of master control system to be installed. Detector placement and function options include individual lane detectors, advance detectors, stop line detectors and queue detectors.

(c) Cycle and Phase Timing - a common cycle or sub-multiple of it is required for co-ordinated systems. The system cycle time will be that of the most critical intersection in heavy traffic or derived from travel time to achieve two-way progression under certain traffic conditions. Phase splits at critical intersections must normally follow the minimum delay criterion ie green terminates when the queue has dissipated otherwise residual queues form with an excessive delay penalty. Non critical intersection phase timing may be adjusted to reduce stops or it may be beneficial to 'double cycle' the intersection.

(d) Phasing - the phasing design of signals needs to consider the co-ordination requirements. For example it may be necessary to vary the phase sequence to achieve two-way co-ordination or use leading and trailing turns during peak periods.

(e) Side Road and Pedestrian Delay - at intersections in a co-ordinated system there could be an increase in delays to vehicles entering from side roads and pedestrians crossing the main route compared with operation on a traffic actuated basis. Therefore careful consideration must be given to this factor to ensure minimisation of this adverse effect. This effect will be more prevalent with fixed plan systems where limited plans are available on a 'time of day' basis compared with traffic responsive systems. It may be beneficial under light flow conditions to revert to isolated traffic actuated operation particularly where the spacing between intersections is such that two-way progression cannot be attained at a low cycle.

(f) Public Transport - the needs of public transport should be considered in the overall design. Benefits to public transport may be achieved by either introducing a passive bias to the signal settings or by actively responding to the presence of a public transport vehicle to adjust the signal operation. It may also be possible to relocate bus stops at certain critical points.

18.13.6 Timing Criteria

Earlier research suggested that the principal criterion for co-ordination timing is minimum overall delay. However, subsequent experience has indicated that this criterion does not take adequate account of the following three factors:

- accident risk - this is the greatest at the change of signal phases and is reduced if fewer vehicles are stopped;
- fuel consumption and exhaust pollution - this is increased by repetitive driving cycles (stop-start driving);
- driver expectation - drivers relate co-ordination more to the number of stops than to overall delay.

The current criteria for co-ordination timing are therefore biased towards minimising overall stops and fuel consumption. This does not yield the same signal timing plans as the minimum delay criterion due to the different offsets necessary and a general requirement for longer cycle times.

For co-ordinated traffic systems several methods of designing signal timing plans are available:

- time distance diagrams manually prepared;
- computer programs such as TRANSYT or SCATES can be used to optimise timing plans according to traffic flow data entered for various times of day.

18.14 Mid-Block Pedestrian Crossings

18.14.1 General

Once the decision to provide a signalised mid-block pedestrian crossing is made, the designer must choose the type of crossing and the best location for it.

Signalised mid-block pedestrian crossings must be located a minimum of 30m from any side streets. This is to avoid side street traffic misinterpreting the traffic signals as controlling their movement. It also prevents the situation where a vehicle enters the main road just as the signals change to the pedestrian phase and the driver of the entering vehicle is unaware of the change or unable to react in time.

Signalised mid-block pedestrian crossings should also be avoided within 130m of an adjacent signalised intersection.

18.14.2 One Stage Crossings

A one stage crossing is used on roads where there is no median or the median is less than 4m wide. Where there is a median then median lanterns need to be provided. Push buttons may be provided if required.

18.14.3 Two Stage (Offset) Crossings

The installation of a signalised one stage pedestrian crossing on carriageways with wide medians (4m or more) may cause excessive delays resulting from lengthy pedestrian clearance times. At sites where long pedestrian crossings are a problem, a two stage crossing should be considered. This allows traffic signal co-ordination under STREAMS and reduces traffic delays. Two stage crossings may be needed in other circumstances with medians as narrow as 2.0m. The crossing point must be flush with the adjacent pavement surface in those cases.

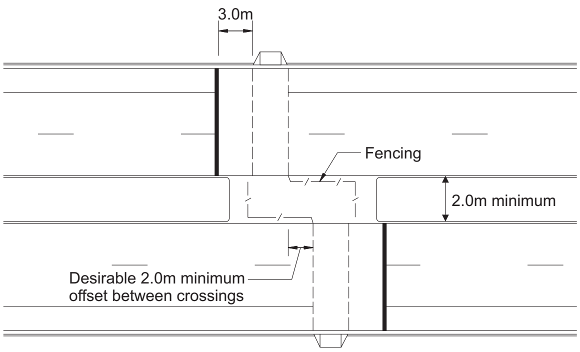

Figure 18.18 Two-Stage Mid Block Crossing (LH Offset)

The kerbside pedestrian lanterns must be aimed so that they are not visible to pedestrians on the opposite side of the road. A physical barrier of suitable fencing should be provided on the median to prevent pedestrians from 'short cutting' between the crossings. Fences should be aligned so that pedestrians face oncoming traffic as they are about to leave the median. The fences should commence at the signal post and not encroach past the push button position.

Intervisibility, as well as the physical layout of the fence, are very important and should be major factors in deciding whether pedestrian fences should be installed.

Particular attention should be given to the height and placement of the fence, and to the material used in its construction, in order to minimise the potential sight obstruction between drivers and pedestrians about to cross the road. Improper installation or rehabilitation of pedestrian fences can effectively negate any potential increase in pedestrian protection and can also increase the severity of vehicle accidents.

Fencing with rigid horizontal railing, installed near roads can be a hazard to occupants of errant vehicles. The horizontal rails can easily become detached and spear into the driving compartment.

18.15 Special Situations

18.15.1 Emergency Service Facilities

When traffic signals are close to a fire or ambulance facility it may be necessary to take special precautions to ensure that emergency service vehicles are not blocked by stationary vehicles when trying to exit in an emergency. This can be achieved by using traffic management treatments such as:

18

- relocating the stop line further from the intersection;
- installing warning signs and flashing lights;
- adding a special emergency vehicle phase.

Relocating the stop line could be appropriate where the emergency vehicle egress is at the intersection. If the resultant position of the stop line is "unnatural" from the motorist's point of view extra facilities such as signs (eg STOP HERE ON RED SIGNAL R6-6) may be necessary.

When the exit from the emergency service facility is more than 10 metres from the intersection and relocation of the stop line would require a longer intergreen period, warning signs with flashing yellow lights may be located at the exit. These are operated from the facility to allow safe egress for the emergency service vehicles. It may also be appropriate to provide signs and/or pavement markings to warn motorists not to queue across the driveway.

An emergency vehicle phase may be introduced where emergency vehicle turnouts provide entry directly to a road adjacent to signalised intersections based on the:

- conflict between emergency vehicles and other traffic;
- possibility of queued vehicles blocking the exit from the emergency service facility;
- delays to emergency service vehicles if the emergency service phase is not provided;

- effect on traffic flow.

The emergency service phase should clear any queued vehicles within the path of the emergency service vehicle to allow it unimpeded travel in any direction through the intersection. Again the facility to activate the emergency vehicle phase is provided within the service facility.

At isolated mid-block emergency vehicle turnouts, signal facilities activated within the facility may also be provided. Emergency vehicle signals are two aspect consisting of a 300mm diameter red and yellow lantern with a target board. Overhead emergency vehicle signals are also provided for either of the following:

- restricted visibility of emergency vehicle signals;
- very wide carriageways.

Overhead emergency vehicle signals are not used where such signals are located adjacent to intersection traffic signals. In these circumstances the need for overhead signals or additional measures is determined in relation to the intersection traffic signals.

At the emergency vehicle turnout the following are provided:

- emergency vehicle signals;
- STOP HERE ON RED SIGNAL sign (R6-6);
- stop line marking.

Where the stopping distance on the approach to the emergency vehicle turnout is restricted flashing yellow aspects are mounted in conjunction with the advance warning sign EMERGENCY VEHICLES (W5-26-1). These lanterns are 200mm in diameter.

18.15.2 Adjacent Rail Level Crossings

If a traffic signal installation is located close to a railway level crossing, special provision should be made to ensure that queues generated by the traffic signals will not extend across the rail tracks and queues generated by the rail crossing will not extend into the intersection.

If traffic signal linking with the level crossing is justified, track switches are provided by Queensland Rail to enable a special queue-clearing sequence to be initiated at a predetermined time before the train is due at the crossing. The track switches should also indicate when the train has cleared the crossing. The traffic signal requirements should be determined in consultation with Queensland Rail during the preliminary design stage.

If the level crossing is fitted with flashing red signals, the queue-clearing sequence should be initiated. The queue clearing sequence should force the traffic signals to a phase which will clear the queue across the level crossing before the arrival of the train.

Once the queue clearing phase has terminated, no phases or turning movements which would cross the rail line can be introduced until the train has cleared the crossing. It may be necessary to provide for additional storage of these vehicles while the level crossing is closed.

In some situations it may be possible to include the level crossing within the vehicular conflict area. In this case, the train movement may be treated as a priority phase.

Special precautions will need to be taken to ensure that green traffic signal aspects are not visible across the level crossing at the same time as the flashing red rail signals. Similarly, the positioning, screening and aiming of vehicle lanterns must be arranged to ensure that traffic signals do not cause confusion to train drivers.

18.15.3 Early Cut-Off Facilities

The early cut-off period is normally used to terminate one movement before another within the same phase. A typical application of this is at staggered T- junctions as shown in Figure 18.19.

In this example there are two A phase stop lines in each direction. The A(ECO) signal group is the first to display a yellow aspect. The A signal group remains green longer to allow the section of road between the stop lines to be cleared.

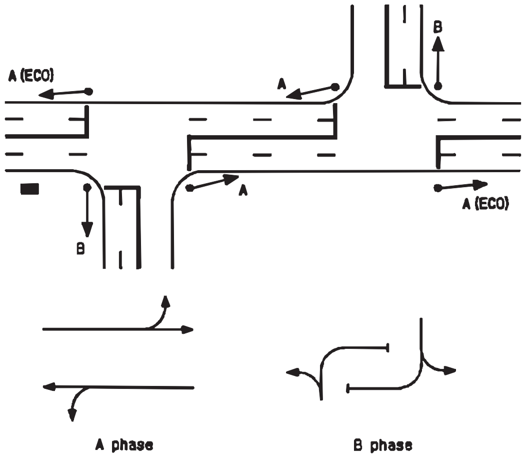

Figure 18.19 Staggered T-junction

Note that this example is simplified in order to describe the principle and would only be used if the number of right turn vehicles from the side street is particularly low. In practice, if the zig-zag movement is dominant, the left turn movements from the main road would be permitted during B phase. Otherwise the side streets would more than likely have separate phases. This would result in a number of conditional early starts and conditional early cut-offs.

18.15.4 Interchange Ramps

A very efficient signal design for an interchange is the "Fast Diamond" where all ramps are concentrated at one signalised intersection as shown in Figure 18.20. This enables the use of a single or double diamond overlap. However, care should be taken when selecting turning radii to ensure that the opposed right turns have sufficient clearance to allow the safe operation of the diamond turns (see Chapter 13).

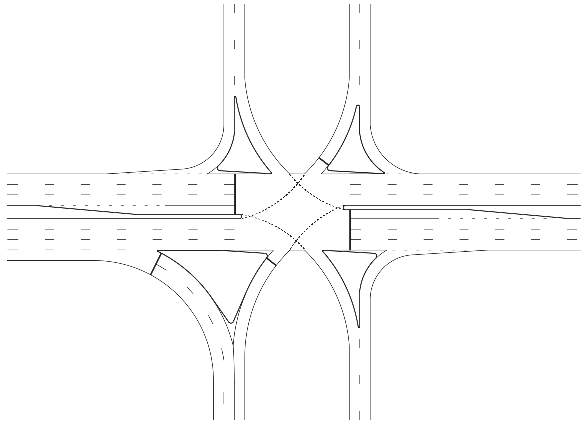

Figure 18.20 Typical SIngle Point Urban, "Fast Diamond", Interchange

Care should be taken to ensure that the long distance between stop lines does not create unsafe conditions. This is particularly so where a pedestrian crossing and/or a distant starting lantern may cause drivers who cross the stop line at the start of the intergreen to hesitate before clearing the intersection.

This type of interchange is usually much more expensive than the traditional type because of additional bridge costs (see Chapter 16).

For closed diamond interchanges, the interchange ramps are separated into two intersections as shown in Figure 18.21. The intermediate stop lines provide safe stopping for slower moving vehicles and enable a reduction in the intergreen time. The two sites may be controlled by one or two controllers. If one controller is used (usually to save costs) the site can have phase options to allow some flexibility in operation. If two controllers are used the sites can be co-ordinated to provide progression.

When two intersections are used the spacing of the intersections needs to be carefully designed to ensure that adequate storage is provided for the right turn vehicles. Storage requirements can be minimised by proper utilisation of the early cut-off interval.

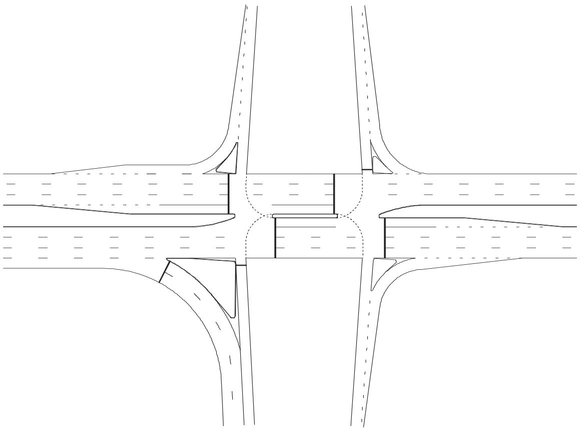

Figure 18.21 Typical Diamond Interchange

When one controller is used, the early cut-off interval may be used in a similar manner to a staggered T-junction. In this case some of the movements may be allowed to start early in association with the early cut-off of another movement. This is known as an early start (ES). An example of this is shown in Figure 18.22.

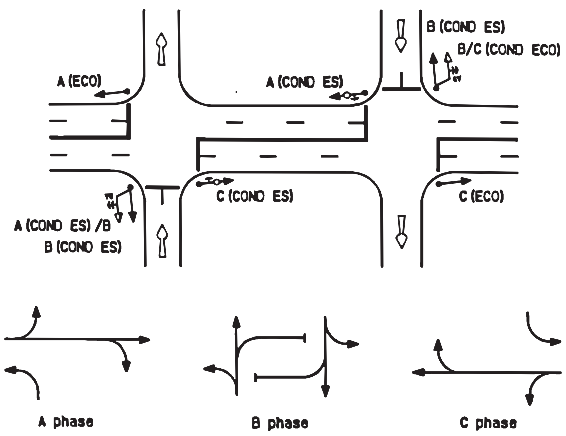

Figure 18.22 Early Start at Interchange Ramps

In this example, when A phase is followed by B phase the A(ECO) signal group turns yellow at the commencement of the A phase early cut-off green interval. At the end of the yellow the A(ECO) signal group turns red and the all-red timer is started. When this timer expires the B(COND ES) signal group displays green. This is permitted because the A(ECO) signal group has cleared traffic from the conflict area. When a signal group is allowed to display green at the start of the yellow interval this is known as green on yellow (GOY).

Note that this example is simplified in order to describe the principle and would only be used if the number of right turn vehicles from the freeway ramps is sufficiently low to allow storage between the two stop lines. In practice, it would normally be more efficient to run all through movements on the main road during A phase and provide separate phases for all other right turns. This would result in a number of conditional early starts and conditional early cut-offs.

18.15.5 Ramp Signal Management

18.15.5.1 General

The Ramp Signal Management service is responsible for all functions relating to ramp signals on freeway on ramps. These functions include the following:

- management of the descriptive and configuration data for the ramp signal;
- specification of recurring schedules. These allow scheduling of ramp signal flows by time of day on a special date. A special time-of-day flow introduction schedule may be used for each ramp signal. The schedule should cover the flow introductions required for a specific date. This schedule has a higher priority than a recurring schedule;
- processing of traffic-responsive requests from the movement service. These requests result from calculations based on current traffic conditions on the freeway and the ramp and aim to avoid congestion on the freeway. These requests are higher priority than the recurring and special schedules but lower priority than operator manual control;
- implementation of operator override requests. These requests allow the ramp signal flow to be controlled manually by the operator. This is the highest priority form of control. The flow will be implemented for the defined period and then automatically be replaced by the next highest priority form of control;

- reporting of operations of metered movements and their associated ramp signals. Screen displays and printed reports are available;
- managing the specific data history.

18.15.5.2 Ramp Metering

The primary purpose of the service is to ensure that ramp metering is active when it should be and that the appropriate metering rate is implemented. The desired metering rate is achieved by adjusting the time that the red lamp is displayed in each cycle (the time that the green lamp is displayed is constant and it is determined by the Green Time Parameter).

When the service determines that a particular metering rate is to be implemented it calculates the required red time according to the following formula (which assumes that only one vehicle per lane is admitted each cycle);

Red time = (3600/metering rate) - green time

Where *Metering Rate* is the desired rate in vehicles per hour per lane, and

Green Time is the time (in seconds) specified by the Green Time parameter.

Example:

If a metering rate of 600 vehicles per hour is to be implemented on a ramp with two lanes at the stop line and the green value parameter is 1.7 seconds, the red time is calculated as follows:

Metering Rate = 600 / 2
= 300 vehicles per hour per lane
Red Time = (3600 / 300) - 1.7
= 10.3 seconds

Provided the calculated Red Time value is between the limits specified by the Minimum Red Time and Maximum Red Time parameters the desired metering rate can be implemented.

The parameters Green Time, Minimum Red Time and Maximum Red Time determine the minimum and maximum metered rates (per lane) that can be achieved by any metered ramp on the system. Although it is possible to specify minimum and maximum metered rates for each metered ramp they must lie within the range determined by these parameters.

Requests for metering (or to turn off metering) can come from any of the following sources:

- recurring schedule;
- special schedule;
- traffic responsive;
- operator override.

The service is responsible for evaluating and implementing these requests and, where conflict arises, deciding which request is to be acted on. This decision is based on the predefined priority ordering assigned to the different types. This ordering, from highest to lowest priority, is:

- operator override;
- traffic responsive;
- special schedule; and
- recurring schedule.

18.15.5.3 Reports

Operations reports can be produced showing the operation of each metered movement and its associated ramp signal.

The current values of each of the following items are shown on the report for each metered movement:

- metered rate (if currently metered);
- level of service;
- demand;
- capacity;
- flow (last minute);
- control type;
- metering state;
- signal state; and

- red time.

Trend reports show a graphical trend of the operations history of a metered movement and its associated ramp signal.

Selection for graphing of several ramp signal settings and also various traffic measurements for the metered movement and the adjacent upstream and downstream freeway movements is possible.

The resulting plot shows how these settings and measurements vary with time for the specified movement and report period.

Items included in the plot are selected from the following:

- metered rate;
- control type;
- traffic responsive rate;
- downstream level of service;
- on ramp demand;
- on ramp capacity (expected);
- on ramp flow (last minute);
- bypass flow (where a bypass movement exists);
- total flow (where a bypass movement exists);
- downstream flow;
- downstream capacity;
- upstream flow;
- upstream demand.

18.15.6 Roundabout Entrance Metering

Roundabouts will not function efficiently if there are insufficient acceptable gaps in the circulating traffic stream. If there is one approach with a very heavy through or right turn movement, which is not interrupted sufficiently by the circulating flow, then this stream will present few acceptable gaps to drivers at the next entry. The capacity of this entry will be very low and the delay to this traffic excessive. Often this situation occurs only during peak flow periods and at these times the operation can be dramatically improved by artificially interrupting the high flow approach.

Entry metering is usually done by installing traffic signals to meter the flow as it approaches the roundabout. This has the effect of bunching the flow of traffic and introducing more of the longer duration gaps. It is important not to locate the signals too close to the entry as this may confuse the 'right of way' requirements at the entry.

Two-aspect signals (red and yellow only) are used with a STOP HERE ON RED SIGNAL (R6-6) sign provided.

Signalisation of roundabouts is not considered to be a long term solution to the relief of congestion and excessive delays due to normally increasing traffic volumes. Conventional signalised intersection layouts or a grade separated treatment will generally be a more effective long term solution.

18.15.7 Late Start for Large Corner Islands

In addition to the uses of the late start described in Section 8.5 the late start interval may be used to delay the introduction of a green signal group at a controlled left turn slip lane where there is a large corner island as shown in Figure 18.23.

In this example the B(LS) signal group is held red for the B late start interval. This allows the A phase vehicles to clear the conflict area before the left turn is introduced.

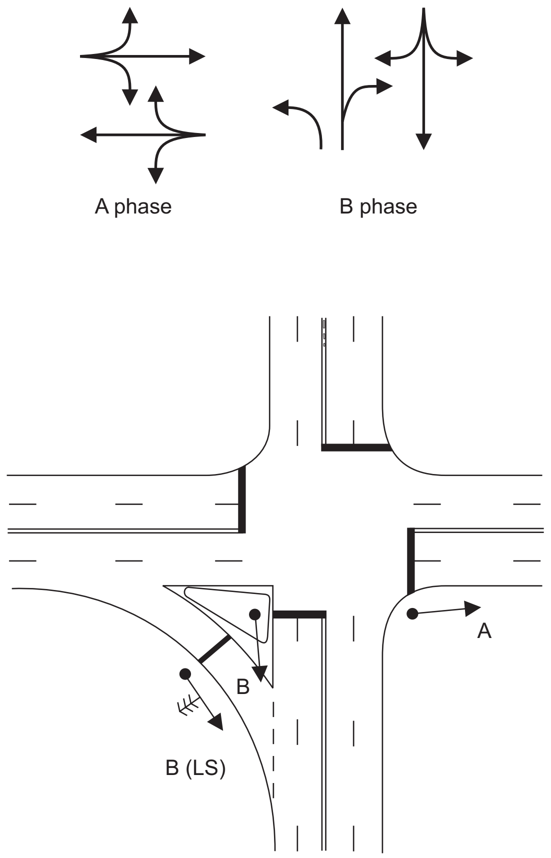

Figure 18.23 Late Start for Large Corner Islands

18.15.8 Temporary Installations

18.15.8.1 Portable Traffic Signals

Portable traffic signals are a short-term traffic control application. Their primary use is as a shuttle control where a portion of the roadway has been closed and a single lane is used alternately by traffic approaching from the opposite directions.

The standard equipment currently used by Main Roads in Queensland is not designed for unattended or overnight operation. The typical set-up does not provide sufficient redundancy to ensure safe operation when unattended. Where unattended or overnight operation is required, temporary traffic signals should be used.

Where circumstances arise where it is impracticable for temporary traffic signals to be installed, it is essential that the installation be designed to provide a sufficient level of redundancy and that operational procedures be established to provide assurance that continuous control will occur. When determining the appropriate equipment and operational procedures to adopt, the following factors for each site must be considered:

- Traffic volumes;
- Length of single lane operation;
- Visibility along the section of road;
- Risks of signal failure and the consequences;
- Availability of power;
- Call-out/ maintenance arrangements and costs.

In general, unattended operation should not be considered where the whole section of single lane is not visible from both ends by approaching drivers.

In any case, if the operation is to continue for an extended period, temporary traffic signals should be installed as described in 18.18.8.2.

18.15.8.2 Temporary Traffic Signals

When a road or bridge is under repair or reconstruction for longer than three months and a long stretch of one lane road is used alternately by traffic approaching from opposite directions, temporary traffic signals can sometimes be used as a control. The general treatment in this instance is to use two phases where one phase controls each direction. Unfortunately, this requires extremely long intergreen times to allow one movement to clear the conflict area before the other movement can be started. This causes lengthy delays which could lead to driver frustration. This cannot be avoided in heavy traffic situations but the overall delays can be minimised in low traffic situations by adding an all-red phase as shown in Figure 18.24. The controller will normally wait in the all-red phase until one of the other phases is demanded. That phase can then be immediately introduced with minimum delay to the motorist. The phase is extended and terminated as usual.

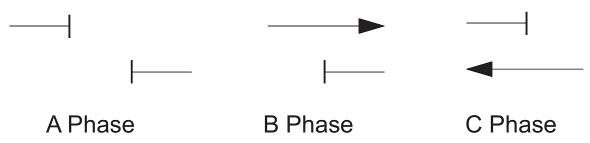

Figure 18.24 All-Red Phase at Temporary Signals

18.16 Time Settings

18.16.1 General

This section provides procedures and states policy for the calculation of various traffic signal controller times.

These times are required as data for all traffic signal controllers.

The controller times in this section are generally those which directly affect the safety of the operation of the intersection eg intergreen, minimum green and extension times. No guidance for the calculation of operational time data such as cycle times, green splits or offsets which are generally calculated using traffic engineering principles are provided.

The times are usually applicable to each phase of the cycle and some may be individually set for each movement within the phase. The availability of the settings may be dependent on the type of controller used.

18.16.2 Yellow and All-Red Times

18.16.2.1 Policy for Clearing Interval

MUTCD Section 14 Appendix A3.3.1 gives the current policy for the clearing interval as follows.

The vehicular clearing interval is indicated by a steady yellow aspect for a period ranging from 3 to 5 seconds and shall be provided in accordance with the following:

i. Speed limit up to and including 60 km/h - 4 seconds;

ii. Speed limit between 60 km/h up to and including 80 km/h - 5 seconds;

iii. Yellow arrow aspect which operates independently of a through movement on the same approach, at all times, and which is always followed by a phase for the associated through movement - 3 seconds.

The yellow interval is followed by a short all-red interval of sufficient duration to provide for the safe clearance of vehicles which have lawfully entered the intersection during the yellow interval. The minimum all-red interval shall be 1 second.

The pedestrian and bicycle clearing intervals are indicated by the red symbolic standing pedestrian and red symbolic bicycle aspects respectively. These aspects may be shown flashing.

18.16.2.2 Calculation of Yellow Times

The purpose of yellow time is to provide a safe transition period before the start of the next phase.

The yellow time is set for each phase with reference to vehicle speeds for each movement that stops when that phase terminates. Vehicle speeds are considered in two ranges (Clause 18.16.2.1) and the applicable range is normally taken to be the range that includes the legal speed limit for that approach.

If the phasing is such that the only movement that is stopped when a given phase terminates is a right turn movement and there is no possibility that the controller will allow a different phase sequence which will result in other movements stopping when the phase is terminated, then the yellow time for the phase may be terminated by the right turn movement (3 seconds).

18.16.2.3 Calculation of All-Red Times

The purpose of the all-red time is to provide a safe clearance time for vehicles that legitimately enter the intersection during the yellow interval.

The initial settings of all-red time can be calculated as:

- d/14 seconds in 60 km/h zones (up to 60 km/h);
- d/21 seconds in 80 km/h zones (between 60 and 80 km/h).

where d = distance, in metres, from the approach stop line to clear the farthest conflicting point of any opposing traffic stream (including pedestrian crossings) which can operate in the next phase.

Note that consideration must be given to the possibility that the next phase may vary with traffic demand or sequences selected for co-ordination and the highest value for the all-red time should be used.

Final settings of all-red times should be determined on site by a visual assessment of clearance times required by vehicles that legitimately enter the intersection during the yellow interval.

It is possible to set all-red times to the nearest 0.1 second but settings of not less than the calculated value or more than the calculated value +0.5 seconds should be used without full investigation of operations on site and with due authority.

The minimum all-red time shall be 1.0 second.

It should be noted that no additional all-red time should be provided to clear vehicles waiting within the intersection to make a right turn.

18.16.3 Other Vehicle Times

18.16.3.1 Late Start Period

The purpose of the late start period is to allow the delay of the introduction of specific signal groups from the start of a phase by a preset time.

Typical settings are:

- to delay left turns by 3 to 8 seconds depending on intersection geometry;
- to delay filtering right turn by 5 seconds.

18.16.3.2 Minimum Green Period

The purpose of a minimum green period is to ensure that the green signals are always displayed for a safe minimum time. This time should be long enough for a single vehicle to start up and enter the intersection.

A typical setting is 5 seconds.

The minimum green period and the increment (Clause 16.3.3) are used to determine the variable initial green (Clause 16.3.5). The variable initial green cannot be less than the minimum green period.

18.16.3.3 Early Cut-Off Green Period

The purpose of the early cut-off green period is to allow the early termination of the green signals to one or more movements within a phase by the early introduction of the yellow and all-red periods to these movements only.

Settings are dependent on intersection geometry but not normally less than 3 seconds.

18.16.3.4 Increment

The purpose of increment is to increase the initial green time beyond the minimum green time to ensure adequate green time for vehicles queued between the detector loop and the stop line.

For vehicle approaches or movements on an approach where vehicles can queue between the detector loop and the stop line each vehicle arriving against a red signal will add a small amount of time (an increment) to the minimum green time.

A typical setting is 2 seconds.

This setting should be increased for upgrades and decreased for downgrades at the rate of 0.1 second per percent of grade. Values should be verified by observation on site under the full range of operational conditions especially where lane utilisation varies or vehicle counts are collected from more than one lane.

18

18.16.3.5 Maximum Variable Initial Green

The purpose of maximum variable initial green is to limit the initial green period determined by increments.

Settings are dependent on the distance between the detector loops and the stop line. For example, if the distance is 40m, then for an assumed occupancy of 6m per vehicle the maximum queue would be 7 vehicles in each lane. Assuming a vehicle leaves this queue every 2 seconds when the signal turns green then the required setting is (7 x 2) = 14 seconds.

Careful site observation is required to ensure that there is sufficient variable initial green time so that vehicles queued beyond the detector loops can move over them and thus extend the phase.

18.16.3.6 Gap Timer

The purpose of the gap timer is to control the maximum allowable time period between successive detector actuations before the movement terminates.

If the gap timer is too short the movement may terminate before the platoon has passed. If the gap timer is too long the movement may be extended unnecessarily.

Typical settings are:

- 3 seconds for presence detectors (as used for right turn lanes where the movement is allowed to filter);
- 4 seconds for normal detectors.

Note that current microprocessor controllers provide for at least 2 and up to 8 gap timers so that different approach characteristics such as grade and turning radii can be catered for.

18.16.3.7 Headway (Space) Timer

The purpose of the headway timer is to set the desirable time period between successive detector actuations for efficient traffic flow so that the running phase is terminated if this flow is not being realised on any approach.

A typical setting is 1.25 seconds.

If detector zone length is taken as 3 x detector length ie 3 x 4.5m = 13.5m, vehicle occupancy time will be 13.5/speed (m/s). For a saturation flow of 1700 veh/h the headway time is 3600/1700 = 2.12 seconds.

Hence the space time between two successive vehicles at 50 km/h is:

Space Time = Headway time - Occupancy Time
= (3600/1700)-(13.5/13.9) = 1.2 seconds

To ensure that the headway time setting will be appropriate for flows of 80% or more of the saturation flow a calibration factor of 1.25 is used.

The result is divided by the number of normal active lanes associated with the timer eg for a 3 lane approach (2 normally active and one parking) the setting will be:

(1.2 x 1.25)/2 = 0.75 seconds.

Note where there is a shared right turn/through lane in conjunction with a right turn phase, a special headway setting of 0.1 second or as small as possible is used in conjunction with a recommended 11m presence loop.

18.16.3.8 Waste Timer

The purpose of the waste timer is to accumulate the amount of wasted time by summing up the excess of actual headway over the headway time setting during the controller rest period. The phase will be terminated when this sum exceeds a limit set by the waste timer.

Typical settings are 10% of maximum green time with minimum setting - 4 seconds and maximum setting - 10 seconds.

It is recommended that the waste timer be disabled for main road movements at isolated sites in areas where the speed limit is over 60 km/h.

18.16.3.9 Maximum Timer

The purpose of the maximum timer is to control the maximum green time available to each phase when opposing demands exist and when the controller is operating in isolated mode.

The maximum green time is additional to the "minimum" and "variable initial" green time.

The maximum green time setting should be sufficient to clear the longest standing queue formed during the red period while the intersection is not over-saturated.

For the first selection it is advisable to select a longer maximum green time since the gap, headway and waste timers should reduce the green time if necessary. Calculated phase times as provided from SIDRA should only be used as a guide to maximum times only.

18.16.4 Pedestrian Times

18.16.4.1 Pedestrian Delay Period

The purpose of the pedestrian delay period is to provide a delay between the push button actuation and the introduction of the pedestrian feature. This helps form pedestrian "platoons" and therefore avoid possible unnecessary cycling.

Typical settings are between 5 - 10 seconds.

18.16.4.2 Pedestrian Walk Period

The purpose of the pedestrian walk period is to set the length of time for the green walk display.

Typical setting is W/2.4 seconds where W is the width of the crossing with a minimum of 6 seconds.

An additional 2 seconds is allowed for each rank of pedestrians waiting.

Extra time may be allowed for:

- schools;
- rail stations;
- to allow crossing of wide roads (beyond medians) in one movement;
- elderly, infirm or visually handicapped pedestrians.

18.16.4.3 Pedestrian Clearance Periods

The purpose of the pedestrian clearance periods is to determine the duration during which a flashing red (DON'T WALK) symbol is displayed.

Typical settings are:

Total Clearance Period	=	length of crossing (m) / 1.2 (m/s)
Clearance 2	=	yellow period
Clearance 1	=	total clearance period - clearance 2

The following factors should be considered for variation of this guideline:

- extremely long crossings in which case provide clearance to the nearest refuge;
- special pedestrian characteristics eg aged, blind, physically handicapped where speed of 1.2 m/s should be reduced.

18.16.5 Presence Timer

The purpose of the presence timer is to set a period for which a detector must be occupied before a demand is registered.

Typical settings are:

- 2-5 seconds for 11m turning detector loops (3 loop configuration);
- 3 seconds for left turn detector on overlapped movements.

References

Queensland Department of Main Roads (1995): Manual of Uniform Traffic Control Devices.

18

Queensland Department of Main Roads: Guidelines on the Use of Portable Traffic Signals.

Queensland Department of Main Roads: Standard Drawings. Roads.

Roads and Traffic Authority (NSW): Traffic Signal Practice - Design.

Austroads (1988a): Guide to Traffic Engineering Practice - Part 6. Roundabouts.

Austroads (1988b): Guide to Traffic Engineering Practice - Part 7. Traffic Signals.

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Australian Standard AS1742 Part 14 - Manual of Uniform Traffic Control Devices. Traffic Signals.

Australian Standard AS2276.1 - Cables for Traffic Signal Installations. Multicore power cables.

Australian Standard AS/NZS2276.2 - Cables for Traffic Signal Installations. Feeder cables for vehicle detectors.

Australian Standard AS2276.3 - Cables for Traffic Signal Installations. Loop cable for vehicle detectors.

Australian Standard AS/NZS 3000 :2000 - Wiring Rules.

Queensland Transport: Bicycle Notes.

Relationship to Other Chapters

- Close relationship to Chapter 13;
- Chapter 17 provides the details for lighting – an essential part of signalised intersections;
- Cross section details are included in Chapter 7;
- Traffic data requirements are discussed in Chapter 5.