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Traffic Signal Operation

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1. Background

1.1 Introduction

This chapter describes the basic terms and concepts which are essential to the understanding of chapters 2 to 4. It covers three main areas – history, system overview and terminology. Unfortunately, the terminology used to describe traffic signal operation has not been standardised on a world-wide basis and the same terms may be used to describe quite different concepts in different countries. The terms used in this version of the manual are those commonly used in Australia.

1.2 Brief history of traffic signals

Traffic signals are a form of traffic control device utilising coloured lamps 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 meant stop. 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 which 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 economic alternative to police control.

One manufacturer of vehicle-actuated equipment was Automatic Telephone Manufacturing (ATM) Co. of Liverpool who 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 New South Wales 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 New South Wales 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 lanterns 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, Bob 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, Bob 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 Bob 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 December 2009 there were 3791 traffic signals in service in NSW including mid block sites.

1.3 System overview

Modern traffic-actuated traffic signals consist of a number of major components which are interrelated as shown in figure 1.1 to form a complete system.

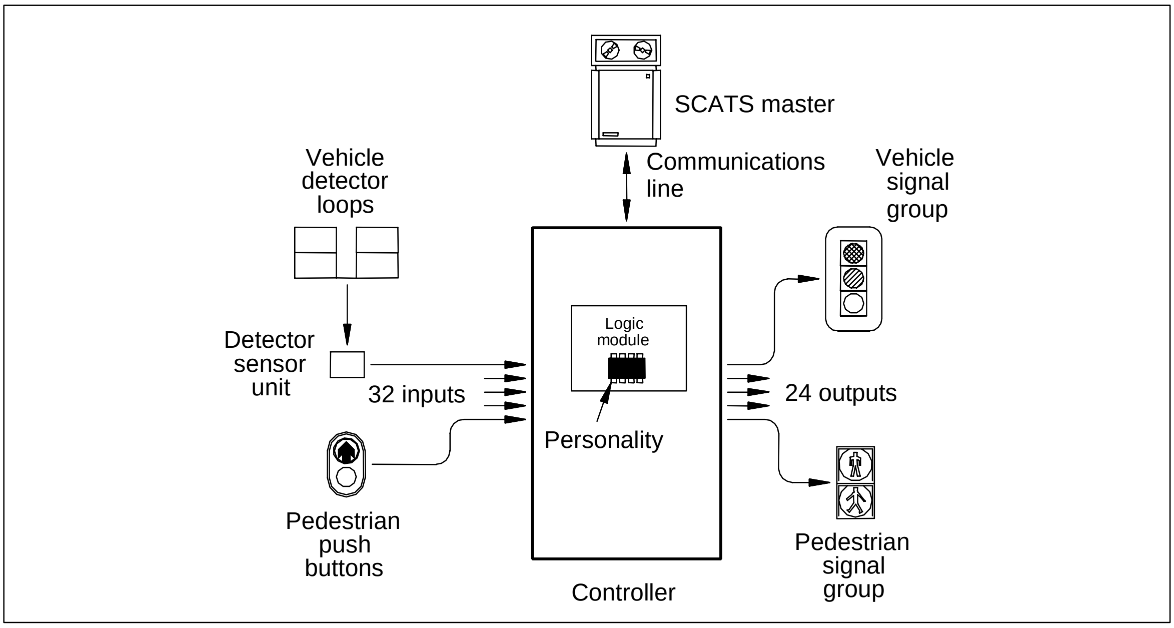


Figure 1.1 System overview of traffic signal operation

There is currently a maximum of 32 inputs to the controller. Of these, a maximum of 24 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 chapter 2.

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 which monitors the inputs from detectors, communicates with the SCATS master computer and drives the outputs to signal groups. The personality is an Erasable Programmable Read Only Memory (EPROM) containing site specific data such as 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 chapter 3. Time settings are discussed in chapter 4.

There are 24 outputs from the system which are used to control the colours displayed at traffic signal lanterns. The software can accommodate up to 16 vehicle outputs and 8 pedestrian outputs.

A communications line is used to allow 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 (SCMS).

1.4 Movements and phases

Each possible trajectory 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 1.2, there are three movements in each approach for a total of 12 movements.

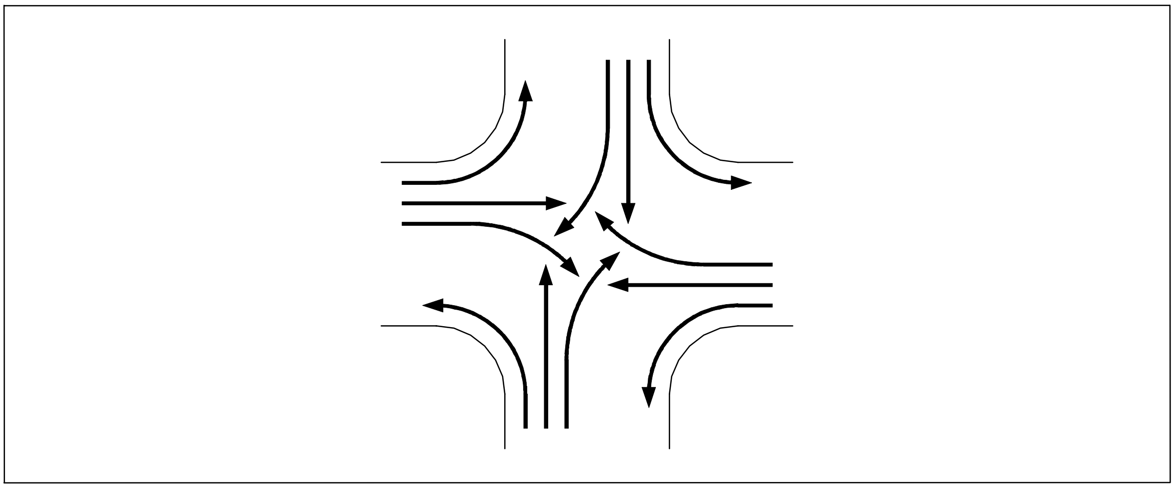


Figure 1.2 Vehicle movements at an intersection

Although it would be 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 may consist 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, then those movements which are obliged to yield right-of-way are said to be filter movements.

Phases are labelled A to G. In some cases, phases may have options within the same phase, e.g. E, E1 and E2. Only one phase can 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.

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 1.3 shows a comparison of two different phasing designs for a four-way intersection. The two-phase design 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 has no conflicts, but is very inefficient.

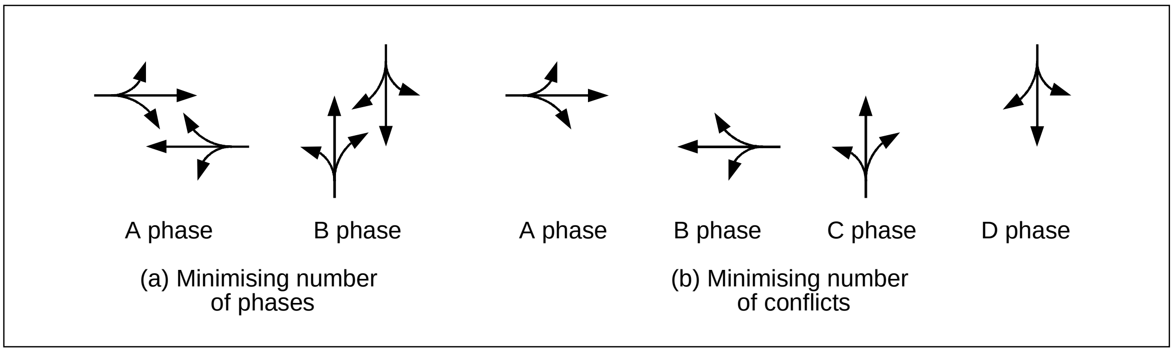


Figure 1.3 Comparison of phasing designs

Selection of an appropriate phasing design for a particular intersection is further discussed in *Traffic Signal Design* (RTA 2008).

1.5 Phase intervals

A phase consists of two major parts as shown in figure 1.4. These are the “running” part and the “clearance” part. The running part of the phase is the portion of the phase between the start of the phase and the termination point. Once the termination point has been passed, the next phase has been determined and cannot be changed. The running part is divided into five sequential time periods or intervals:

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

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

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

The uses of these intervals are described in the following sub-sections.

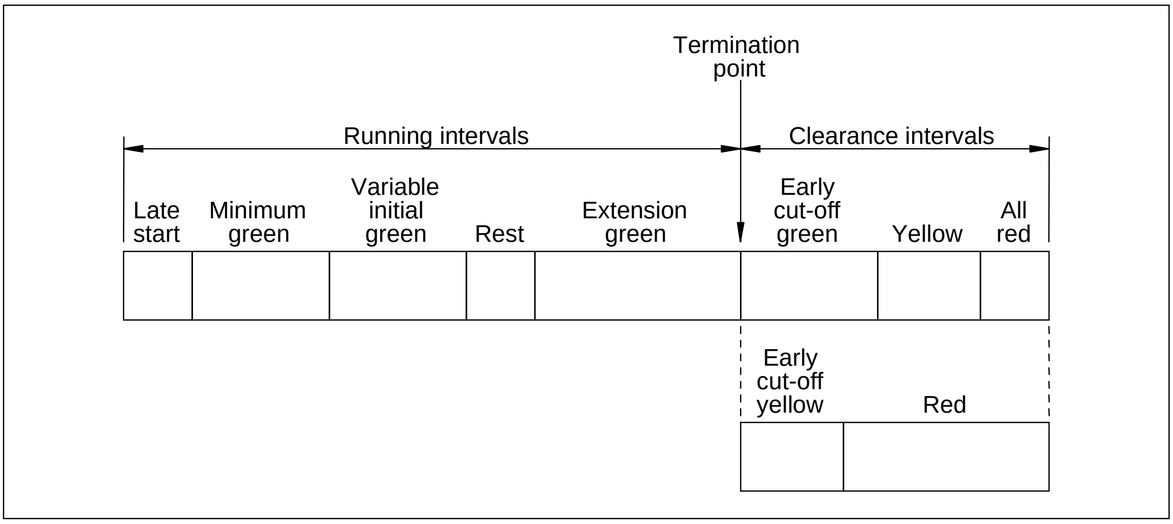


Figure 1.4 Phase intervals

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

1.5.1 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. However, the late start interval is only included in the phase when required for a particular phase transition, otherwise it is skipped.

1.5.2 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.

1.5.3 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. This is further explained in chapter 3.

1.5.4 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.

1.5.5 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 chapter 3. Under SCATS operation, its duration is determined by coordination equipment (i.e. the SCATS master computer under Masterlink). A phase can only terminate (i.e. 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 cannot be changed. The controller may stay in the extension green interval if the demands for other phases are cancelled.

1.5.6 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.

1.5.7 Early cut-off yellow

The early cut-off yellow interval is an auxiliary phase interval which is used to provide a yellow display for any signal groups which 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 1.4. 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.

1.5.8 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.

1.5.9 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.

1.6 Lanterns

Traffic signal lanterns are the medium by which vehicles and pedestrians are controlled. Lanterns intended for vehicle control may consist of full roundels or arrows, each in red, yellow or green. Each different coloured roundel or arrow is called an aspect. Thus, a lantern with one full roundel or arrow is called a one-aspect (or single aspect) lantern, a lantern with two full roundels or arrows is called a two-aspect lantern and so on. An assembly with more than three aspects arranged in two columns is called a dual lantern. For example, an assembly consisting of three left-turn arrows and three full roundels is called a dual three-aspect lantern.

Lanterns 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 lanterns including their function, size, aiming and shielding, use of visors and louvres, lamp monitoring and labelling is given in *Traffic Signal Design* (RTA 2008).

1.7 Signal groups

All traffic signal lanterns which 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 a number of movements (such as a full roundel controlling left-, through- 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, 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.

Phase-related signal groups are identified by the phase or phases in which they are green, e.g. A, B or B/C. When a signal group is permitted to display a green aspect 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. These signal groups are identified by the phases in which they are green and their operation is explicitly defined by standard tables as described in drawing No. VD018-8.

2. Vehicle detector operation

2.1 Introduction

This chapter discusses the requirements of vehicle detection systems for traffic signals in Australia. This should 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 various technical papers and *Guide to Traffic Management Part 9: Traffic Operations* (Austroads 2009).

2.2 Objectives of vehicle detection

For a traffic-actuated system to be effective, it must obtain information on 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. Therefore, in order to operate effectively, the vehicle detection system must 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 requirements can be met by:

- using a suitable type of detector
- choosing the correct dimensions for the detection zone
- locating the detector correctly in respect to the stop line, and
- correctly interpreting the data from the detector

2.3 Type of detector

The type of detector needed to meet the objectives of section 2.2 must have a clearly defined detection zone such that each lane can be examined individually. To achieve this, interference from adjacent lanes must be low. Detectors which emit a broad beam of energy (such as microwave and infrared detectors) fail to satisfy this criterion, so their use is limited to temporary installations and special applications. See Equipment Specification MD/4 for further details on microwave vehicle detectors.

There are various types of detector which reasonably meet all of the above requirements. 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 shows much promise for the future.

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.

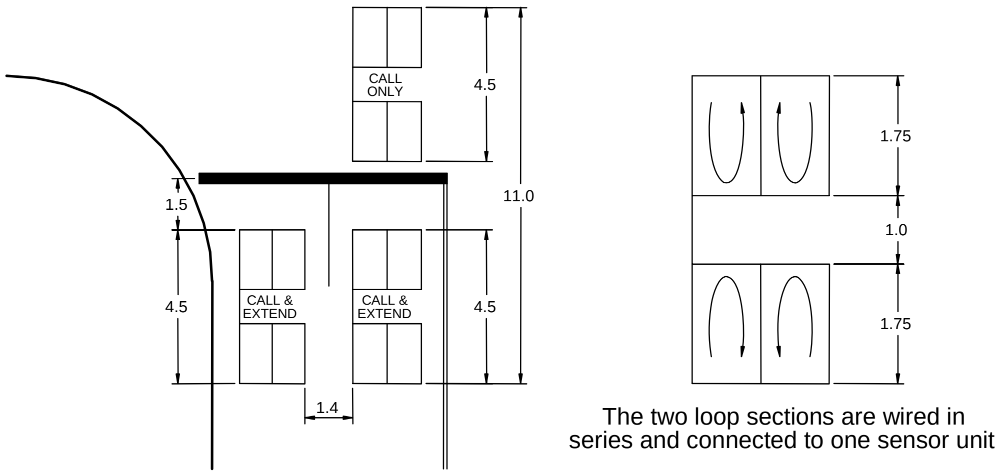
When in presence mode, detectors provide a continuous output whenever a vehicle (or part of it) is within the detection zone. The duration of the output is affected by the length of the detector loop, the length of the vehicle and the speed of the vehicle. Nevertheless, the duration of the output signal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

Presence mode is also essential for SCATS operation as it needs the number of detector actuations and the total space time (i.e. the sum of the non-actuated periods) to determine coordination parameters.

Types of detectors are further described in *Traffic Signal Design* (RTA 2008).

2.4 Layout of loop detectors

Many operational factors have been considered in determining the optimum loop layout for the inductive loop detector. Figure 2.1 shows the recommended layout and configuration for stop line detectors operating in the presence mode. The reason for the optimum loop lengths of 4.5 m and 11.0 m is described in *Guide to Traffic Management Part 9; figure 7.9: Traffic Operations* (Austroads 2009).



The two loop sections are wired in series and connected to one sensor unit

(a) Layout of 4.5 m and 11.0 m loops

(b) Configuration of loop

Figure 2.1 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:

- unwanted detection of vehicles in the adjacent lane (over counting), and
- the number of undetected vehicles (especially two-wheeled vehicles) which do not travel through the loop’s zone of influence (undercounting)

The optimum spacing between detectors in adjacent lanes is theoretically achieved when over counting 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 must 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 2.1 represent a good compromise between the various factors.

Further details of the overall dimensions of inductive loop detectors (including detectors other than stop line detectors) may be found in *Traffic Signal Design* (RTA 2008).

2.5 Detector location

The location of the loop affects both the demand and processing functions which 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 by tending to:

- provide an advance call for a relevant phase, and
- avoid the termination of a green display when a vehicle is in the "dilemma zone"

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
- demands must be processed 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 cannot be detected
- arbitrary provisions have to be made for the green time requirements for traffic trapped between the detector loop and the stop line at the start and end of the phase
- excessive allowances need to be made for the time necessary for individual vehicles to travel from the loop to the stop line during the green interval
- the further the detector is located away from the controlled area (i.e. the stop line), the less accurately it is able to respond to changes in traffic flowing into the controlled area (e.g. a decrease in capacity and queue formation), and
- the installation of detector loops far in advance of the stop line is generally unattractive from an economic point of view

These shortcomings can be avoided by using detector loops at the stop line. These must 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 approximately 4.0 m. This allows a vehicle to be detected over a range of approximately 13.0 m (i.e. the length of the detector plus two car lengths) which is adequate for demand purposes.

The use of a dual detection 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.

3. Controller operation

3.1 Introduction

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

3.2 Demanding a phase

A vehicle held at a red signal places a demand for a phase which will give the vehicle right-of-way via a green signal. Vehicles which are permitted to filter, but are unable to 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 three basic types of demand are:

- 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 3.1) and held until the movement receives a green signal. This ensures that the demand is "locked", even if the detector actuation ceases, so that the vehicle will eventually receive a green signal. This type of demand is used wherever the vehicle causing the demand cannot legally proceed.

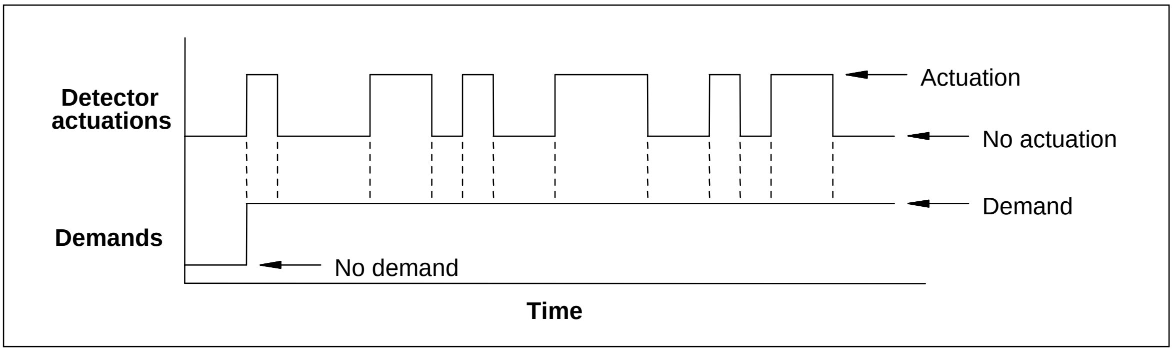


Figure 3.1 Locked demand

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 3.2. A non-locked demand is used where a vehicle may legally proceed either by "left turn on red" or by filtering.

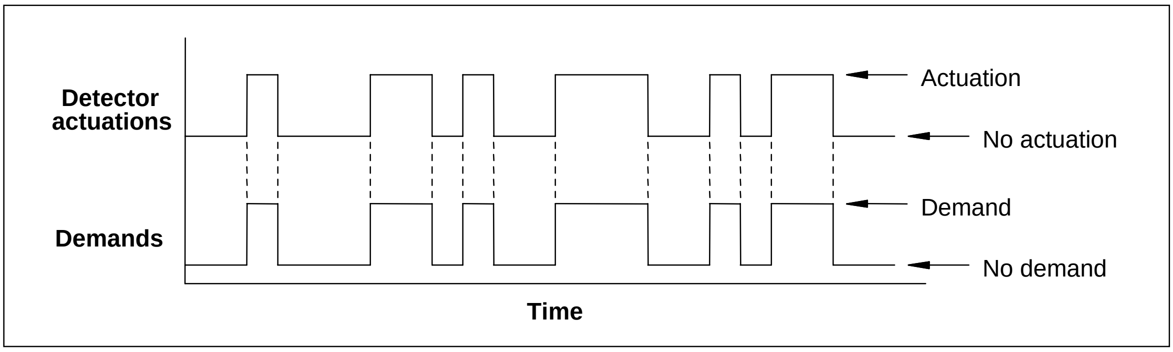


Figure 3.2 Non-locked demand

A presence-timed demand is a non-locked demand with the additional condition that the vehicle actuation must be present for a nominated time (typically 2 to 3 seconds) before the demand is placed. This is illustrated in figure 3.3. This type of demand is used where a lane is shared by vehicles making movements which 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 are unable to proceed in the running phase.

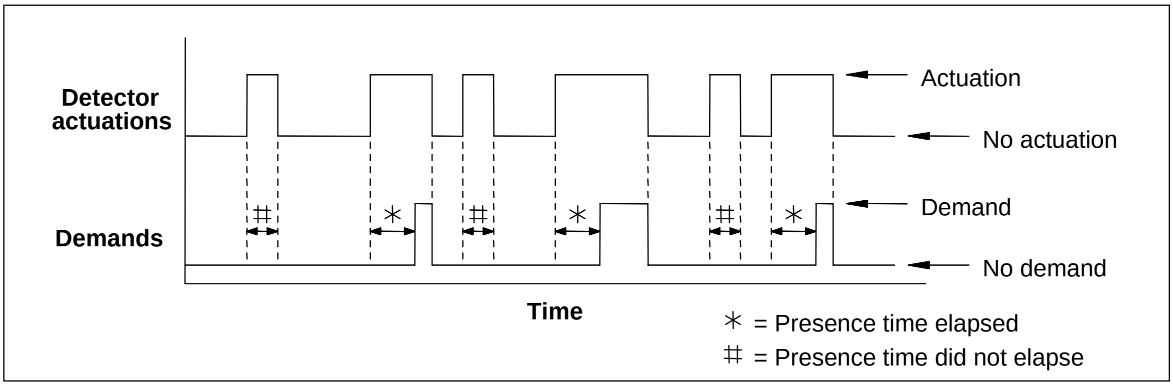


Figure 3.3 Presence-timed demands

Under normal circumstances, 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 which are not demanded can be skipped. However, 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 below.

3.3 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. (Remember that the controller cannot 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 timers for each approach operate as described below.

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 3.4. 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 re-loaded with the gap time setting. Hence the gap timer may time out more than once per phase. The gap timers affect phase termination as described below.

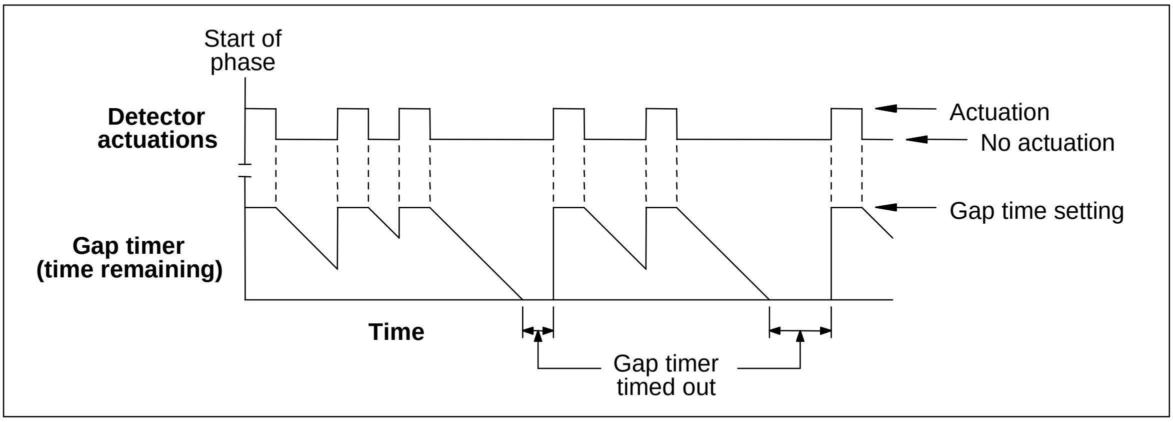


Figure 3.4 Operation of gap timer

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 3.5. 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 re-loaded with the headway time setting. Hence the headway timer may time out more than once per phase.

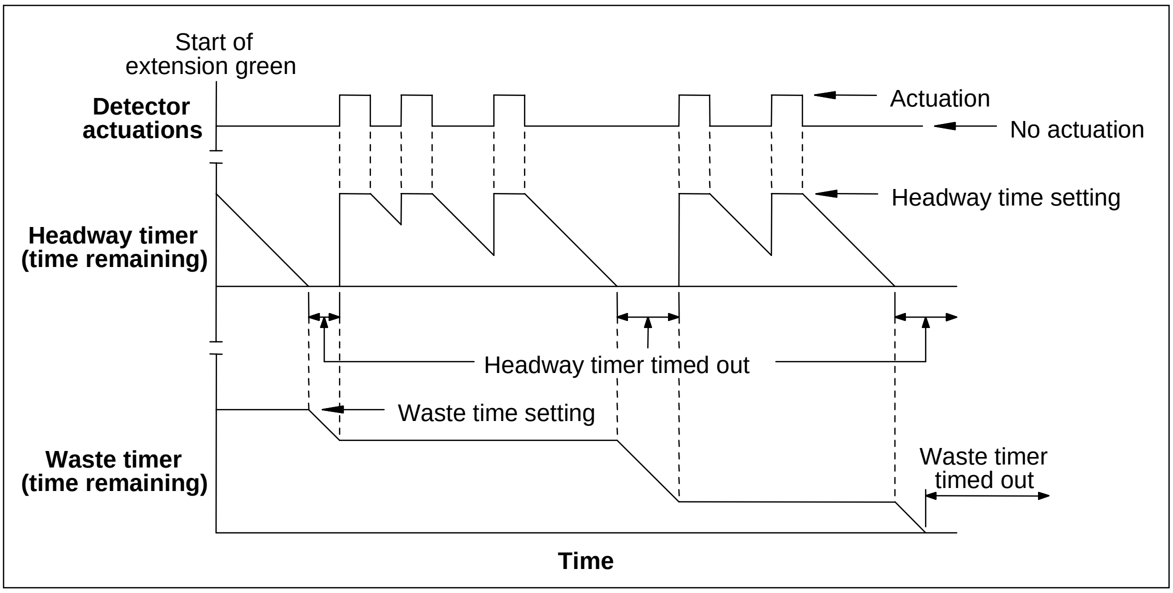


Figure 3.5 Operation of headway and waste timers

Whenever the headway timer is timed out, the waste timer decrements as shown in figure 3.5. 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 (i.e. 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 can 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. (Alternatively, the controller personality can allow the maximum time setting to be the maximum duration of the running part of the phase from the start of the minimum green interval, but this is not used in NSW.)

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.

3.4 Maximum time transfer

Although each phase has only one maximum time setting, the maximum time of a given phase can 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 is particularly tidal. However, it is only effective 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 and are discussed in the following sub-sections. Note that 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 (short circuit) detector.

3.4.1 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.

An example of unused maximum time transfer is shown in figure 3.6. In this example, 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.

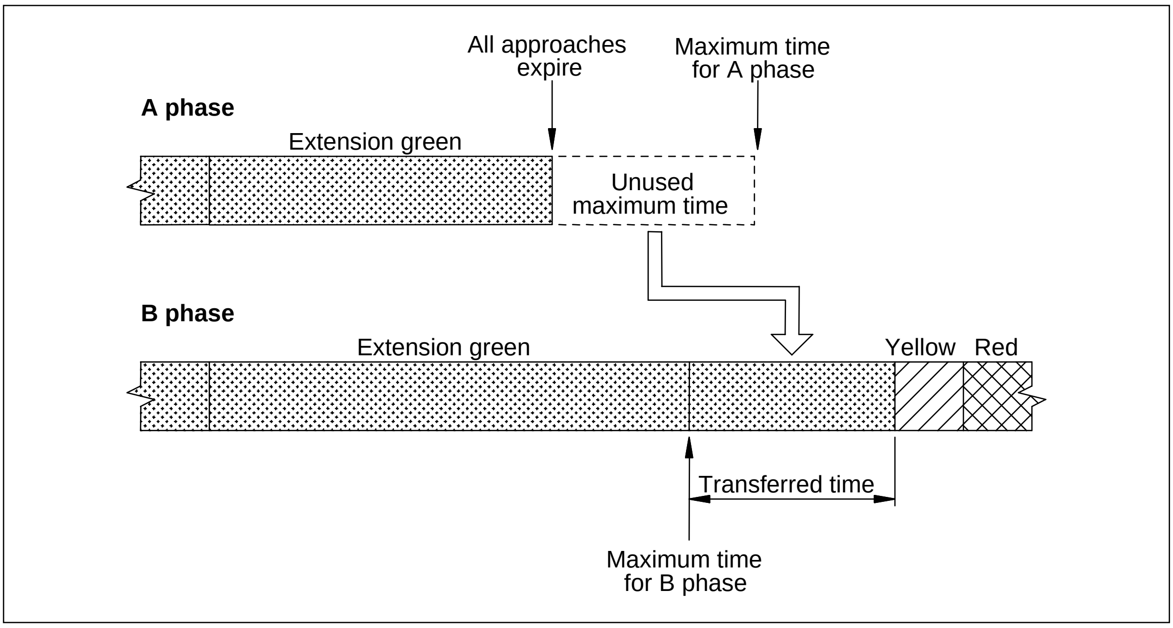


Figure 3.6 Unused maximum time transfer

3.4.2 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 which have not been demanded. When one of the following phases has its maximum time stolen in this way, it is then inhibited from running in the same cycle unless:

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

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

An example of maximum time stealing is shown in figure 3.7. If there is a demand for B phase before the A phase maximum time has expired, then A phase cannot steal the maximum time from B phase. However, if there is no demand for B phase before the A phase maximum time has expired, and then A phase can steal the maximum time from B phase as shown in figure 3.7. When A phase is timing the stolen maximum time, it is said to be in false green.

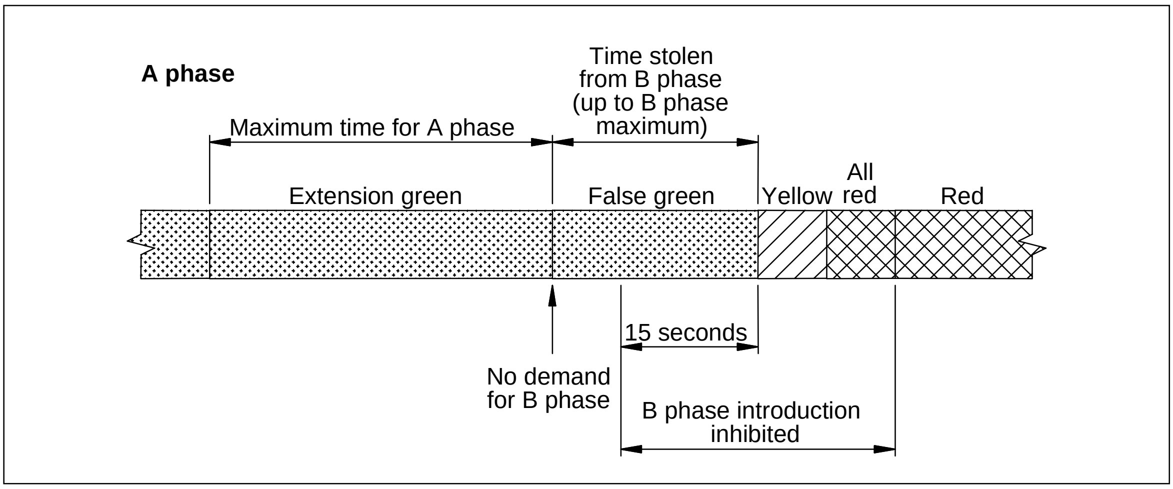


Figure 3.7 Maximum time stealing

3.5 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 are unable to demand a phase. In order to minimise the probability of this happening, the following techniques 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 as follows:

- 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 those vehicles which 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.

3.6 Pedestrian movement operation

Pedestrian movements are normally grouped with vehicle movements to form a phase. This grouping should be such that the pedestrian movements run concurrently with parallel vehicle movements when appropriate. Where turning vehicles can cross a pedestrian movement, it may be necessary to provide pedestrian protection as discussed in section 3.7. If pedestrian movements are grouped into one phase without any vehicle movements, then 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 3.8.

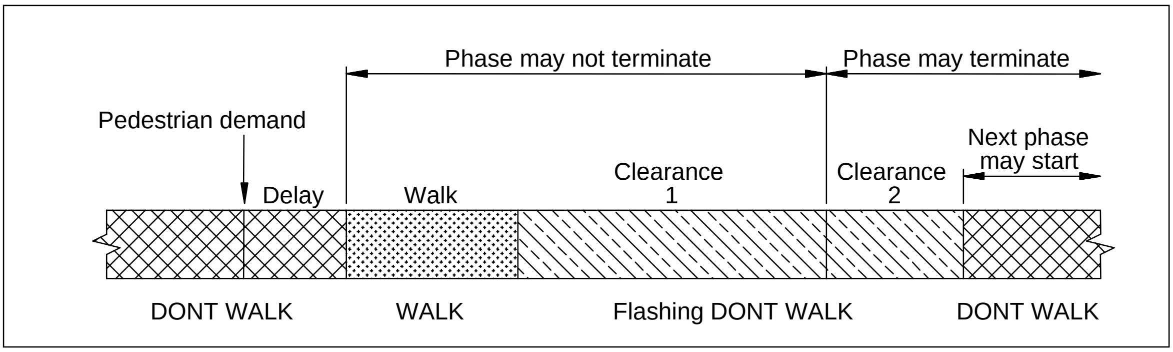


Figure 3.8 Pedestrian movement operation

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 display is divided into walk 1 and walk 2. Walk 1 is a timed interval to provide a minimum time for the walk 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 walk 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 normally cannot terminate until the clearance 1 interval has finished. (An exception is when the pedestrian movement is allowed to overlap.) The clearance 2 interval can run concurrently with the phase clearance. It should not be longer than the phase clearance period (i.e. 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 relatively long time that pedestrians take to cross a road, the pedestrian clearance can represent a significant amount of wasted time which could have been used by vehicle movements in another phase. Therefore, pedestrian movements are usually introduced only by demand.

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 walk display. Normally, such demands must be 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 (i.e. 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 if:

- there are no demands for other phases, and

- there are no conflicting vehicle movements running (this includes turning movements)

If the controller is operating in full Flexilink mode, then the walk signal may be introduced at the call phase pulse. If the controller is operating in Masterlink mode, then the walk signal 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 can result in re-introduction subject to the same conditions as for late introduction. Re-introduction can occur while the pedestrian movement is timing the pedestrian clearance intervals, but once a phase has terminated (i.e. 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 walk display as walk 2 is skipped. This is called a timer terminated pedestrian movement. Pedestrian movements may also be terminated by:

- the end of the extension green interval as shown in figure 3.9 (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)

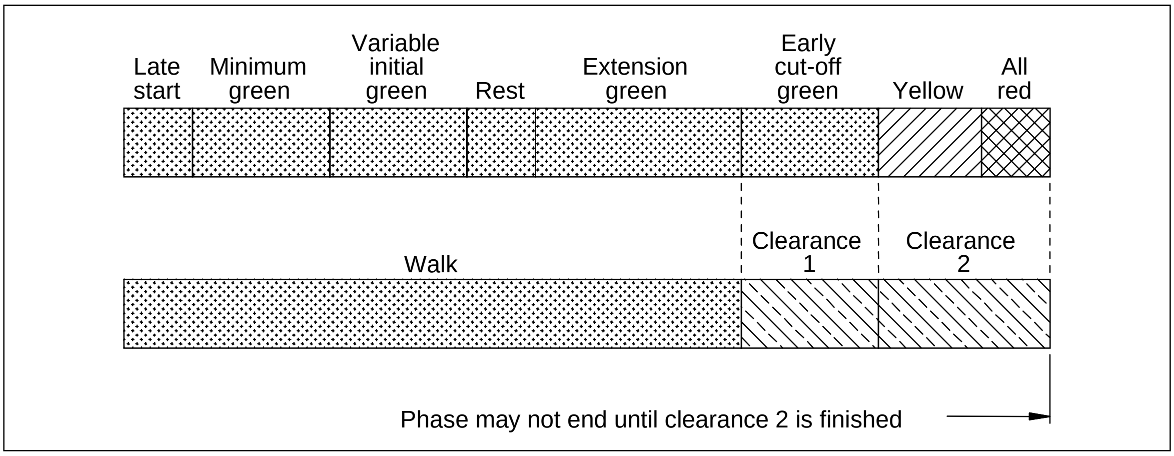


Figure 3.9 Walk for green

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.

The operation of pedestrian movements at SCATS-controlled sites is further described in drawing No. VD018-11.

3.7 Pedestrian protection

When a vehicle movement conflicts with a pedestrian movement, it may be necessary to provide protection for the pedestrians by displaying a red aspect (usually an arrow aspect). The degree of protection depends on the severity of the conflict, the degrees of protection being:

- full protection by a red arrow or red roundel for the whole of the walk and clearance intervals

- timed protection by a red arrow for the whole of the walk interval and part of the clearance interval followed by a flashing yellow arrow for part or all of the remainder of the clearance interval
- timed protection by a red arrow for the whole of the walk interval followed by a flashing yellow arrow for part or all of the clearance interval
- timed protection by a red arrow or red roundel for the whole of the walk interval and part of the clearance interval
- timed protection by a red arrow or red roundel for the whole of the walk interval
- timed protection by a red arrow or red roundel for part of the walk interval #
- no protection

This is not to be used for an opposed right turn movement where that right turn is permitted to filter.

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 can establish their movement. The duration of the red signal is usually controlled by a special red-arrow timer. For example, in figure 3.10, when the pedestrian movement runs, the red arrow is held for a fixed time and then changes to off to allow vehicles to filter.

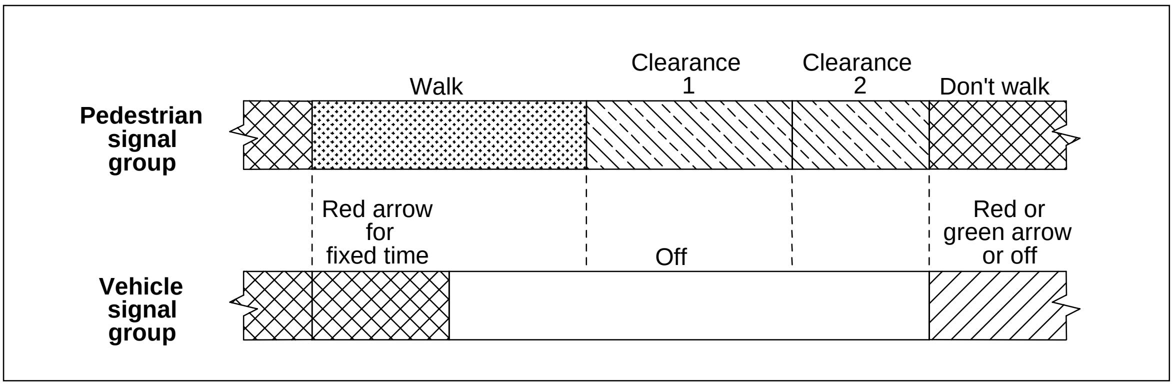


Figure 3.10 Timed pedestrian protection for part of the walk interval

When protection is used for the whole of the walk interval, the operation is the same as above, except that the red signal is held for the walk interval and vehicles are allowed to filter during the clearance intervals. For example, in figure 3.11, the red arrow is held for the walk interval and then the signal group goes off to allow vehicles to filter through the pedestrian movement.

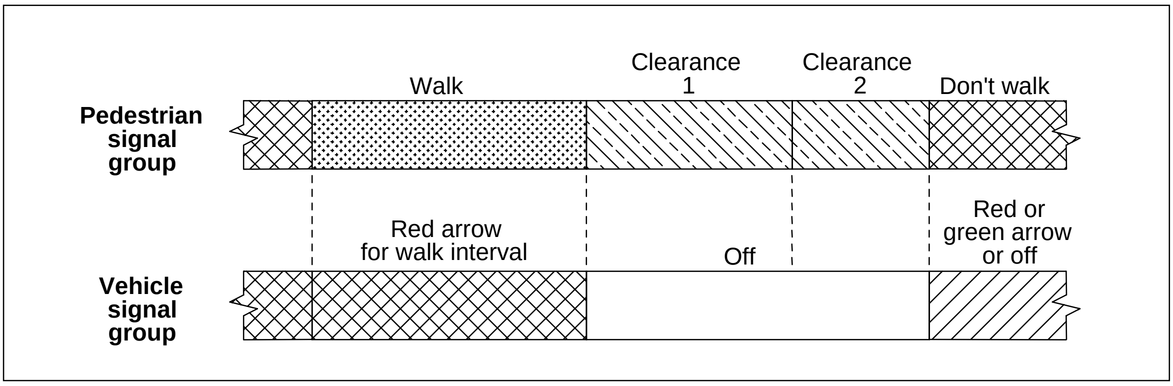


Figure 3.11 Pedestrian protection for the whole of the walk interval

When full protection is used, vehicles are held on a red signal for the whole of the walk and clearance intervals. For example, in figure 3.12, 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.

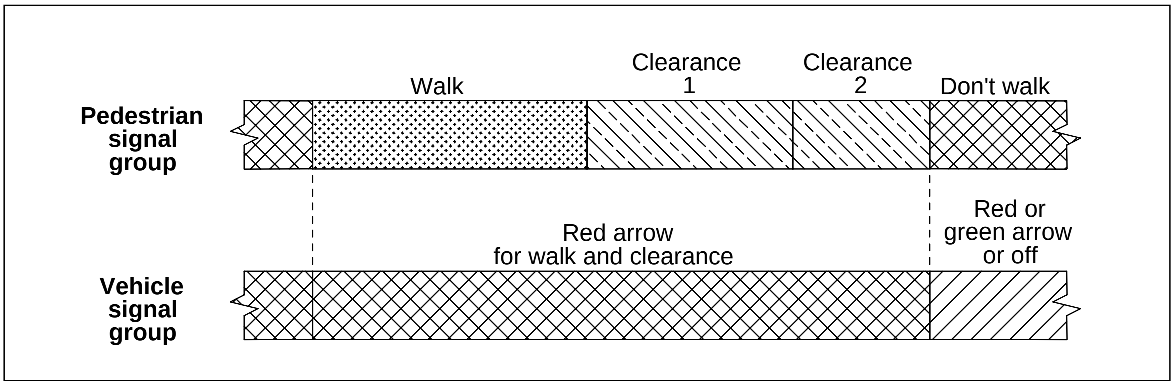


Figure 3.12 Full pedestrian protection

When protection is provided, the signal group is said to be “conditional” if the green 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 after the pedestrian clearance has completed. However, this can only be done if it is possible to display the green signal 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, then it is not possible to leave the current phase until the signal group minimum green timer has expired.

3.8 Alternative movements

It is possible for a vehicle movement to be conditional on another vehicle movement. In this case, 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.

For example, in figure 3.13 the choice of which alternative runs in C phase depends on the demands received from the detectors as follows:

- 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, double diamond overlap phasing and single diamond overlap phasing with a filter option. The operation of these is described in drawing Nos. VD018-5, VD018-6 and VD018-14 respectively.

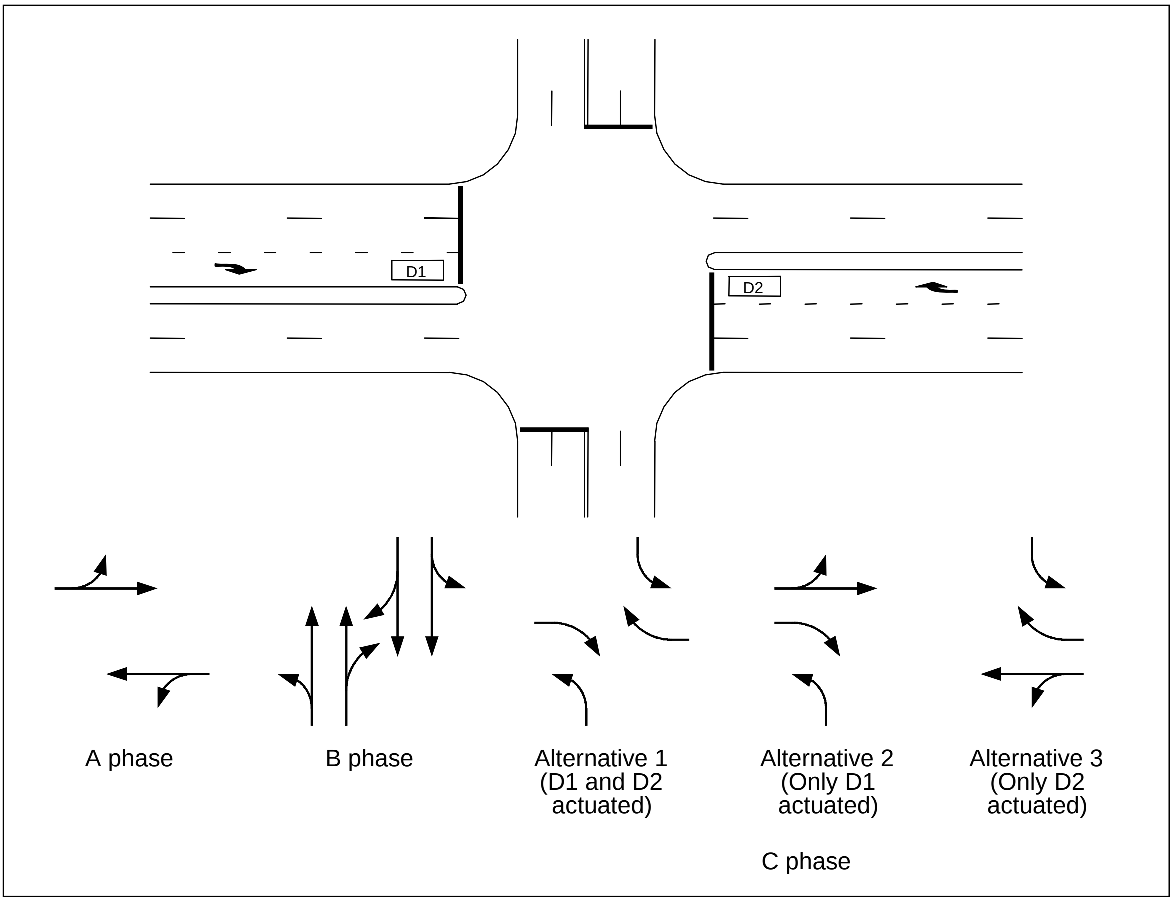


Figure 3.13 Example of an alternative overlap

4. Time settings

4.1 Introduction

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

All time settings have an upper and lower limit. The lower limit (i.e. minimum value) for the majority of time settings is zero. The only exception is the yellow time setting which is a minimum of three seconds. The upper limit (i.e. maximum value) for each time setting is given in these guidelines. Time settings should be chosen so that they do not exceed these limits. However, in special circumstances, the controller personality can be modified to exceed the upper limit, but never the lower limit.

4.2 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 section 7 of *Traffic Signal Design* (RTA 2008), the time setting is typically 4 to 5 seconds. When the late start interval is used for special situations such as that described in section 15 of *Traffic Signal Design* (RTA 2008), the time setting will depend on the intersection geometry, but is typically 2 to 5 seconds.

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 actually required.

The maximum value is 20 seconds.

4.3 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, *table 12 of the National Transport Commission* “*Network Classification guidelines (2007)*” is to be used.

The maximum value is 20 seconds.

4.4 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 required, the time setting will depend on the intersection geometry. A typical application is for very wide intersections or staggered T-junctions where there is a storage area between two stop lines. In such cases, the time setting is typically 3 seconds or more.

If this feature is not required, 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 is 20 seconds.

4.5 Yellow

A separate time setting is provided for the yellow interval of each phase. Legislation requires that these be no less than 3 seconds and, accordingly, the background software in the controller will not permit values less than 3 seconds.

The yellow time setting must allow sufficient time for vehicles to stop at the stop line and will therefore be governed by vehicle speed limits and, in some cases, by the grade of the approach to the stop line. Typical time settings for relatively flat grades are shown in table 4.1. Where grade needs to be considered, *table E.2 Guide to Traffic Management Part 9, appendix E* (Austroads 2009) can be used. Should yellow times less than 4 seconds be required for a special situation, then the written concurrence of the Manager Network Operations, Transport Management Centre shall be sought.

Table 4.1
TYPICAL TIME SETTINGS FOR YELLOW INTERVAL

Design speed (km/h)	Time setting (seconds)
40	4.0
50	4.0
60	4.0
70	4.5
80	5.0
90	5.5

The maximum value is 6.4 seconds.

4.6 All-red

A separate time setting is provided for the all-red interval of each phase.

Initial time settings can be estimated from table 4.2 and rounded up to the nearest 0.5 seconds. The all-red time should never be less than 1 second.

Table 4.2
INITIAL TIME SETTINGS FOR ALL-RED INTERVAL

Design speed (km/h)	Time setting (seconds)
40	$w / 14$
50	$w / 14$
60	$w / 14$
70	$w / 18$
80	$w / 21$
90	$w / 24$

where w = **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 which legitimately enter the intersection during the yellow interval. No additional all-red time should be provided to clear vehicles waiting within the intersection to make a right turn.

The maximum value is 15 seconds.

4.7 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 at the rate of 0.1 seconds per 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 is 5 seconds.

4.8 Maximum initial green

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

The time setting is determined as follows:

$$\text{time setting} = MG + VIG_{max}$$

where MG = minimum green (seconds)

VIG_{max} = maximum variable initial green required to clear queue between stop line and advance detector (seconds)

The maximum variable initial green time required to clear the queue can be estimated as follows:

$$VIG_{max} = i \times (n - 1)$$

where i = increment per vehicle (seconds/vehicle)

n = maximum number of vehicles between stop line and advance detector (vehicles)

The number of vehicles between the stop line and the advance detector in any one lane can be calculated as follows:

$$n = d / l$$

where d = distance between stop line and advance detector (metres)

l = storage length per vehicle (metres/vehicle)

The storage length per vehicle is 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 is 40 seconds.

4.9 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.

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. Traffic modelling may be used as a guide to provide maximum green times.

The maximum value is 150 seconds.

4.10 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 which 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 is 15 seconds.

4.11 Special time settings

There are 24 special time settings which are normally used for the specific purposes listed below.

Special time settings 1 to 8 are special movement time settings which may be used to time the duration of an equivalent all-red period when a yellow and all-red sequence is provided for signal groups that are terminated independently of the normal early cut-off yellow, yellow and all-red intervals. However, current practice is to use “time setting substitution” for this purpose, whereby the phase all-red time setting is used in place of the special movement time setting.

Special time setting 9 is used in single and double diamond overlap phasing as described in drawing Nos VD018-5 and VD018-6 respectively. Special time setting 10 is used in double diamond overlap phasing as described in drawing No. VD018-6.

Special time settings 11 to 19 are available for general use. They are commonly used for timing the duration of the red arrow used for timed pedestrian protection.

Special time setting 20 is used for start red as described in section 4.12.

Special time settings 21 and 23 are used for the offset time settings as described in section 4.13.

Special time settings 22 and 24 are used for the storage time settings as described in section 4.14.

The time settings used for special time settings depend on the application. The maximum value is 15 seconds for the special movement time settings and 200 seconds for the others.

4.12 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.

The time setting is typically 4 seconds in NSW.

The maximum value is 200 seconds.

4.13 Offset

Each controller can have up to two vehicle-pedestrian (V-P) links. 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.

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 is 200 seconds.

4.14 Storage

Each controller can have up to two vehicle-pedestrian (V-P) links. 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 exceed 60 seconds.

The maximum value is 200 seconds.

4.15 Signal group minimums

Signal group minimums are used to guarantee a minimum green period for signal groups introduced late in a phase, e.g. a vehicle group which is conditional on a pedestrian movement. When a signal group minimum is used, it will normally use the same time setting as the minimum green interval for the current phase. This is set by the controller personality. Alternatively, it can 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 is 20 seconds.

4.16 Pedestrian delay

A separate time setting is provided for the pedestrian delay of each pedestrian movement. The purpose of the pedestrian delay 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 thus 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 should be set to zero.

The maximum value is 20 seconds.

4.17 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 that 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 preferably 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 should 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 is 40 seconds.

4.18 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 as follows:

$$\text{total clearance period} = d / 1.2$$

$$\text{where } d = \text{length of pedestrian crossing (metres)}$$

In the case of a scramble crossing at an intersection, the length of the pedestrian crossing is the length of the diagonal movement. The constant 1.2 is the design walking speed for pedestrians in metres per second.

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 the elderly 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 thus shall not be longer than the clearance part of the phase (i.e. early cut-off green + yellow + all-red). The maximum value of the clearance 2 interval is 10 seconds.

4.19 Pelican crossings

Figure 4.1 shows the time settings for the operation of pelican crossings. 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 sections 4.17 and 4.18 respectively. However, the cumulative time for Walk and Clearance 1 shall be sufficient to get a pedestrian completely across the carriageway, kerb to kerb.

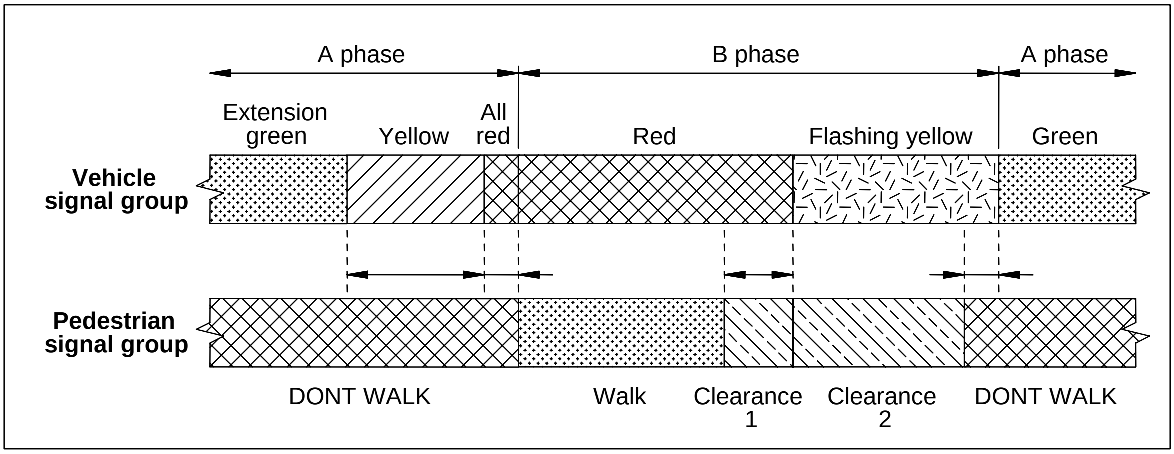


Figure 4.1 Time settings for pelican crossings

4.20 Gap timers

There are eight gap timers, but only four gap time settings per phase. This is sufficient to provide different approach 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 start-up 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.

Typical time settings for stop line (presence) detectors are:

- 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 can 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 as follows:

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

where d = distance between stop line and advance detector (metres)
v = speed limit (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 must be verified by observing traffic conditions on site.

The maximum value is 10 seconds.

4.21 Headway timers

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

Typical time settings for stop line (presence) detectors can be taken from *table E1: Guide to Traffic Management Part 9* (Austroads 2009), or calculated as follows:

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

where s = space time at saturation flow (seconds/vehicle)
n = 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:

$$s = h - o$$

where h = headway at saturation flow (seconds/vehicle)
o = occupancy at saturation flow (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 as follows:

$$h = 3600 / MF$$

where MF = maximum flow (vehicles/hour)

$$o = KP / 100$$

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

Otherwise, headway and occupancy at saturation flow can be estimated from the saturation flow and prevailing speed as follows:

$$h = 3600 / q_{max}$$

where q_{max} = saturation flow (vehicles/hour)

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

where d = length of detection zone (metres/vehicle)
l = average length of vehicle (metres/vehicle)
v = speed (km/h)

For example, for a three lane approach where two lanes are normally active, saturation flow is 1700 veh/h, the length of the detection zone is 4.0 m, the average vehicle length is 5.0 m and the speed is 50 km/h, then:

$$\begin{aligned} s &= (3600 / q_{max}) - (3.6 \times (d + l) / v) \\ &= (3600 / 1700) - (3.6 \times (4.0 + 5.0) / 50) \\ &= 1.5 \text{ seconds} \end{aligned}$$

$$\begin{aligned} \text{time setting} &= 1.25 \times s / n \\ &= 1.25 \times 1.5 / 2 \\ &= 0.9 \text{ seconds} \end{aligned}$$

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 (see drawing No. VD018-10).

Passage detectors give a short output pulse of fixed duration in accordance with vehicle headway times. Thus, the equation for the headway time setting uses headway instead of space time as follows:

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

For example, for a three-lane approach where two lanes are normally active, the typical time setting for the headway timer is calculated as follows:

$$\begin{aligned}\text{time setting} &= 1.25 \times 2 / 2 \\ &= 1.25 \text{ seconds}\end{aligned}$$

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

The maximum value is 5 seconds.

4.22 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 is 50 seconds.

4.23 Presence timers

A separate time setting is provided for each of 24 presence timers.

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 should have a time setting of zero.

The maximum value is 5 seconds.