TS 05493:1.0

RTA-TC-106

Manual

Traffic Signal Operation

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Document history

Revision	Effective date	Summary of changes
1.0	1 April 2010	First issue as RTA-TC-106
1.0	18 November 2024	First issue as TS 05493, superseding RTA-TC-106 version 1.3, version numbering recommenced in line with new designation. Changes from previous version include reflecting the capabilities of current hardware and software.

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Preface

This manual is a first issue as TS 05493, superseding RTA-TC-106 *Traffic Signal Operation*, version 1.3.

The intended outcomes of this document are to explain the development of signal controller software, available inputs and outputs, and programming capability to ultimately improve safety and efficiency of signalised intersections.

Changes from the previous issue include reflecting the capabilities of current hardware and software.

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1 Scope

This manual describes the following aspects of a traffic signal controller, to provide an understanding of the inputs and outputs for operating traffic signals:

- control system - components and phases
- traffic detection
- operation
- time settings.

This document does not cover writing or preparation of controller software.

2 Application

This document provides guidance to practitioners on efficiently managing conflicting traffic streams at a signalised intersection in response to competing demands. This document applies to all permanent traffic signal controlled intersections in NSW. This document does not apply to portable traffic control signals.

3 Referenced documents

The following documents are cited in the text. For dated references, only the cited edition applies. For undated references, the latest edition of the referenced document applies.

Transport for NSW standards

TS 00003.1 *Concessions to Transport Standards – Part 1 – Concession Process*

TS 02670 (RTA/Pub. 08.092) (series) *Traffic signal design*

TS 06322 (TS-TN-019) (series) *Specification of Vehicle Group Operation*

TS 06323 (TS-TN-020) (series) *Specification of Detector Logic Operation – Guidelines for Developing*

TS 06324 (TS-TN-021) (series) *Specification of Pedestrian Movement Operation*

TS 06325 (TS-TN-022) *Specification of Ancillary Operation – Guidelines*

TS 06326 (TS-TN-026) (series) *Standard for Single Diamond Overlap Phasing – Guidelines for Developing*

TS 06327 (TS TN 027) *Standard for Double Diamond Overlap Phasing – Guidelines for Developing*

Other referenced documents

Austroads, 2020, *Guide to Traffic Management Part 9: Transport Control Systems – Strategies and Operations*

National Transport Commission, 2007, *Performance-Based Standards Scheme – Network Classification Guidelines*

Transport for NSW, *NSW Combined Higher Mass Limits (HML) and Restricted Access Vehicle (RAV) Map* (available from the National Heavy Vehicle Regulator (NHVR) National Network Map)

4 Terms, definitions and abbreviations

The following terms, definitions and abbreviations apply in this document.

Flexilink a mode of traffic signal controller operation used when the connection to the regional controller is not available. The phase sequence and duration are determined by stored time-of-day plan settings. Adjacent traffic signal sites are coordinated by mains power frequency or a crystal-controlled clock.

Masterlink a mode of traffic signal controller operation that allows full dynamic control by the SCATS regional computer

SCATS Sydney coordinated adaptive traffic system

TfNSW Transport for NSW

5 System overview

5.1 General

The controller operation system has two main areas: components, and movements and phases. The components are how information is received by the controller (inputs), processed, then translated to action for traffic to respond (outputs). Movements and phases are the way interaction between traffic streams are allocated time and space through an intersection to eliminate or reduce conflicts and promote efficient travel.

A brief history of traffic signals is provided in Appendix A.

5.2 Components

Modern traffic-actuated traffic signals consist of interrelated major components, as shown in Figure 1, to form a complete system.

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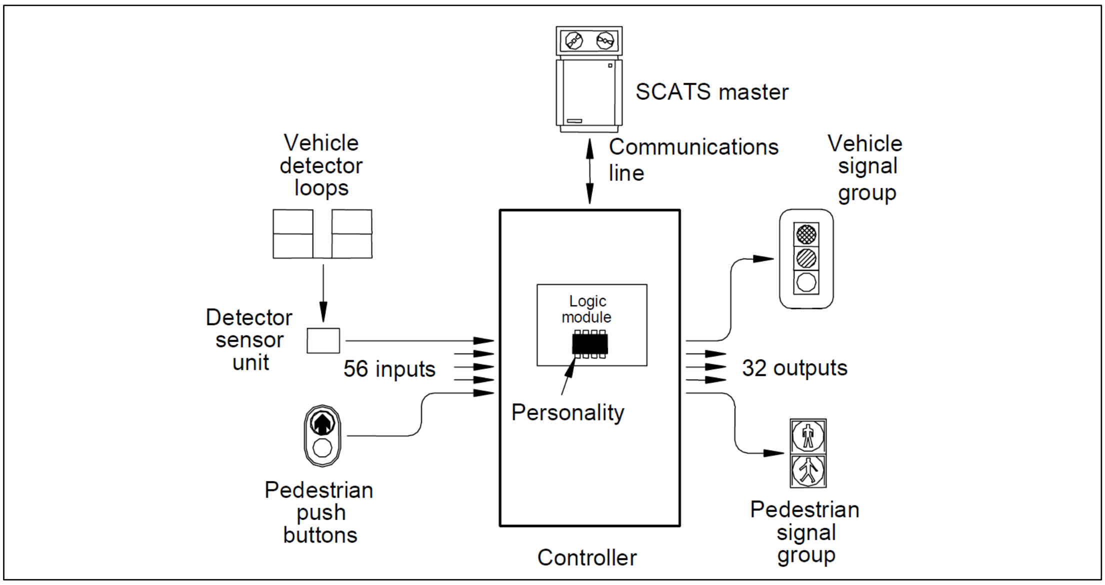


Figure 1 – System overview of traffic signal operation

There are a maximum of 56 inputs to the controller. Of these, a maximum of 48 may be vehicle inputs (from vehicle detector sensor units) and a maximum of 8 may be pedestrian inputs (from pedestrian push-button detectors). The operation of vehicle detectors is discussed in Section 6.

The controller is the heart of the system. It consists of a housing containing all the controlling hardware including the logic module and personality. The logic module runs the background software that monitors the inputs from detectors, communicates with the SCATS master computer and drives the outputs to signal groups. The personality is stored in a memory device and contains site specific data, including the following examples:

- the number of inputs and their function
- the logic associated with each input
- the number of different outputs and how they operate
- and time settings.

The operation of the controller is discussed in Section 7. Time settings are discussed in Section 8.

There are 32 outputs from the system that are used to control the colours displayed at signal faces. The software can accommodate up to 32 vehicle outputs, which includes a maximum of 8 pedestrian outputs. A communications line is used for the controller to send data to the SCATS regional computer and for the SCATS regional computer to control the traffic signals. This allows the traffic signals at two or more sites to be coordinated. Each regional computer can control up to 250 sets of traffic signals and the regional computers can be monitored by the SCATS Central Monitoring System.

5.3 Movements and phases

Each possible direction of traffic flow is called a movement. At a typical four-way intersection, each approach to the intersection can accommodate three movements:

- vehicles turning left
- vehicles travelling straight through
- vehicles turning right.

In the simple intersection shown in Figure 2, there are three movements in each approach for a total of 12 movements.

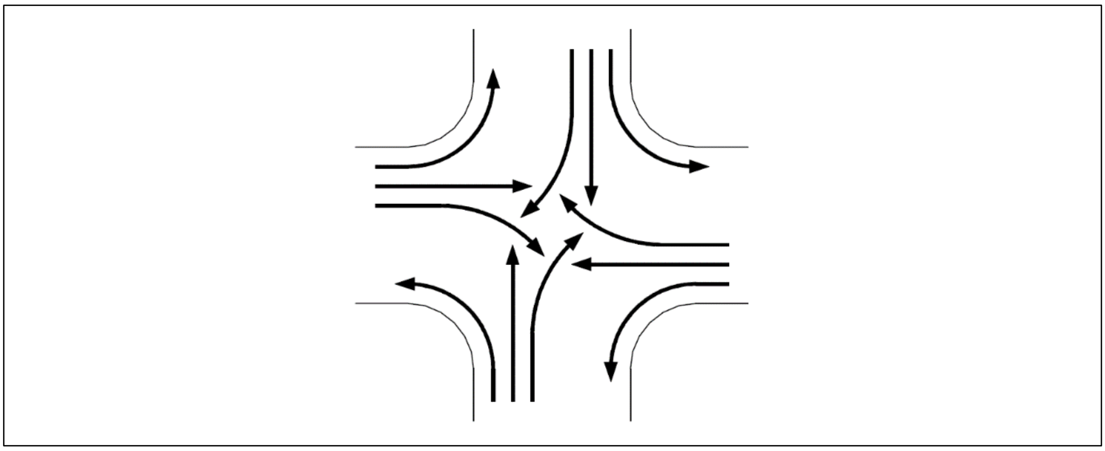


Figure 2 – Vehicle movements

Although possible to allocate a given amount of time to each movement and control it separately, it is more efficient to group sets of compatible movements into phases. The phase is the entity which the controller uses to share time among the various compatible movements.

A phase consists of a set of non-conflicting movements or certain conflicting movements where the right-of-way is defined by traffic regulations. Where a phase contains conflicting movements, movements that are obliged to yield right-of-way are said to be filter movements.

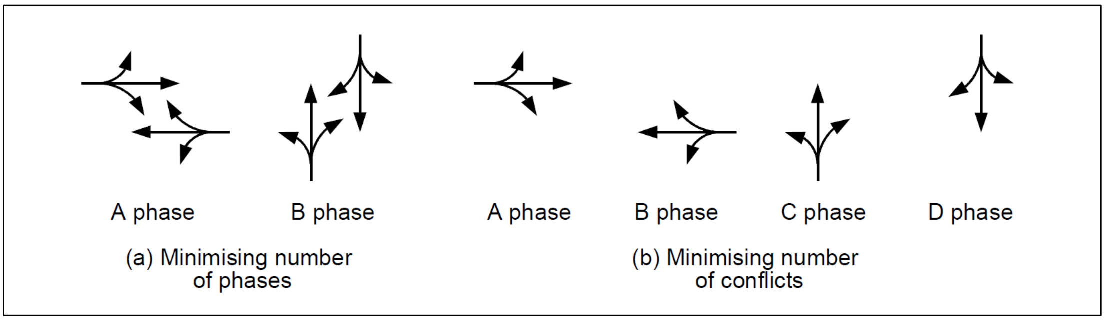
There is a maximum of seven phases, labelled A to G. In some cases, phases may have options within the same phase, for example, E, E1 and E2. Only one phase may be running at any one time. Phases are typically serviced in alphabetical order (although this is not essential) and phases may be skipped if they are not demanded or not required for operational conditions.

The selection of a phasing design for a particular intersection depends on the traffic flows of vehicles and pedestrians for each of the movements. However, the following general guidelines apply to any phasing design:

- the number of phases should be as few as possible to maximise the use of time
- as many compatible movements as possible should be allowed to run in every phase

- a phase should preferably consist of non-conflicting movements
- each movement should be allowed to run in as many phases as possible.

Figure 3 shows a comparison of two different phasing designs for a four-way intersection. The two-phase design (a) satisfies the first two of the above points very well but there are four crossing conflicts (right turns with opposing through movements) and four merging conflicts (right turns with opposing left turns). By contrast, the four-phase design (b) has no conflicts but is less efficient.



(a) Minimising number of phases

(b) Minimising number of conflicts

Figure 3 – Comparison of phasing designs

Selection of an appropriate phasing design for a particular intersection is further discussed in relevant parts of TS 02670 (series).

5.4 Phase intervals

5.4.1 General

A phase consists of two major parts, as shown in Figure 4: the running part; and the clearance part.

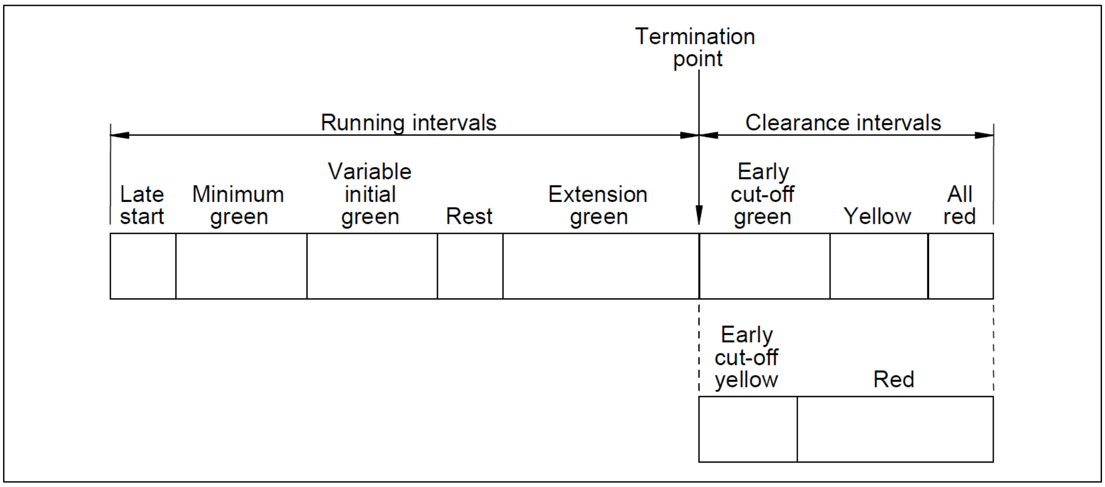


Figure 4 – Phase intervals

The running part of the phase is the portion between the start of the phase and the termination point. Once the termination point has been passed, the next phase has been determined and may not be changed. The running part is divided into the following five sequential intervals:

- late start
- minimum green
- variable initial green
- rest
- extension green.

The clearance part of the phase is the portion between the termination point and the end of the phase. The clearance part is divided into the following three sequential intervals:

- early cut-off green
- yellow
- all-red.

The intergreen is the interval between the termination of a green signal display in one phase and the beginning of a green signal display in the next phase. This usually corresponds with the yellow and all-red intervals.

5.4.2 Late start

The late start interval allows the introduction of some signal groups to be delayed from the start of the phase. The duration of the late start interval is determined by the late start time setting. The late start interval is only included in the phase when applied to a particular phase transition, otherwise it is skipped.

5.4.3 Minimum green

The minimum green interval ensures that the green signal is displayed for a safe minimum time. The duration of the minimum green interval is determined by the minimum green time setting.

5.4.4 Variable initial green

The variable initial green interval is used in conjunction with advance detectors where it is necessary to provide additional green time to discharge a queue of vehicles stored between the stop line and the advance detectors. See Section 7.5 for further details.

5.4.5 Rest

The rest interval is an untimed interval in which the controller rests until there is a demand for another phase. The rest interval is skipped when one or more demands already exist for other phases.

5.4.6 Extension green

The extension green interval is a variable length interval. Under isolated operation, its duration is determined by the approach timers and the maximum green timer as described in Section 7.5. Under SCATS operation, its duration is determined by coordination equipment (that is, the SCATS master computer under Masterlink). A phase may only terminate (that is, move from the running part to the clearance part) when the phase is in the extension green interval. When a controller moves from the extension green interval to the clearance interval, the direction of phase transition is determined and may not be changed. The controller may stay in the extension green interval if the demands for other phases are cancelled.

5.4.7 Early cut-off green

The early cut-off green interval allows some signal groups to be terminated earlier than others. The duration of the early cut-off green interval is determined by the early cut-off green time setting.

5.4.8 Early cut-off yellow

The early cut-off yellow interval is an auxiliary phase interval that is used to provide a yellow display for any signal groups that are terminated at the beginning of the early cut-off green interval. The early cut-off yellow interval starts at the same time as the early cut-off green interval, as shown in Figure 4. If the early cut-off green interval is skipped, the early cut-off yellow and yellow intervals will be co-incident. If the early cut-off green interval is not skipped, but its duration is less than the early cut-off yellow interval, then the early cut-off yellow interval will extend into the yellow interval. The duration of the early cut-off yellow interval is determined by the yellow time setting.

5.4.9 Yellow

The yellow interval is provided to allow a vehicle enough time to stop at the stop line following the termination of a green display. The duration of the yellow interval is determined by the yellow time setting.

5.4.10 All-red

The all-red interval is to provide a safe clearance time for vehicles to clear the intersection before the start of the next phase. The duration of the all-red interval is determined by the all-red time setting.

5.5 Signal faces

Signal faces are the medium by which vehicles and pedestrians are controlled. Signal faces intended for vehicle control may consist of circle, arrow or symbolic aspects, each in red, yellow or green. A signal face with two aspects is called a two-aspect traffic signal, and so on.

Signal faces intended for pedestrian control always use two aspects. These consist of a symbol of a standing pedestrian in red and a symbol of a walking pedestrian in green.

Further details of traffic signals including their function, size, aiming and shielding, use of visors and louvres, lamp monitoring and labelling are provided in TS 02670.

5.6 Signal groups

All signal faces that have common electrical switching such that they share the same colour sequence within each phase and for each phase sequence are called a signal group. A signal group may control one movement (such as a left-turn arrow controlling a left turn) or multiple movements (such as circles controlling through, left- and right-turn movements).

The operation of signal groups is normally tied to phases so that certain signal groups are green in certain phases. For example, in the simple case of a four-way intersection with two phases shown in Figure 3, A and B phase will each have one signal group. If lamp monitoring is provided, A and B phase will each have two signal groups. Under more complex control, signal groups may be associated very loosely with phases or, in some cases, signal groups may even operate independently of phases.

All signal groups are uniquely labelled; vehicles are labelled with a V and pedestrians are labelled with a P, each with a numeric suffix to distinguish between the different signal groups, for example V1 and V2, P1 and P2.

When a signal group shows a green signal display continuously over two or more phases (including the intergreen), it is said to overlap and is called an overlap signal group.

Apart from phase and overlap signal groups, there are other types of signal groups (usually arrows) which operate in a manner conditional on one or more factors.

Signal group operation is specified in TS 06322, TS 06323, TS 06324, TS 06325, TS 06326, and TS 06327.

6 Vehicle detector operation

6.1 General

This chapter discusses vehicle detection systems for traffic signals in Australia to assist in understanding the rationale for the location and configuration of detector loops and the operational requirements of inductive loop detectors. The theory of vehicle detector operation is described in *Guide to Traffic Management Part 9: Transport Control Systems – Strategies and Operations*.

6.2 Objectives of vehicle detection

For a traffic-actuated system to be effective, it relies on information about the traffic conditions in the controlled area and the approaches to it. If the detection system sends incorrect or incomplete data to the controller, the efficiency of the overall system is reduced, irrespective of the sophistication of the control logic. To operate effectively, the vehicle detection system should be capable of providing the following information on a lane-by-lane basis:

- whether there are vehicles waiting against a red signal
- whether filter movements are filtering freely
- whether free-running movements need an extension of green time.

These provisions may be met by implementing the following features to the detection:

- type of detector
- dimensions for the detection zone
- location of the detector with respect to the stop line
- interpreting the data from the detector.

6.3 Type of detector

The type of detector that meets the objectives of Section 6.2 has a distinct detection zone such that each lane can be examined individually and minimise interference from adjacent lanes. Detectors that emit a broad beam of energy (such as microwave and infrared detectors) fail to satisfy this criterion, so their practical use is only for temporary installations and special applications.

The inductive loop detector has been found to be the most reliable for use in NSW as other types have operational or economic disadvantages. However, new technology in areas such as infrared, video radar and other wireless detectors has potential for future use.

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The sensor units for vehicle loop detectors have a switch to allow the detector to be operated in passage mode or presence mode. When in passage mode, detectors produce a brief pulse as each vehicle enters the detection zone. The time between successive pulses is the headway time. This can be used to yield information about vehicle flow, but it does not provide information about stationary (or very slow moving) traffic. In addition, the information may be ambiguous, as very slow, congested traffic may have the same headway as very fast, uncongested traffic.

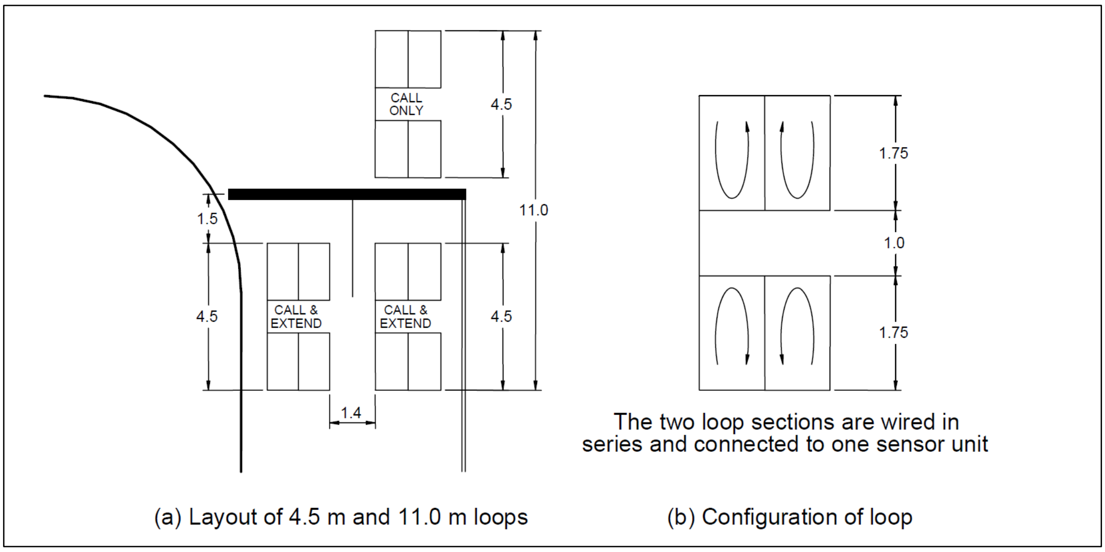
When in presence mode, detectors provide a continuous output whenever a vehicle (or part of it) is within the detection zone. The duration of the output is affected by the length of the detector loop, the length of the vehicle and the speed of the vehicle. Nevertheless, the duration of the output signal may be used to determine the characteristics of the vehicle stream, and therefore the presence mode is preferred for traffic management.

Presence mode is also required for SCATS operation as it uses the number of detector actuations and the total space time (that is, the sum of the non-actuated periods) to determine coordination parameters.

Types of detectors are further described in relevant parts of TS 02670 (series).

6.4 Layout of loop detectors

Many operational factors have been taken into account in determining the optimum loop layout for the inductive loop detector. Figure 5 shows the recommended layout and configuration for stop line detectors operating in the presence mode. For further details on loop detectors, see *Guide to Traffic Management Part 9: Transport Control Systems – Strategies and Operations*.



(a) Layout of 4.5 m and 11.0 m loops

(b) Configuration of loop

Figure 5 – Layout and configuration of inductive loop detectors at stop line

The transverse spacing between the outer conductor of the loop and the lane boundary has been chosen to minimise the following actuations:

- unwanted detection of vehicles in the adjacent lane (overcounting)
- the number of undetected vehicles (especially two-wheeled vehicles) that do not travel through the loop’s zone of influence (undercounting).

The optimum spacing between detectors in adjacent lanes is theoretically achieved when overcounting errors are equal to undercounting errors. A spacing of 1.4 m has been found to provide a good compromise.

The gap between the two sections comprising each 4.5 m loop should be kept to a minimum to give good longitudinal response for all classes of vehicle. However, the smaller this gap, the more the overall sensitivity is reduced. In practice, the dimensions in Figure 5 show a good compromise between the various factors.

Further details of the overall dimensions of inductive loop detectors (including detectors other than stop line detectors) are provided in TS 02670.

6.5 Detector location

The location of the loop affects both the demand and processing functions that the detector is required to perform. Advance detectors are located upstream from the stop line and stop line detectors are located at the stop line.

The use of advance detectors can lead to a reduction in delays and stops under light to moderate traffic flows with the following features:

- providing advance call for a relevant phase
- avoiding the termination of a green signal display when a driver is in the ‘dilemma zone’ (a region where drivers have to decide whether to accelerate to clear the intersection or slow down and wait).

In some control strategies, advance detectors are used in a gap-seeking role on high-speed approaches or where there are a large number of heavy vehicles to enable the onset of a gap to be identified earlier. However, because of the long distance from the stop line, they have the following shortcomings:

- they cannot detect slow-moving vehicles, queues or stationary vehicles if operating in passage mode
- processing of demands is on the assumption that vehicles do not change lanes or turn off before reaching the stop line

- vehicles entering the traffic stream between the detector loop and the stop line are not detected
- green time requirements are arbitrary for traffic trapped between the detector loop and the stop line at the start and end of the phase
- the time necessary for individual vehicles to travel from the loop to the stop line during the green interval can be excessive
- the further the detector is located away from the controlled area (that is, the stop line), the less accurately it can respond to changes in traffic flowing into the controlled area (for example, a decrease in capacity and queue formation)
- the installation of detector loops far in advance of the stop line is uneconomic.

These shortcomings may be avoided by using detector loops at the stop line. Detector loops should be located so that vehicles do not normally stop short of or past the detection zone. The 4.5 m loop provides a detection zone of about 4.0 m. This allows a vehicle to be detected over a range of about 13.0 m (that is, the length of the detector plus two car lengths), which satisfies demand purposes.

The use of a dual detector system employing both stop line and advance detectors is not usually justified on economic grounds. However, on approaches where fast, free-flowing traffic prevails, sight distance is inadequate or down-grades are steep, a dual detector system may be warranted on safety grounds.

7 Controller operation

7.1 General

Controller operation varies from country to country and even state to state. In NSW, controller operation has been standardised so that any controller can interpret a personality, irrespective of the manufacturer or model. This section describes the operation of such a controller.

7.2 Demanding a phase

A vehicle held at a red signal display places a demand for a phase that will permit legal movements with a green signal display. Vehicles that are permitted to filter, but cannot do so because of opposing vehicles or pedestrians, may demand a phase in a similar manner. The way demands are placed is determined by the detector logic in the controller personality. The following are the three basic types of demand:

- locked
- non-locked

- presence-timed.

A locked demand is one for which the demand is registered at the first detector actuation (as shown in Figure 6 and held until the movement receives a green signal display. This ensures that the demand is locked, even if the detector actuation ceases, so that the vehicle will eventually receive a green signal display. This type of demand is used wherever the vehicle registering the demand cannot legally proceed.

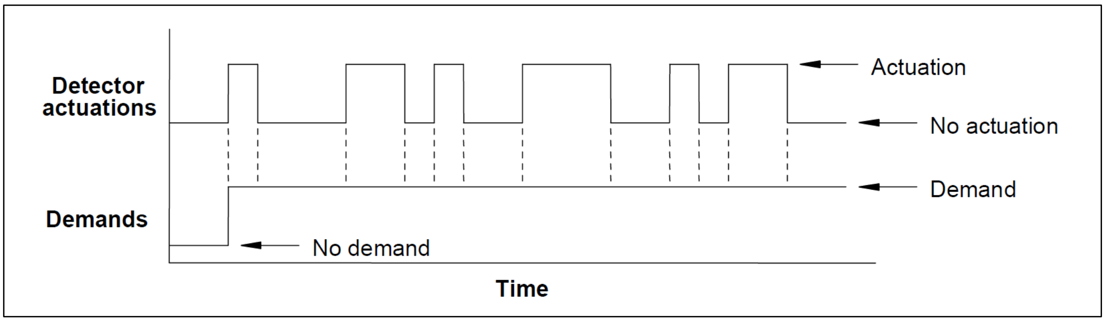


Figure 6 – Locked demand

A non-locked demand requires the detector actuation to be maintained until the phase is serviced, otherwise the demand is lost, as shown in Figure 7. A non-locked demand is used where a vehicle may legally proceed by filtering.

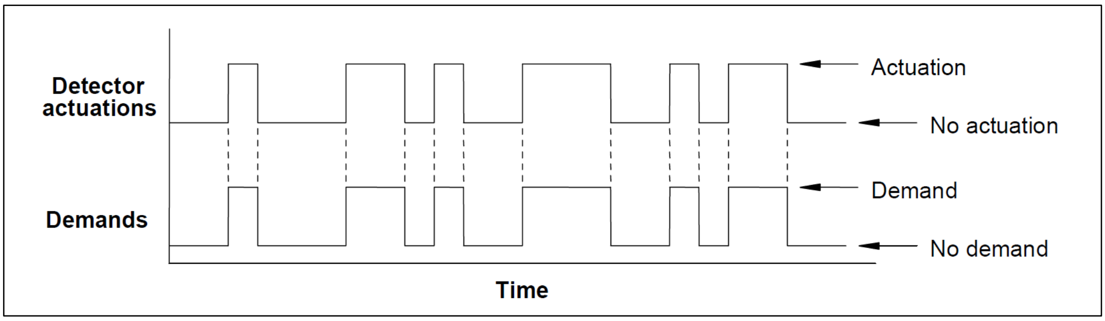


Figure 7 – Non-locked demand

A presence-timed demand is a non-locked demand with the additional condition that the vehicle actuation be present for a nominated time (typically 2 to 3 seconds) before the demand is placed, as shown in Figure 8. This type of demand is used where a lane is shared by vehicles making movements that belong to more than one phase. The purpose of the time delay is to ensure that vehicles do not register a demand unless their speed is below a desired value or they cannot proceed in the running phase.

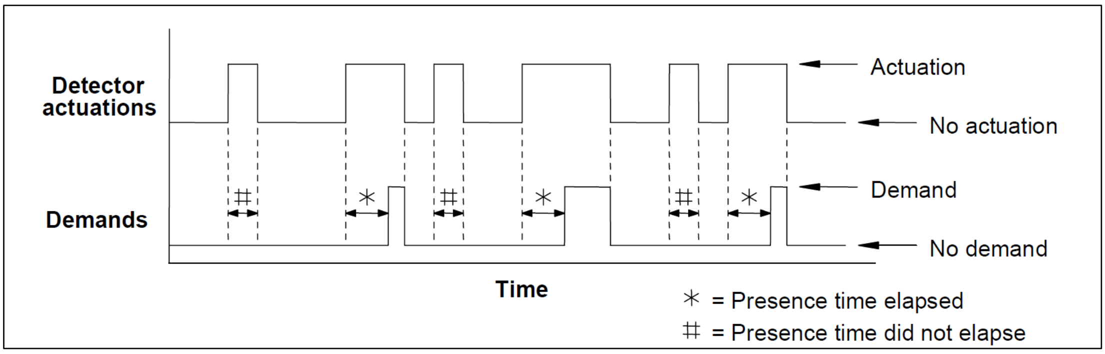


Figure 8 – Presence-timed demands

In most situations, the controller is programmed to place demands only from detectors on approaches facing yellow or red signals, and clears all demands for a phase when the signal group for that approach is green.

By using vehicle detectors to demand phases, those phases that are not demanded may be skipped.

This technique alone cannot adequately share the time between the demanded phases to suit the prevailing traffic conditions. This is done by extending the phases as described in Section 7.3.

7.3 Extending a phase

Once a demanded phase is running, the vehicle detectors associated with that phase are used to extend the phase by increasing the extension green interval. The controller may not enter the extension green interval unless there is a demand for another phase during the rest interval. If a demand exists at the start of the rest interval, then the rest interval is skipped.

The duration of the extension green interval at an isolated site is governed by the gap, headway and waste timers, and the maximum green timer. A set of gap, headway and waste timers are referred to as an approach (since a set of timers is frequently associated with a physical approach). Each phase may have one or more approaches.

The gap timer is loaded with zero at the start of the phase, and then operates as follows for the whole of the running part of the phase. When a detector actuation occurs, the gap timer is loaded with the gap time setting for that approach. When the detector actuation ceases, the gap timer starts decrementing, as shown in Figure 9. If the gap timer reaches zero before another detector actuation occurs, the timer is said to have timed out. This indicates that there is a break in the traffic or the end of a platoon on that approach. When another detector actuation occurs (irrespective of whether or not the gap timer has timed out), the gap timer is reloaded with the gap time setting. Therefore, the gap timer may time out more than once per phase. The gap timers affect phase termination.

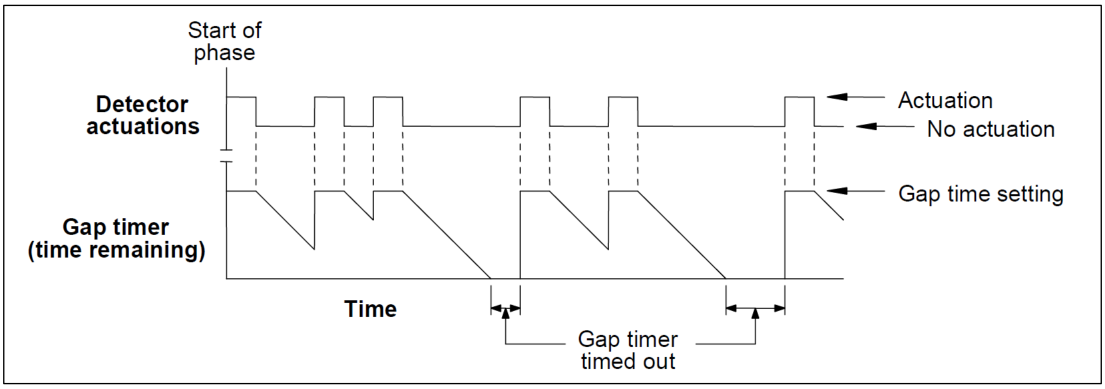


Figure 9 – Operation of gap timer

The headway timer also operates for the whole of the running part of the phase, but its operation is ignored until the start of the extension green interval, when it is loaded with the headway time setting. When a detector actuation occurs, the headway timer is loaded with the headway time setting for that approach. When the detector actuation ceases, the headway timer starts decrementing, as shown in Figure 10. If the headway timer reaches zero before another detector actuation occurs, the timer is said to have timed out. When another detector actuation occurs (irrespective of whether or not the gap timer has timed out), the headway timer is reloaded with the headway time setting. Therefore the headway timer may time out more than once per phase.

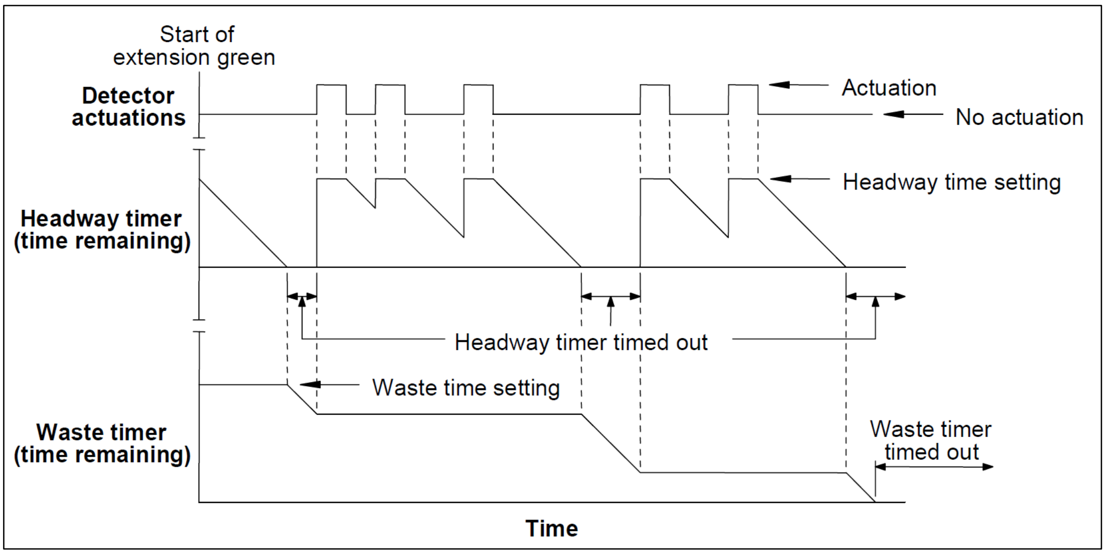


Figure 10 – Operation of headway and waste timers

The waste timer begins to decrement whenever the headway timer is timed out, as shown in Figure 10. When the waste timer reaches zero, the waste timer is said to have timed out. This indicates that the stream of vehicles is flowing inefficiently (that is, not closely packed) and wasting green time. The waste timer accumulates this wasted time. Once the waste timer has timed out, it remains in the timed-out state for the remainder of the phase. Note that in Masterlink operation, the waste timer is not enabled in the extension green interval until the plan data allows termination of the phase by approach expiry.

Once the controller is in the extension green interval, if either the gap timer or the waste timer of an approach has timed out, then that approach is said to have expired. When all the approaches of a phase have expired and no pedestrian movements or signal group minimum timers are inhibiting termination, then the controller may terminate the phase.

If there is saturated flow on one or more approaches, then the phase cannot be terminated by approach expiry because the approach timers will not time out. In order to prevent the phase being extended indefinitely, there is a maximum time setting for each phase. This represents the maximum duration of the extension green interval.

The maximum time setting is only effective when the controller is operating in the isolated mode of operation. When operating in Flexilink or Masterlink, the maximum time is determined by the Flexilink or Masterlink plan data respectively.

7.4 Maximum time transfer

7.4.1 General

Each phase has only one maximum time setting, however the maximum time of a given phase may be increased by transferring maximum time from other phases. This provides an automatic method of adjusting the relative allocation of maximum time where traffic flow can be tidal. Maximum time transfer is only available when the signals are operating in isolated mode. Transfer may occur via unused maximum time transfer or maximum time stealing. These may be used together or independently, as required.

> Note: the use of unused maximum time transfer or maximum time stealing may exacerbate faulty detector operation by transferring maximum time to a phase which is being extended by a faulty detector (for example, a short-circuit).

7.4.2 Unused maximum time transfer

The unused maximum time of a phase that has already run may be added to the maximum time of the running phase. If the phase donating its unused maximum time does not run (because it is skipped in the current cycle), then the whole of its maximum time is transferred. Any number of phases may have their unused maximum time transferred to a particular phase. Conversely, the unused maximum time from a particular phase may be specified as being able to be transferred to any number of phases. In this case, the first of these phases to run will be the one that receives the unused maximum time. In the example of unused maximum time transfer shown in Figure 11, when A phase terminates due to the expiry of the approach timers, B phase receives its unused maximum time. B phase is not compelled to use the maximum time and will use only what it needs.

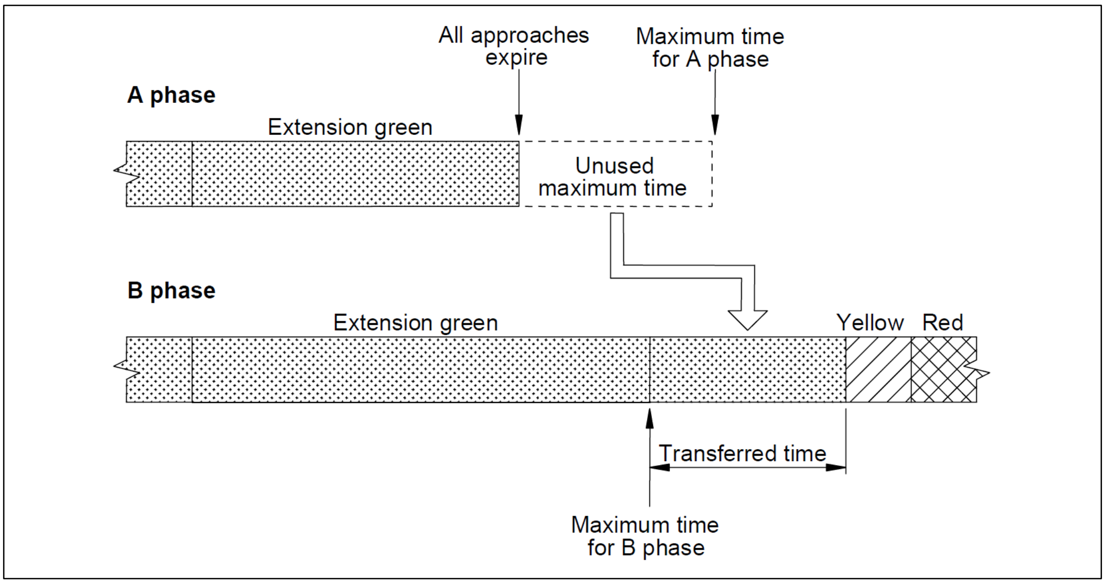


Figure 11 – Unused maximum time transfer

7.4.3 Maximum time stealing

A running phase that has used all its maximum time may gain further time by stealing maximum time from any of the following phases in the cycle that have not been demanded. When one of the next phases has its maximum time stolen in this way, it is then inhibited from running in the same cycle unless all the following conditions exist:

- the phase is demanded
- the phase will run immediately after the phase that stole its maximum time
- the phase that stole the maximum time is terminated with more than 15 seconds of the maximum time unused.

If these conditions are satisfied, then the phase that lost its maximum time may run in the current cycle, but its maximum time is limited to the unused portion of the time that was originally stolen.

In the example of maximum time stealing shown in Figure 12, if there is a demand for B phase before the A phase maximum time has expired, then A phase may not steal the maximum time from B phase. However, if there is no demand for B phase before the A phase maximum time has expired, then A phase may steal the maximum time from B. When A phase is timing the stolen maximum time, it is said to be in false green.

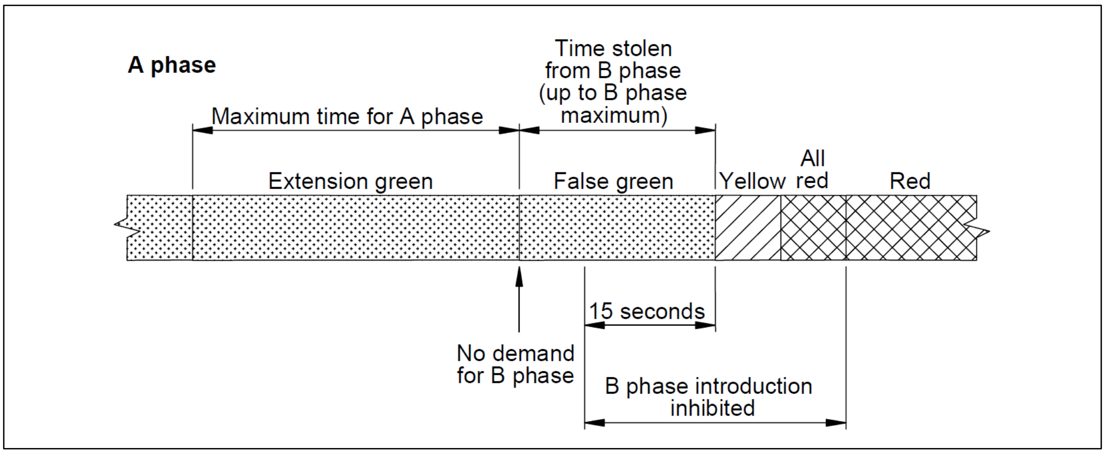


Figure 12 – Maximum time stealing

7.5 Increments, variable initial green and maximum reversion

When advance (passage) detectors are used on an approach without stop line (presence) detectors, traffic between the stop line and the advance detector cannot be detected. There is a possibility that vehicles in this area could become trapped because they cannot demand a phase. In order to minimise the probability of this happening, the techniques described in this section are used.

When the signal group servicing the approach is yellow or red, each advance detector on that approach counts the number of vehicles passing over it. When the signal group turns green, the duration of the variable initial green interval is calculated such that the queue of vehicles between the stop line and the advance detectors has adequate time to discharge before the extension green interval starts. The variable initial green is calculated in the following way:

- determine the highest count collected by the advance detectors
- subtract one (because the first vehicle is assumed to use the minimum green time and therefore does not need any variable initial green time)
- multiply by the increment time setting.

The amount of variable initial green is determined by the count (which is limited to 63), the increment time and the maximum initial green time setting. The maximum initial green timer starts timing at the beginning of the minimum green interval, but is ineffective until the variable initial green interval commences.

The gap time settings for the advance detectors are set to extend the phase green time enough to allow a vehicle crossing an advance detector to clear the stop line or pass over another detector (double extension) before the phase terminates.

If a phase terminates due to expiry of the maximum timer or one or more waste timers, an artificial demand is placed to introduce the phase in the next cycle. This is called reversion and caters for vehicles that may be trapped between the advance detector and the stop line. When the phase next runs, the controller personality may permit the variable initial green interval to be held for its maximum time. This is called maximum reversion and ensures that queues have adequate time to discharge under heavy traffic conditions.

7.6 Pedestrian movement operation

Pedestrian movements are normally grouped with vehicle movements in the same phase. This grouping should be such that the pedestrian movements run concurrently with parallel vehicle movements when appropriate. Where turning vehicles cross a pedestrian movement, pedestrian protection is provided, as discussed in Section 7.7. If pedestrian movements are grouped into one phase without any vehicle movements, it is said to be an exclusive pedestrian phase.

The pedestrian movement is divided into three sequential time intervals called walk, clearance 1 and clearance 2, as shown in Figure 13.

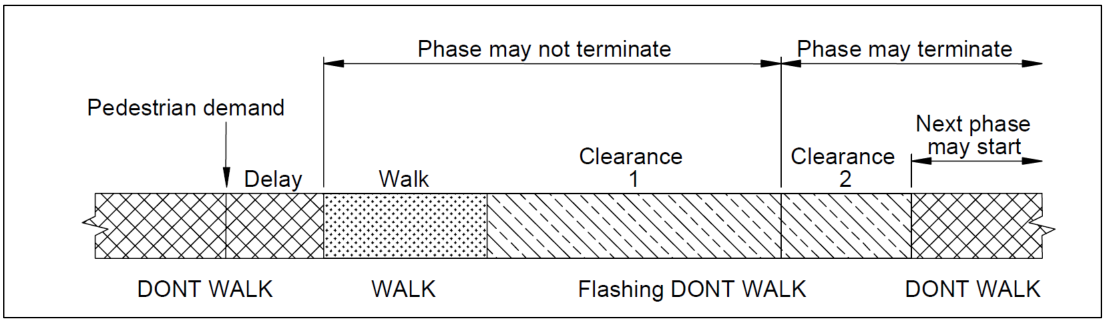


Figure 13 – Pedestrian movement operation

The delay period is seldom used. When it is used, it is normally to delay the registration of a pedestrian demand.

The duration of the walk interval is divided into walk 1 and walk 2. Walk 1 is a timed interval to provide a minimum time for the green pedestrian signal display. This is intended to allow time for pedestrians to begin their crossing. Upon expiry of the walk 1 interval, the pedestrian movement enters the untimed walk 2 interval, where it rests until the green signal display is terminated.

The clearance 1 and clearance 2 intervals provide time for the pedestrians to complete their crossing. When a pedestrian movement is introduced, the phase may not terminate until the clearance 1 interval has finished, except when the pedestrian movement may overlap. The clearance 2 interval may run concurrently with the phase clearance. It should not be longer than the phase clearance period (that is, early cut-off green + yellow + all-red), otherwise the phase will be held in the all-red interval until the clearance 2 interval finishes timing.

Because of the time that pedestrians take to cross a road, the pedestrian clearance can represent a significant amount of wasted time that could have been used by vehicle movements in another phase. Therefore, pedestrian movements are usually introduced only by demand. However, in areas of high pedestrian activity (public transport interchange, CBD environments) or locations where missing a pedestrian crossing introduction would lead to pedestrians spilling into the carriageway, automatic introduction of the pedestrian movement may be implemented through either SCATS (Y-Pulse) or a predetermined XSF bit in the controller personality.

The push buttons associated with a pedestrian movement demand phases in a similar manner to a locked-call from a vehicle detector, as well as demanding the pedestrian movement. Both these demands are cleared when the pedestrian movement receives a green signal display. Normally, such demands are placed before the phase runs.

The pedestrian movement generally commences from the start of the phase. However, if a late demand for the pedestrian is received (that is, during the phase in which it runs), the pedestrian movement may still be introduced in some circumstances. This operation is referred to as late introduction. If the controller is operating in isolated or Flexilink-isolated mode, then the pedestrian movement may be late introduced under both the following conditions:

- there are no demands for other phases
- there are no conflicting vehicle movements running (including turning movements).

If the controller is operating in full Flexilink mode, then the pedestrian movement may be introduced at the call phase pulse. If the controller is operating in Masterlink mode, then the movement may be introduced in the stretch phase upon permission from the SCATS master.

When a pedestrian movement has already run in a phase, a further demand for the movement may result in re-introduction subject to the same conditions as for late introduction. Re-introduction may occur while the pedestrian movement is timing the pedestrian clearance intervals, but once a phase has terminated (that is, left the extension green interval), demands will be stored for the next cycle.

The duration of the walk 1 interval is governed by the walk time setting. In isolated operation, this usually corresponds with the duration of the green signal display as walk 2 is skipped. This is called a timer terminated pedestrian movement. Pedestrian movements may also be terminated in the following conditions:

- the end of the extension green interval as shown in Figure 14 (called walk for green)
- the presence of an opposing phase demand (called demand terminated)
- the presence of a special signal from a master controller (called early cut-off termination)

- the arrival of a phase command from a master controller (called command termination or phase walk).

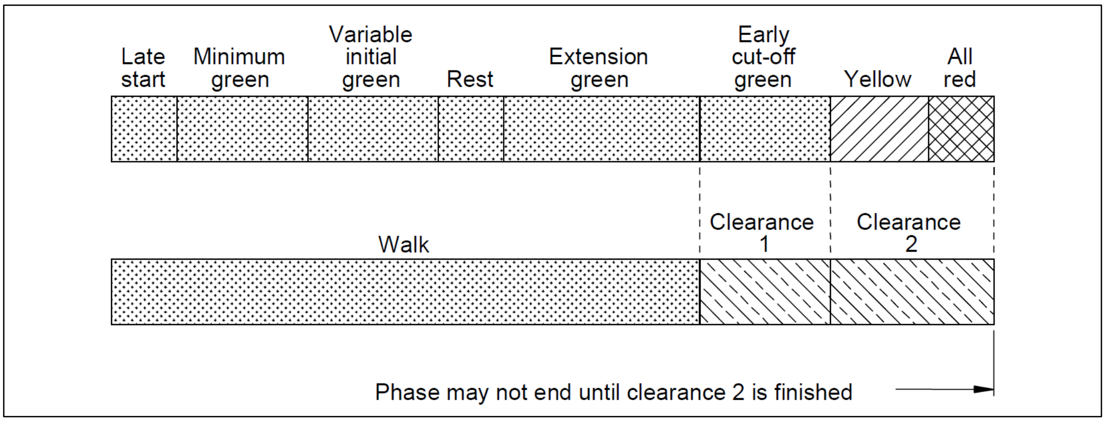


Figure 14 – Walk for green

Pedestrian movements may overlap in a similar manner to vehicle signal groups. In this case, the walk or clearance or both may overlap from one phase to another. The overlaps are determined by the data in the personality. Detailed operation of pedestrian movements at SCATS-controlled sites is provided in TS 06324.

7.7 Pedestrian protection

When a vehicle movement conflicts with a pedestrian movement, protection is provided for the pedestrians by displaying a red signal display (often an arrow aspect). The degree of protection may be any of the following:

- full protection for the entire walk and clearance intervals
- timed protection for:
  - the entire walk interval followed by a flashing yellow arrow for part or all the clearance interval
  - the entire walk interval and part of the clearance interval
  - part of the walk interval. This is not used where the signal operation for opposing traffic directions is non-identical and an opposed right turn filter movement is included
- protection for the entire walk interval.

When there is no protection, vehicles are permitted to filter through the pedestrian movement with the statutory requirement that turning vehicles must give way to pedestrians.

When timed protection is used for part of the walk period, vehicles are held on a red signal (usually an arrow) so that the pedestrians may establish their movement. The duration of the vehicle red signal display is usually controlled by a special red-arrow timer. For example, when the pedestrian movement runs, the red arrow signal display is held for a fixed time and then changes to off to allow vehicles to filter, as shown in Figure 15.

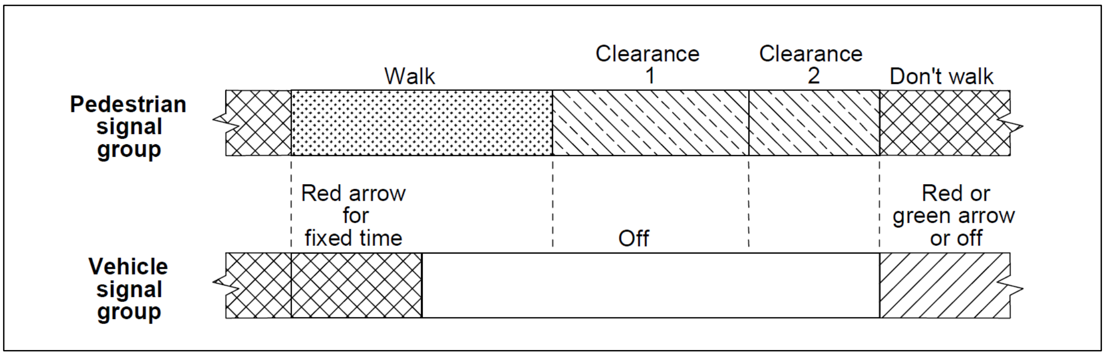


Figure 15 – Timed pedestrian protection for part of the walk interval

When protection is used for the whole of the walk interval, the operation is the same as for timed protection, except that the red signal display is held for the walk interval and vehicles are allowed to filter during the clearance intervals. For example, the red arrow signal display is held for the walk interval and then the signal group goes off to allow vehicles to filter through the pedestrian movement, as shown in Figure 16.

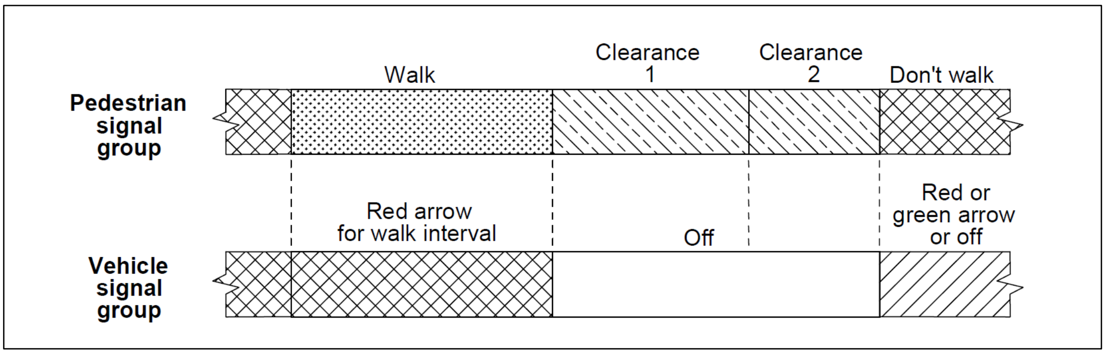


Figure 16 – Pedestrian protection for the whole of the walk interval

When full protection is used, vehicles are held on a red signal display for the whole of the walk and clearance intervals. For the example shown in Figure 17, it is assumed that the vehicle movement conflicts dangerously with the pedestrian movement because of the angle of the intersection or multiple lanes of traffic turning through the pedestrian crossing. The pedestrian movement is fully protected by holding the vehicle signal group red for the whole of the walk and clearance intervals.

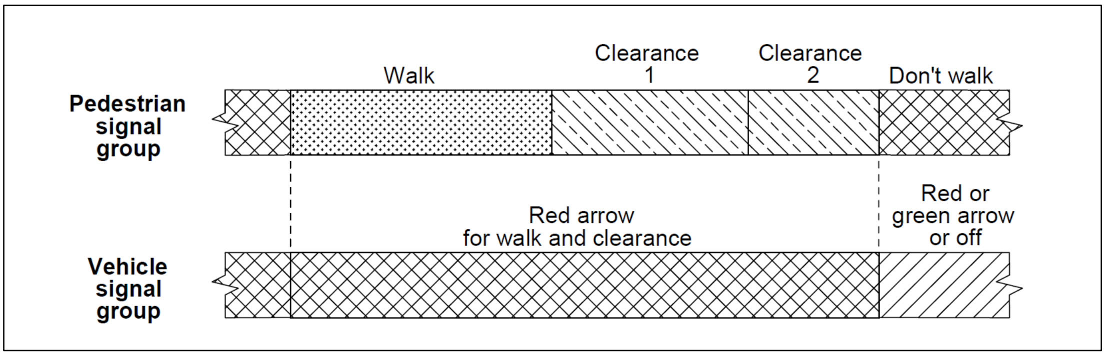


Figure 17 – Full pedestrian protection

When protection is provided, the signal group is said to be conditional if the green signal display is affected by the running of the pedestrian movement. When pedestrian protection is provided, there will be some cases where it is possible to introduce the green arrow signal display after the pedestrian clearance has completed. However, this may only be done if the green signal display is shown for a minimum period (for safety reasons). This period is called a signal group minimum green. If the signal group is not green in the next phase, it is not possible to leave the current phase until the signal group minimum green timer has expired.

7.8 Alternative movements

A phase is not a fixed set of vehicle movements but may allow alternative sets of movements depending on the demands received from the vehicle detectors. In some cases, a vehicle movement may be conditional on another vehicle movement.

In the example shown in Figure 18, the choice of which of the following alternatives run in C phase depends on the demands received from the detectors:

- alternative 1 runs if both D1 and D2 place a demand
- alternative 2 runs if only D1 places a demand
- alternative 3 runs if only D2 places a demand.

The most common use of alternative movements is with single diamond overlap phasing and double diamond overlap phasing. The operation of these is described in TS 06326 and TS 06327 respectively.

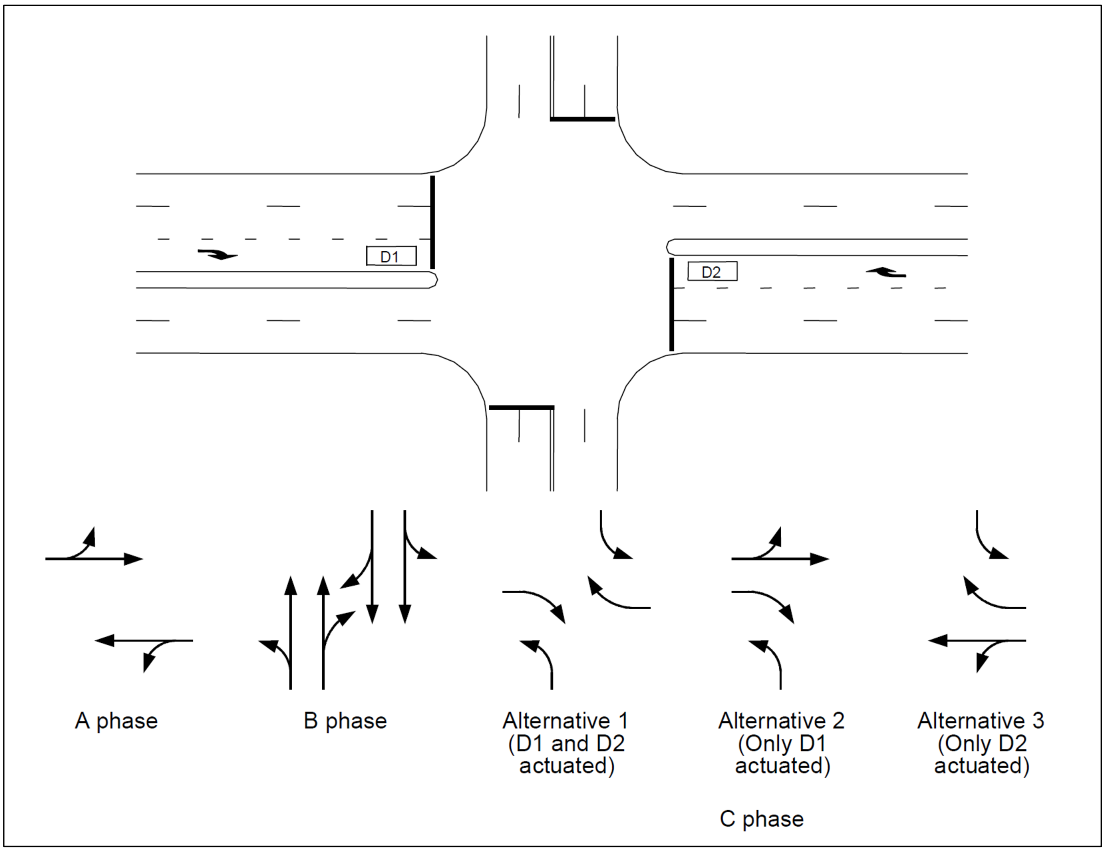


Figure 18 – Example of an alternative overlap

8 Time settings

8.1 General

This section is a guide to determining time settings for traffic signal controllers. It has been prepared specifically for microprocessor controllers that use a TfNSW standard personality, but the procedures are generally applicable to all controllers. The settings may be varied for unusual situations, and these are indicated where possible.

All time settings shall have an upper and lower limit. The lower limit (that is, minimum value) for time settings shall be zero, except where noted. The upper limit (that is, maximum value) for each time setting is given in these guidelines. Time settings should not exceed the upper limits.

8.2 Late start

A separate time setting is provided for the late start interval of each phase.

When the late start interval is used in one of the four standard ways described in TS 02670, the time setting is typically 4 to 5 seconds. When the late start interval is used at a left turn slip lane, the time setting will depend on the intersection geometry, but is typically 2 to 5 seconds.

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If the late start interval is not required for a given phase, then the time setting should be set to zero.

In practice, the late start interval is automatically set to zero by the controller, except when the late start is applied.

The maximum value shall be 20 seconds.

8.3 Minimum green

A separate time setting is provided for the minimum green interval of each phase.

The minimum green is typically 5 seconds but may be increased to 8 seconds to allow for longer start up times with steep up-grades or a high percentage of heavy vehicles. On a designated B-double route the minimum shall be 8 seconds. On roads where road trains are permitted, the signalised intersection clearance times provided in *Performance-Based Standards Scheme – Network Classification Guidelines* shall be used. (B-double and road train routes are provided in the *NSW Combined Higher Mass Limits (HML) and Restricted Access Vehicles (RAV) map*.)

The maximum value shall be 20 seconds.

8.4 Early cut-off green

A separate time setting is provided for the early cut-off green interval of each phase.

When the early cut-off green is applied, the time setting will depend on the intersection geometry.

A typical application is for multi-lane intersections or staggered T-junctions where there is a storage area between two stop lines. In such cases, the time setting is typically at least 3 seconds. Where this feature is not applied, the time setting should be set to zero. As the early cut-off yellow commences timing at the start of the early cut-off green interval, the normal yellow and early cut-off yellow are then coincident.

The maximum value shall be 20 seconds.

8.5 Yellow

A separate time setting is provided for the yellow interval of each phase.

The yellow time setting shall allow sufficient time for vehicles to halt at the stop line and will therefore be governed by vehicle speed and the grade of the approach to the stop line. Time settings for a range of downhill grades are shown in Table 1. The grade reference shall be that shown on the traffic signal design plan. The table values are calculated from the yellow time equation provided in *Guide to Traffic Management Part 9: Transport Control Systems –*

Strategies and Operations applying a reaction time of 1.0 second. For TfNSW, the posted speed shall apply as the design speed.

Table 1 – Time setting for yellow interval on downhill and level grades (in seconds)

Grade (downhill %)	Design speed 40 km/h	50 km/h	60 km/h	70 km/h	80 km/h
15	5	6	6.4	6.4	6.4
14	4.5	5.5	6.4	6.4	6.4
13	4.5	5	6	6.4	6.4
12	4	5	6	6.4	6.4
11	4	5	5.5	6	6.4
10	4	4.5	5.5	6	6.4
9	4	4.5	5	6	6.4
8	3.5	4.5	5	5.5	6
7	3.5	4	5	5.5	6
6	3.5	4	4.5	5	6
5	3.5	4	4.5	5	5.5
Level	3	3.5	4	4.5	5

Note to Table 1: The time setting for a level grade shall apply to downhill grades less than 5 % and all uphill grades.

The minimum value shall be 3 seconds and the maximum value shall be 6.4 seconds. The background software in the controller does not permit values outside this range.

8.6 All-red

A separate time setting is provided for the all-red interval of each phase. Initial time settings can be estimated from Table 2 and rounded up to the nearest 0.5 seconds. The all-red time shall never be less than 1 second. For TfNSW, the posted speed shall apply as the design speed for the all-red time setting.

Table 2 – Time settings for all-red interval

Design speed (km/h)	Time setting (seconds)
40	$w / 14$
50	$w / 14$
60	$w / 14$
70	$w / 18$

Design speed (km/h)	**Time setting (seconds)**
80	$w/21$

Note to Table 2: w is the distance (in metres) measured from the departure stop line to the furthest point of conflict with vehicles or pedestrians in the next or subsequent phase, taking into account the longest distance of any straight or turning movement within the phase.

Final time settings should be determined on site by a visual assessment of clearance times required by vehicles that legitimately enter the intersection during the yellow interval. Additional all-red time should not be provided to clear vehicles waiting within the intersection to make a right turn. All-red time should not be increased above the limits mentioned above to accommodate for vehicles who enter in the intersection after all-red period has started.

The maximum value shall be 15 seconds.

8.7 Increment

A separate time setting is provided for the increment in each phase. The typical time setting for an increment is 2 seconds. This should be increased for up-grades and decreased for down-grades by 0.1 seconds for each percent of grade. The site should be observed under a range of conditions to ensure that the increment is appropriate. This is especially so where a detector covers more than one lane or the lane utilisation varies.

The increment time setting is only used with advance detectors. If this feature is not required, the time setting should be set to zero.

The maximum value shall be 5 seconds.

8.8 Maximum initial green

A separate time setting is provided for the maximum initial green of each phase.

The time setting is determined using the following equation:

$$\mathrm{maximum\ initial\ green\ time} = \mathrm{MG} + \mathrm{VIG}_{\mathrm{max}}$$

where MG is the minimum green time (in seconds) and

$\mathrm{VIG}_{\mathrm{max}}$ is the maximum variable initial green required to clear queue between the stop line and advance detector (in seconds) and can be estimated using the following equation:

$$\mathrm{VIG}_{\mathrm{max}} = \mathrm{i} \times (\mathrm{n} - 1)$$

where i is the increment (in seconds) per vehicle and

n is the maximum number of vehicles between the stop line and advance detector, which can be calculated for any one lane using the following equation:

$$n = d / l$$

where d is the distance (in metres) between the stop line and advance detector and

l is the storage length (in metres) per vehicle (typically 6.0 m).

The site should be observed under a range of conditions to ensure that the maximum initial green time setting is appropriate and that there is sufficient variable initial green to allow vehicles between the stop line and the detectors to reach the stop line before the phase terminates.

The maximum initial time setting is only used with advance detectors. If this feature is not required, the time setting should be set to zero.

The maximum value shall be 40 seconds.

8.9 Maximum green

A separate time setting is provided for the maximum green time of each phase. This is only used when the controller is operating in isolated mode.

If the intersection is not saturated, the maximum green time for each phase should be sufficient to clear the longest queue for that phase under normal peak traffic conditions. If the intersection is saturated, the maximum green times should be such that the delays to all approaches are balanced and the overall cycle time is acceptable.

Traffic modelling may be used as a guide to provide maximum green times. When determining the maximum green times, it is preferable to initially err on the high side, since the gap, headway and waste timers will terminate the green for under-saturated traffic flow.

The maximum value shall be 150 seconds.

8.10 Special red

A separate special red time setting is provided for each phase.

The purpose of the special red time setting is to provide an alternative to the all-red time setting that may be used for particular phase sequences. This is not recommended for SCATS usage unless a variation routine is used to let the SCATS master know the duration of each intergreen.

The maximum value shall be 15 seconds.

8.11 Special time settings

8.11.1 General

There are 40 special time settings. Special time settings 1 to 8, 11 to 19 (commonly used for setting the duration of timed red arrow pedestrian protection), and 25 to 40 are available for general use. Other special time settings are used for the following specific purposes:

- Special time setting 9 – single and double diamond overlap phasing, as described in TS 06326 and TS 06327 respectively
- 10 – double diamond overlap phasing as described in TS 06327
- 20 – start red as described in Section 8.11.2
- 21 and 23 – offset time settings as described in Section 8.11.3
- 22 and 24 – storage time settings as described in Section 8.11.3.3.

The time settings used for special time settings depend on the application. The maximum value shall be 200 seconds.

8.11.2 Start red

A single time setting is provided for the start red. This is used to time the period following the initial start-up or restart of the signals during which all signal groups display a red aspect. This feature is not used on mid block type signalised pedestrian crossings. The time setting in NSW is 4 seconds.

The maximum value shall be 200 seconds.

8.11.3 Vehicle-pedestrian link

8.11.3.1 General

PSC type controllers can have up to two vehicle-pedestrian (V-P) links, each with separate offset and storage time setting, as described in Section 8.11.3.2 and Section 8.11.3.3.

TSC/4 type controllers use SCATS to connect sites.

8.11.3.2 Offset

A separate offset time setting is provided for each link. The purpose of the offset time setting is to control the period between the termination of the coordinated phase at the vehicle site and the vehicle phase at the pedestrian site.

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The time setting used depends on the distance between the vehicle and pedestrian sites and vehicle speeds. It should allow vehicles to progress through the vehicle site and the pedestrian site without getting trapped in between.

The maximum value shall be 200 seconds.

8.11.3.3 Storage

A separate storage time setting is provided for each link. The purpose of the storage time setting is to determine the maximum time before the introduction of the walk at the pedestrian site if the adjacent vehicle site does not cycle.

The time setting used depends on the cycle length at the vehicle site but should not generally exceed 60 seconds.

The maximum value shall be 200 seconds.

8.12 Signal group minimums

Signal group minimums are used to guarantee a minimum green period for signal groups introduced late in a phase (for example, a vehicle group which is conditional on a pedestrian movement). When a signal group minimum is used, it may be set by the controller personality to use the same time setting as the minimum green interval for the current phase. Alternatively, it may use a special time setting.

For SCATS operation, the time setting should be no greater than 5 seconds to avoid SCATS alarms.

The maximum value shall be 20 seconds.

8.13 Pedestrian delay

A separate time setting is provided for the pedestrian delay of each pedestrian movement. Its purpose is to provide a delay between the push-button actuation and the demand for the pedestrian movement. This helps to form platoons of pedestrians and therefore avoid possible unnecessary cycling.

Typical time settings are 4 to 5 seconds for signalised mid-block pedestrian crossings and crossings at intersections with independent pedestrian features. If this feature is not required, the time setting shall be set to zero.

The maximum value shall be 20 seconds.

8.14 Pedestrian walk

A separate time setting is provided for the pedestrian walk interval of each pedestrian feature. The pedestrian walk interval provides sufficient time for pedestrians to begin their crossing.

Typical time settings are a minimum of 6 seconds with an additional 2 seconds for each rank of pedestrians up to 10 seconds. Crossings located at schools and railway stations may require walk times greater than 10 seconds.

In the case of short-term peak pedestrian activity, such as at schools and railway stations, a time-of-day variation should be used to provide a selection of alternative pedestrian walk time settings.

If a single-stage mid-block pedestrian crossing is used at a divided carriageway, the walk time should be long enough to allow pedestrians to complete the first crossing and begin the second before the clearance period starts.

In some cases (such as walk for green), a walk signal is displayed for all or most of the green time of the associated phase. In such cases, the minimum walk time shall be set to 6 seconds. The pedestrian movement is held in the walk 2 interval for the remainder of the walk time.

The maximum value shall be 40 seconds.

8.15 Pedestrian clearances

The pedestrian clearance period provides time for pedestrians to complete their crossing. The total clearance period required for a particular crossing may be calculated using the following equation:

total clearance period = d / k

where d is the length of pedestrian crossing (in metres) and

k is the pedestrian walking speed (in metres/second).

The walking speed used should be 1.2, but may be reduced to a minimum of 0.8 where slower walkers are observed, for example nearby schools, retirement homes and train stations. The length of the pedestrian crossing for a scramble crossing is the length of the diagonal movement.

This guideline may be varied in the case of extremely long crossings (where a staged crossing should be considered) or where the crossing will be used by elderly people or people with a disability.

Timing of the pedestrian clearance period is done via the clearance 1 and clearance 2 time settings. A separate time setting is provided for each of the clearance 1 and clearance 2 intervals of each pedestrian feature.

The time setting for the clearance 1 interval is the total clearance period minus the time setting for the clearance 2 interval. The maximum value of the clearance 1 interval is 40 seconds.

The clearance 2 interval allows the pedestrian clearance to overlap into the intergreen and therefore shall not be longer than the clearance part of the phase (that is, early cut-off green + yellow + all-red). The maximum value of the clearance 2 interval is 10 seconds.

8.16 Pelican crossings

An example of time settings for the operation of pelican crossings is shown in Figure 19. The duration of the vehicular green is determined by site conditions and system conditions if operating under SCATS. The duration of the walk and clearance intervals are determined as per Section 8.14 and Section 8.15, respectively. However, the cumulative time for Walk and Clearance 1 shall be sufficient to get a pedestrian completely across the carriageway, kerb to kerb.

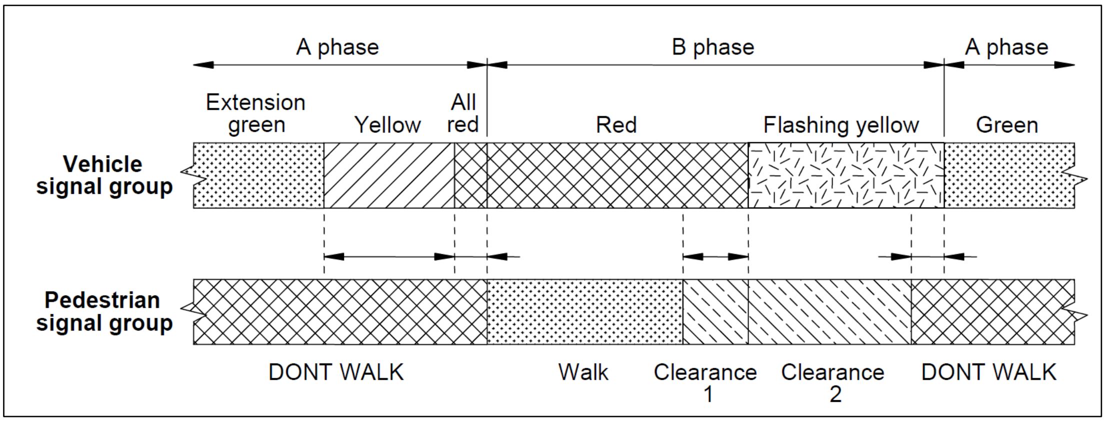

Figure 19 – Time setting for pelican crossings

8.17 Gap timers

Gap timers provide timing to cater for different approach characteristics, such as grade and turning radius. For example, an uphill approach requires a longer gap time to compensate for longer startup delays and slower speeds, especially where the proportion of heavy vehicles is significant. Small turning radii tend to cause lower turning speeds and increase traffic density. In this case, shorter gap times may be appropriate. There are eight gap timers, but only four gap time settings per phase.

The following are typical time settings for stop line (presence) detectors:

- 2.5 seconds for an exclusive left- or right-turn lane
- 3 to 4 seconds for a through or shared lane.

Some bias for major/minor roads may be obtained by increasing the gap times on the major road.

For the case of advance (passage) detectors, the gap time settings should be sufficiently high to allow a vehicle to travel from the detector to the stop line before expiry of the gap timer. Initial time settings can be estimated with the following equation:

$$\text{time setting} = (3.6 \times \mathrm{d}) / (0.6 \times \mathrm{v})$$

where d is the distance between stop line and advance detector (in metres) and

v is the posted speed limit (in km/h).

The constant of 3.6 in this equation is a conversion factor to ensure the units are compatible. The constant of 0.6 is because it is assumed that the slowest vehicle needing to be cleared travels at 60% of the speed limit. If this figure is inappropriate, adjust the constant on the bottom line of the equation to suit.

In any case, the final time setting shall be verified by observing traffic conditions on site.

The maximum value shall be 10 seconds.

8.18 Headway timers

There are eight headway timers, but only four time settings per phase.

Time settings for stop line (presence) detectors tabulated in *Guide to Traffic Management Part 9: Transport Control Systems – Strategies and Operations* may be adopted, or calculated with the following equation:

$$\text{time setting} = 1.25 \times (\mathrm{s} / \mathrm{n})$$

where s is the space time at saturation flow (in seconds/vehicle) and

n is the number of normally active lanes which influence the headway timer.

The constant of 1.25 is a calibration factor to ensure that the headway time setting will be appropriate for flows in the range 0.8 to 1.0 times the saturation flow.

The space time at saturation flow can be calculated as follows:

$$\mathrm{s} = \mathrm{h} - \mathrm{o}$$

where h is the headway at saturation flow (in seconds/vehicle) and

o is the occupancy at saturation flow (in seconds/vehicle).

If the site is connected to SCATS and the subject detectors are used as strategic inputs, the headway and occupancy at saturation flow can be calculated from the strategic input data with the following equations:

$$\mathrm{h} = 3600 / \mathrm{MF}$$

where MF is the maximum flow (in vehicles/hour)

$\mathrm{o} = \mathrm{KP} / 100$

where KP = average occupancy when MF occurred (in centiseconds/vehicle).

Otherwise, headway and occupancy at saturation flow can be estimated from the saturation flow and prevailing speed with the following equations:

$\mathrm{h} = 3600 / \mathrm{q}_{\mathrm{max}}$

where $\mathrm{q}_{\mathrm{max}}$ is the saturation flow (in vehicles/hour)

$\mathrm{o} = 3.6 \times (\mathrm{d} + \mathrm{l}) / \mathrm{v}$

where d is the length of detection zone (in metres/vehicle) and

l is the average length of vehicle (in metres/vehicle) and

v is the vehicle speed (in km/h).

For example, on a three-lane approach with two active lanes, with saturation flow of 1700 vehicles/hr, a detection zone length of 4.0 m, an average vehicle length of 5.0 m, and a speed of 50 km/h, then:

$\mathrm{s} = (3600 / \mathrm{q}_{\mathrm{max}}) - (3.6 \times (\mathrm{d} + \mathrm{l}) / \mathrm{v})$

$\mathrm{s} = (3600 / 1700) - (3.6 \times (4.0 + 5.0) / 50)$

$\mathrm{s} = 1.5\ \mathrm{s}$

$\text{time setting} = 1.25 \times \mathrm{s} / \mathrm{n}$

$\text{time setting} = 1.25 \times 1.5 / 2$

$\text{time setting} = 0.9\ \mathrm{s}.$

Where there is a shared right and through lane in conjunction with a right-turn phase, a special headway time setting of 0.1 seconds is used for the 11 m presence detector. Refer to TS 06323.

Passage detectors give a short output pulse of fixed duration in accordance with vehicle headway times. Therefore, the time setting relies on headway, rather than space time, and is calculated with the following equation:

$\text{time setting} = 1.25 \times \mathrm{h} / \mathrm{n}$

For example, for a three-lane approach with two active lanes, then:

$\text{time setting} = 1.25 \times 2 / 2$

$\text{time setting} = 1.25\ \text{seconds}$

For both presence and passage detectors, no (or minimal) waste time occurs under near-saturated conditions. During saturated conditions, the phase should terminate at the phase maximum time.

The maximum value shall be 5 seconds.

8.19 Waste timers

There are eight waste timers, but only four time settings per phase.

Typical time settings are 4 to 10 seconds, these being 10% of the maximum green time.

The maximum value shall be 50 seconds.

8.20 Presence timers

All 48 detectors have presence timed functionality. Though there are only 24 presence time settings, special time settings may be used for this purpose (see Section 8.11).

Typical time settings are 2 seconds for an 11 m stop line (presence) detector and 3 seconds for a B-C type left turn stop line (presence) detector.

Unused presence timers shall have a time setting of zero.

The maximum value shall be 15 seconds.

Appendix A A brief history of signalised intersections

Traffic signals are a form of traffic control device utilising coloured, illuminated displays to indicate which traffic streams have the right-of-way. The first traffic signals were installed in Bridge Street, London (opposite the Houses of Parliament) on 10 December 1868. They consisted of a semaphore arm on top of a 6.7 m post with red and green gas lamps. Police officers were able to change the signals by pulling a lever at the foot of the pole. When the semaphore arms were extended, they indicated a stop signal. When lowered, they meant caution. At night, the red gas lamp was used with the stop position and the green lamp with the caution position.

Londoners were enthusiastic about the new device, but it was plagued by problems. Horses were frightened by the arm movements during the day, and the lights at night, and many horses bolted. Two policemen were killed while operating the semaphores and another was killed by a gas explosion when trying to light the lamps.

The next major step was in 1918 when the first three-coloured light signals were installed at several intersections in New York. These were manually operated by police officers. Two years later, similar signals were installed in England.

Signals were soon operated by an electro-mechanical fixed-time controller that determined the period of green time for each traffic movement. These were inefficient as far as traffic management was concerned and often caused unnecessary delays. This system was adopted in Melbourne.

Adler introduced the horn-actuated detector to the USA in 1928 and the first crude vehicle-actuated signals were developed soon after. Traffic conditions in England fostered the introduction of vehicle-actuated equipment and this was further developed until it became an efficient and economical alternative to police control.

One manufacturer of vehicle-actuated equipment was Automatic Telephone Manufacturing (ATM) Co. of Liverpool, which was represented in Sydney by Automatic Electric Telephones Pty Ltd. One of this firm's eager young salesmen, Bob Filmer, made a determined effort to convince the NSW government that ATM's traffic-actuated signal equipment possessed none of the shortcomings of the fixed-time equipment used in the USA and Melbourne. He offered to import one set of equipment, supply it for a three-month trial period and remove it at the end of the trial if the installation was considered unsatisfactory, all without obligation to the government and at no cost to the NSW taxpayer.

The Police Commissioner opposed the offer, as he did not want his point-duty officers replaced by machines. However, the government eventually accepted on the condition that the Police

Commissioner could select the trial site. He nominated the intersection of Kent and Market Streets. This was a particularly busy intersection, but also posed special problems for horses because Market Street was paved with wooden blocks. These formed a slippery surface for the horses' hooves as they travelled uphill from the Pyrmont and Darling Harbour wharves with heavily laden carts. Poor traffic control at this intersection would wreak havoc with the horse-drawn traffic ascending Market Street.

The equipment was imported from England at a cost of £390 and installed at a cost of just over £183. It consisted of an ATM type 33 controller, three-aspect signal face and massive contact-plate detectors, all specially adapted for use on Sydney's 240-volt power supply. The signals were switched on by the Minister for Transport, Colonel Michael F. Bruxner, on 13 October 1933.

Although the commissioning was carried out with much fanfare and publicity, Mr Filmer knew that the battle was far from won, especially as the reliability of the cumbersome contact-plate detectors left much to be desired. During the three-month trial period, Mr Filmer was frequently seen on the site leaning against the controller cubicle, anxiously watching the operation of the signals. Many years later, it became known that Mr Filmer had become quite adept at changing the signals by means of a switch concealed in his coat pocket so that any faults in the detectors would go unnoticed. His efforts were not in vain, as the government decided to retain the signals permanently.

Tenders were invited for the installation of further sets of signals in 1935, but the tender prices were considered to be excessive and no further signals were installed until 1937. From then on, the number of installations increased rapidly. The 1000th installation in NSW was placed in service on 8 April 1974. By August 1991, there were over 2120 traffic signals in service at intersections throughout NSW and a further 280 at mid-block sites. By January 2013 there were 3930 traffic signals in service in NSW including mid-block sites.