Traffic Signal Design
Section 7 Phasing and Signal Group Display Sequence
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Preface

The traffic signal design guidelines have been developed to assist in designing traffic control signals. The information contained in the various parts is intended to be used as a guide to good practice. Discretion and judgement should be exercised, taking into account all the factors that may influence the design of traffic signals at any particular site.

The guidelines make reference, where relevant, to current Australian Standards or the Austroads Guides, and are intended to supplement and otherwise assist in their interpretation and application. If any conflict arises, the Australian Standards, the Austroads Guides and the RMS Supplements are to prevail.

The complete set of traffic signal design guidelines is as follows.

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Primary references and complementary material

Roads and Maritime has adopted the Australian Standards and the Austroads Guides as its primary technical references. Roads and Maritime has developed the following complementary material which must be used in conjunction with the Standards and Guides.

- Australian Standards Traffic Supplements.
- Supplements to the Austroads Guides.
- Delineation Manual.
- NSW Bicycle Guidelines.
- Standard Drawings.
- Technical Directions.
- Technical Specifications.


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Prepared by: Lyndall Johnson, Network Operations

Contributors: Alan Dixon, Ennio Morson, Harry Campara, Chris Bunnik, Chris Harding, Rod Kinny, Leanne Hyatt, Neil Leitch, Adrian Paul, (Network Operations); Joseph Le (Centre for Road Safety, TfNSW), Jorge Sales-Luis (Road Design Engineering).

Endorsed by: Alan Dixon, Principal Manager Network Operations

Authorised by: Craig Moran, General Manager Road Network Operations

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Email for enquiries or feedback: technical_directions_publication@rms.nsw.gov.au

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7.1 Introduction

The choice of phasing for a particular intersection depends primarily on the flows of vehicles and pedestrians for each movement. Phasing can also depend upon geometry, i.e., intersection layout and vertical alignment. Design objectives should be to:

- Minimise the number of phases to make the best use of the time available.
- Minimise the cycle time.
- Run as many compatible movements as possible during each phase.
- Restrict each phase to non-conflicting movements.
- Allow each movement to run in as many phases as possible.

Aiming for these design objectives will help to:

- Promote safety, efficiency, consistency and simplicity.
- Optimise capacity and reliability.
- Minimise operation costs and driver frustration.

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

A signal group is a set of lanterns which share the same colour sequence within each phase and for each phase sequence. 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).

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

7.2 General principles

All traffic signals with marked foot crossings should incorporate pedestrian protection (see Section 7.10.2).

The simplest possible phasing at an intersection is two phases with any pedestrian movements running concurrently with the parallel vehicle movements as shown in Figure 7.1.

Figure 7.1 Two-phase design

This phasing leaves four crossing conflicts (between right-turn vehicles and through vehicles), four merge conflicts (between right-turn vehicles and left-turn vehicles) and eight vehicle/pedestrian conflicts (between left- and right-turn vehicles and pedestrians). Nevertheless, this phasing will
usually work quite adequately for a site with geometry and sight distance which meets the required design standards, no record of severe accidents, and low vehicle and pedestrian flows because the priority for each conflict is determined by traffic regulations.

As the potential safety and efficiency of an intersection declines due to poorer geometry, inadequate sight distance, reduced capacity (eg fewer lanes) or increased vehicle or pedestrian flows, it becomes necessary to increase the number of phases and use more complex phasing by using additional signal groups to control certain movements. Additional references to the determination of signal phasing may be found in the Guide to Traffic Management: Part 9 Section 7, ARRB Research Report ARR, 123 Traffic Signals: Capacity and Timing Analysis (ARRB, seventh reprint, 1998). Considerations specific to left and right turns are given in the following subsections.

A site can have a maximum of seven phases. These are labelled alphabetically from A to G with no letters skipped. If a phase allows alternative movements, these are distinguished by a numeric suffix, eg E, E1 and E2 in a standard single diamond overlap (see specification TS-TN-026).

When allocating phase labels, the following conventions should be adopted to ensure uniformity and to facilitate adaptive engineering:

- The phase which allows the through movements in the main road is labelled A phase (where the main road is the non-terminating leg of a T-junction, or the road with the highest flow at an intersection).
- If a right turn phase is associated with one of the through movements on the main road, then the right turn phase is labelled B phase.

Similar procedures should apply to the side street where a controlled right turn is provided, ie the through phase labelling should alphabetically precede the right turn phase labelling. Phase labelling for single and double diamond overlaps is shown in drawings Nos TS-TN-026 and TS-TN-027 respectively.

Movements that run in more than one phase should preferably be allowed to overlap to reduce delays and improve safety. However, there are situations where this is not possible because other more dangerous conflicts would result (see Section 7.3 and Section 7.5). In this case, it is necessary to stop the relevant movements and restart them following a suitable delay.

If a site has a record of severe accidents, the traffic accident data should be analysed to see whether any patterns emerge or whether a particular type of traffic accident predominates. The phasing should ensure that any safety problems are eliminated or at least minimised. For example, accidents involving filtering right turn vehicles may be eliminated by displaying a right turn red arrow in the through phase and providing a right turn phase only.

### 7.3 Right turn movements

Right turn movements can be:

- Banned.
- Allowed to filter through the opposing flow.
- Controlled by providing a right turn phase.

A right turn movement can operate as a:

- Filter only.
- Phase only.
- Phase, and filter in another phase.
For a right turn phase with filter turn operation a repeat right turn movement may be provided within a cycle to cater for heavier right turn movements during specific flow periods.

For right turn phase only operation the following repeat and optional right turn movements may be provided within a cycle for specific flow periods:

- Filter option.
- Repeat turn.
- Filter option and repeat turn.

Regardless of the right turn treatment selected, if the right turn is stopped at any time when the corresponding through movement is running, it is preferable to provide a right turn bay or an exclusive right turn lane to help reduce the incidence of rear-end collisions. See Section 5 Geometry and the Austroads Guide to Road Design, for geometric details.

### 7.3.1 Right turn ban

Banning the right turn should be avoided unless the right turn flows are low and a suitable alternative route is available. The opposing right turn, in the case of a trailing right turn sequence, is always banned for safety reasons (see Section 7.3.3). When the right turn is banned, the signals must be supplemented by NO RIGHT TURN signs R2-6(R) as shown in Figure 7.2. The location of no right turn signs is discussed in Section 10 Signs.

![Figure 7.2 Signal display and regulatory sign for banned right turn](image)

### 7.3.2 Right turn filter

A right turn filter is where right turn vehicles select gaps in the opposing vehicle flow. A filter right turn may be used where a right turn bay exists or can be provided, or in a shared lane where the right turn does not cause excessive delays to other vehicles and the flows are low enough to allow filtering without compromising safety or causing excessive delays. The flow rate of the filter right turn is affected by:

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

The techniques outlined in *ARRB Research Report, ARR 123 Traffic Signals: Capacity and Timing Analysis* (ARRB, seventh reprint, 1998) may be used to determine whether a filter right turn will operate effectively. Often one or two vehicles will be able to filter during the intergreen.
Any right turn vehicle which has crossed the stop line during the green interval may legally complete the turn during the intergreen.

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

- Sight distance is insufficient for the right turn vehicles to filter safely. The criteria for measuring the sight distance is the minimum gap sight distance, the details of which are found in the Austroads Guide to Road Design Part 4A.

- There is more than one right turn lane.

- It is possible for a yellow signal to be displayed to the right turn vehicles when the opposing approach has a green signal, eg the opposing approach has a trailing right turn OR the approach with the right turn has an early cut-off (ECO) (See Section 7.3.3).

- The 85th percentile speed of the opposing traffic, measured in free flow conditions, is greater than 70 km/h and the right turn has to filter across more than two lanes.

- There is an adverse traffic accident history involving filtering right turn vehicles (including rear-end collisions).

- The opposing approach is four lanes or more wide. See Figure 7.3.

**Figure 7.3** Examples of opposing right turn bay configurations.

Figure 7.4 shows the signal display necessary to allow a through movement with a filter right turn when there is no right turn phase. The full green aspect implies that filtering is permitted unless there is a NO RIGHT TURN sign or a right turn red arrow to the contrary.
7.3.2.1 Filter option
At some sites a filter right turn movement may operate efficiently during off-peak periods but not operate efficiently during peak periods because it becomes more difficult to accept gaps in the opposing flow. It is possible to make the filter optional. However, the site must have a right turn phase for use when the filter right turn is not permitted. The signal group display sequence for this type of operation is described in specification TS-TN-019 and the detector logic is described in specification TS-TN-020. For example, the filter movement may be introduced after the evening peak by introducing a special facility signal, eg Z-signal (see Section 12.4 and Section 12.5 in Controller).

7.3.2.2 Conflict with controlled left turn
A problem occurs if a filter right turn is provided when the opposing left turn is held by a left turn red arrow due to a late start (see Section 7.5) or pedestrian protection (see Section 7.10). If a right turn vehicle can pick a gap in the opposing through traffic while the left turn is stopped, the right turn vehicle may filter. When the left turn red arrow is extinguished, a conflict occurs between the left turn vehicles and the filtering right turn vehicles. The right turn vehicles cannot see the signal group displayed to the left turn vehicles and once the right turn is established, the remaining right turn vehicles have a tendency to “Stream” (follow the leader) until there is no longer a gap in the opposing through vehicles. This not only increases the chance of collisions between vehicles, but may also place pedestrians at risk.

This type of conflict does not happen very regularly because the duration of the left turn red arrow is usually fairly short. Therefore, the number of through vehicles is usually sufficient to prevent the right turn vehicles from filtering until after the left turn red arrow is extinguished. However, when the number of through vehicles is low (due to an exclusive left turn or low demand for the through movement), the conflict will occur.

The solution to this problem is to prevent the right turn vehicles from filtering by displaying a right turn red arrow for at least the same time as the opposing left turn red arrow. If there is no right turn phase (such as at a two phase site), consideration should be given to using a 4 aspect lantern incorporating a right turn red arrow such as Table 29 in specification TS-TN-019. Full pedestrian protection (for the walk and clearance intervals) is not recommended in this case as the right turn may not receive enough time to filter. Sites that require full pedestrian protection should have a separate right turn phase.
If there is a single right turn phase, Table 6, 7, 41 or 42 should be used depending on the degree of pedestrian protection and whether or not there is an option on the filter. If there is a repeat right turn, Table 36, 37, 39 or 40 should be used.

### 7.3.3 Right turn phase, with or without right turn filter

A right turn phase can be provided as the only means by which vehicles are permitted to turn right, or it can be provided in addition to a filter right turn, permitted in another phase, for the same right turn movement. When a right turn filter does not provide sufficient safety and/or capacity for right turn vehicles a right turn phase should also be provided.

A right turn phase must be provided without a right turn filter where one or more of the following conditions apply:

- Sight distance is insufficient for right turn vehicles to filter safely.
- There is a record of severe traffic accidents involving filtering right turn vehicles.
- There is more than one lane turning right for that movement.
- The 85th percentile speed of opposing traffic is greater than 70 km/h and the right turn must filter across more than two lanes.

A right turn phase should be provided without a right turn filter where one or more of the following conditions apply:

- Right turn vehicles cause excessive delays to other vehicles using the same approach because a right turn bay is not, or cannot be, provided.
- The right turn flow exceeds 120 vehicles/hour and is opposed by at least:
  - 900 vehicles/hour for a one lane approach
  - 700 vehicles/hour/ lane for a two lane approach
  - 500 vehicles/hour/ lane for a three lane approach.

Exemptions to the above must be sought from the Principal Manager Network Operations.

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

A trailing right turn occurs when the right turn phase follows the phase in which the opposing through movement runs. This is the sequence most road users expect at the majority of signalised intersections where an approach has a right turn phase. See Figure 7.5.

![Figure 7.5 Trailing right turn](image)

A leading right turn occurs when the right turn phase precedes the phase in which the opposing through movement runs. See Figure 7.6.
When a right turn movement operates as a phase and filter turn:

- The trailing right turn sequence is normally used when the opposing right turn filter can be banned.
- The leading right turn sequence is normally used when the opposing right turn filter is light and cannot be banned, or the sequence is necessary for coordination purposes.
- Specific signal group displays are required under certain conditions for safety reasons.

The reason for banning the opposing right turn filter for a trailing right turn sequence is illustrated in Figure 7.7. Consider the traffic stream labelled "A". In heavy traffic, it may not be possible for vehicles in this stream to filter during the through phase. At the end of the through phase, a yellow signal is displayed to these vehicles and a right-turning vehicle could mistakenly assume that the opposing traffic is also about to stop. If this vehicle attempts the right turn during the phase change, a collision could occur with a through vehicle from the opposite approach which has a full green signal display. A similarly unsafe situation could arise if an early cut-off (ECO) is provided on an approach where the right turn filter is permitted. Hence the turn should be banned or the phase sequence reversed so that the overlap from the through to right turn phase is prevented.

Specific signal group displays are required under certain conditions, for safety reasons, whether the right turn phase follows the right turn filter, or vice versa, for a right turn movement.

The right turn phase can follow the right turn filter movement as part of a trailing turn sequence or when a phase or phases are skipped in the case of a leading right turn sequence. For a trailing right turn sequence, or a leading right turn sequence without an opposing right turn filter
movement, there is no safety problem because the opposing right turn filter is banned. However, for a leading right turn sequence with and opposing right turn filter, an unsafe filter movement can occur during the intergreen (see Figure 7.7 and its preceding paragraph). To prevent this all movements must be stopped at the end of the through phase. The through movement, which conflicts with the opposing right turn filter movement, is then held for the late start interval of the right turn phase. The controlled right turn movement is allowed to commence at the start of the right turn phase as there is no conflict between the two right turns (see Figure 7.8). The operation of the through signal groups for this situation is described in Table 4 of specification TS-TN-019. This type of operation is inefficient. As a general rule, the leading turn sequence should only be used at locations where the opposing right turn flows are light and cannot be banned, or where this sequence is necessary for coordination purposes.

The right turn filter movement can follow the right turn phase as part of a leading right turn sequence or when a phase or phases are skipped in the case of a trailing right turn sequence. When this occurs there is a potential conflict between the filter right turn and the opposing through movement at the beginning of the through phase. Therefore, the right turn must be stopped during the intergreen between the right turn phase and the through phase and the introduction of the filter turn delayed by displaying the right turn red arrow for the late start interval (see Figure 7.9). The operation of signal groups for this situation is described in Tables 5 to 8, 41 and 42 (for right turn signal groups) and Tables 35 to 40 (for right turn/repeat right turn signal groups) in specification TS-TN-019.

![Figure 7.8 Late start when controlled right turn follows opposing filter right turn](image)

![Figure 7.9 Late start when filter right turn follows controlled right turn](image)
7.3.4 Repeat right turn

A repeat right turn is where the right turn phase is introduced for a second time within the same cycle.

A repeat right turn can be provided at any site with a right turn phase and is normally used where:

- The right turn phase does not provide sufficient capacity within a cycle for specific flow periods.
- It is necessary for progression in a coordinated system.

It is possible to have both a leading right turn and trailing right turn within the same cycle by repeating the right turn.

The phasing should be designed by using an additional phase for the repeat right turn and not by reusing the existing right turn phase. For example, in Figure 7.10, B phase is not repeated and D phase is used whenever the right turn phase needs repeating. See specification TS-TN-021 for notes on additional phases and repeat phasing for coordination purposes. It is possible to control whether or not the repeat right turn phase can be introduced by using a special facility signal, usually a Z+ signal. See specifications TS-TN-019 and TS-TN-020 for details.

![Figure 7.10 Repeat turn](image)

A typical use is where a right turn bay is too short to cope with the number of right turn vehicles which can arrive within the cycle during specific flow periods. The repeat turn can also be used for peak periods which can occur on certain days during the year such as holiday peaks, eg in country towns on major routes. It is unusual to have a repeat right turn phase operating 24 hours a day seven days a week.

7.3.5 Signal displays for single right turn movements

When a trailing right turn, leading right turn or repeat right turn is used, the signal displays necessary to control the through and right-turn movements including a filter turn are as shown in Figures 7.11 to 7.13.

Figure 7.11 shows the signal display necessary to allow the through movement with a filter right turn. The full green aspect is displayed with all the right-turn arrows off.
Figure 7.11 Signal display for through movement with filter right turn (right-turn phase provided)

Figure 7.12 shows the signal display necessary to allow the through movement, but to prevent the filter right turn. The full green aspect is displayed with a right-turn red arrow.

Figure 7.12 Signal display for through movement with right turn stopped (right-turn phase provided)

Figure 7.13 shows the signal display necessary to allow the through and right turn movements to run when the right turn is unopposed. The full green aspect and the right turn green arrow are displayed concurrently.

Figure 7.13 Signal display for concurrent through and right turn movements (not split approach)

7.3.6 Diamond turn

When it is necessary to signalise opposing right turns and exclusive right turn lanes or right turn bays are available, or can be provided, it is possible to allow both right turns to run
simultaneously while the through movements are stopped. This is called a diamond turn and is shown in Figure 7.14.

This phasing is inefficient and not recommended. It should only be considered when both right turn flows are the same under all flow conditions. It is more efficient to use a single diamond overlap (see Section 7.3.7).

Figure 7.14 Diamond turn

### 7.3.7 Single diamond overlap

Single diamond overlap phasing is the combination of a diamond turn with alternative overlaps and repeat right turns for one intersecting street as shown in Figure 7.15. This phasing is more flexible and efficient than diamond turn phasing because it is able to cater for widely varying demands. There are many variations possible, see specification TS-TN-026.

It is possible to have a filter option in A phase on either or both right turn movements, see specification TS-TN-026.

Figure 7.15 Single diamond overlap

### 7.3.8 Double diamond overlap

Where diamond overlap phasing is required in both intersecting streets a double diamond overlap should be used as shown in Figure 7.16 and described in specification TS-TN-027.

It is possible to have a filter option on any of the right turn movements in A and E phases as described in specification TS-TN-027.
### 7.3.9 Signal displays for diamond turns

Figure 7.17 shows the signal display necessary for a diamond turn. The full red aspect is displayed with a right turn green arrow to allow the right turn movement while the through movement is stopped.

### 7.4 Split-approach phasing

When it is necessary to signalise opposing right turns and exclusive right turn lanes or right turn bays cannot be provided, then split approach phasing may be used as shown in Figure 7.18. This type of phasing is very inefficient and should only be used as a last resort.
If a pedestrian movement is allowed to run concurrently with each of the split approach phases, then the combined clearance times may exceed the cycle time required by vehicle actuation alone. Therefore, when using split approach phasing, one of the marked foot crossings may be sacrificed, however, this will require an exemption granted from the Principal Manager Network Operations. The marked foot crossing that is retained should preferably be the one which runs in conjunction with the phase with the longest running time.

### 7.4.1 Signal displays for split approach phasing

Figure 7.19 shows the signal display necessary to allow the through and right turn movements with split approach phasing. A four aspect display is normally used in the dual primary and secondary positions with the full green and right-turn green arrow displayed simultaneously during the split approach phase.

### 7.5 Left turn movements

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

Left turn lanes may be shared or exclusive. A shared left turn lane is one where through or right turn vehicles use the same lane as the left turn vehicles. An exclusive lane (sometimes referred to as a dedicated lane) is used solely by left turn vehicles.
Signal control of left turns can be complex depending upon whether the turn is from a shared lane, an exclusive lane, conflicts with a signal controlled marked foot crossing, or overlaps from one phase to another. These conditions are discussed in the following sub-sections.

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

- One phase.
- Separate phases (overlapping/non overlapping).
- All phases (left turn at any time with care, exclusive protected departure lane, or LTOR).

### 7.5.1 Corner islands
If a corner island is provided (ie there is a slip lane), the left-turn movement can be:

- Allowed to turn left at any time after giving way in accordance with NSW Road Rule 69.
- Allowed to turn at any time into an exclusive departure lane.
- Allowed to turn when a left-turn green aspect is displayed.

The first two options are not controlled by signals.

### 7.5.2 No corner island
If a corner island is not provided (ie no slip lane), the left turn movement can be:

- Banned.
- Allowed to turn left on a full red aspect in accordance with a LEFT TURN ON RED PERMITTED AFTER STOPPING sign R2-20.
- Allowed to run concurrently with other vehicles on the same approach by displaying a full green aspect.
- Allowed to run independently of other vehicles on the same approach by displaying a left turn green arrow.

### 7.5.3 Left turn bans
Banning the left turn is very rare and should be avoided unless the left-turn geometry is so restrictive that vehicles cannot safely negotiate the turn. For the signposting of left-turn bans, see Section 10 Signs.

### 7.5.4 Left turn on red (LTOR)
The installation of LEFT TURN ON RED PERMITTED AFTER STOPPING (LTOR) signs R2-20 should be considered on all approaches with left turns as a means of reducing delays, especially in off-peak periods.

Appendix E Left Turn on Red describes the tests and checks which are to be applied to ensure the safety of pedestrians and motorists. A "YES" response to any of the tests disqualifies a site from further consideration. If a site is not disqualified by the tests, the checks are applied. A "YES" response to six or more of the checks also disqualifies a site. If a site is not disqualified by this process, LTOR should be adopted unless there are any other critical safety problems that may adversely affect the safe operation of LTOR.

### 7.5.5 Arrow controlled left turns
Left turns can be controlled for one phase operation by either a three aspect lantern (three arrows) or a four aspect lantern (three roundels plus a green arrow). For more than one phase operation left turns can be controlled by three plus two aspect lanterns (three roundels plus green, and yellow arrows), or three plus three aspect lanterns (three roundels plus green,
yellow, and red arrows), see Appendix D Location & Dimensions of Components for lantern details.

Left turn vehicles can normally be catered for during the same phase as the through and/or right turn vehicles on the same approach. However, it is often beneficial to increase the left turn capacity by allowing the left turn vehicles to turn during a complementary right turn phase as shown in Figure 7.20.

![Figure 7.20 Example of left-turn green arrow](image)

There are situations where the provision of a left turn green arrow does not improve capacity. For example, if the left turn flow is low and the lane is shared with a relatively heavy movement, few vehicles will be able to turn left during the left turn green period because they will be blocked by these other vehicles. In this case, the left turn arrows should be omitted. A similar situation exists with shared lanes when a pedestrian movement delays the left turn blocking the passage of a heavy through movement.

The suitability of providing the left turn during the corresponding right turn phase should be tested by traffic modelling computer analysis or micro-simulation.

Left turn green arrows must only be used when vehicles can turn without conflict with other vehicles or pedestrians. Most conflicts are obvious, but there are subtle situations where conflicts occur that the designer should avoid. For example, in the simple two-phase arrangement shown in Figure 7.21, if the left turn green arrow was displayed during the through-side street intergreen, there would be a conflict between the left turn and any right turn vehicles that attempt to filter during the intergreen. In this case, the left turn must be stopped during the through-side street intergreen and held during the side street phase late start interval.

![Figure 7.21 Example of filtering conflict with left-turn green arrow](image)
A standard for signal group display sequences has been established to help ensure that conflicts such as this do not occur (see specification TS-TN-019). However, it is up to the designer to select the correct signal group and display sequence table and to ensure that there is no conflict with the display sequences of other signal groups.

Similarly, as shown in Figure 7.22, when a left turn vehicle is following a right turn vehicle a rear end collision could occur if the green arrow is displayed during the phase and intergreen. The operation of the left turn signal groups for these situations is described in Tables 9, 12, 13, 16 17 and 21 to 24 of specification TS-TN-019.

**Figure 7.22 Late start when controlled left turn follows shared left turn**

### 7.5.6 Signal displays for left-turn arrows

If a left-turn green arrow is followed by a full green aspect, the signal group display sequence depends on:

- Whether any of the left-turn lanes are shared by through or right-turn movements.
- Whether or not there is an opposing right-turn filter.
- Whether there is a parallel marked foot crossing and, whether that pedestrian movement is demanded.

#### 7.5.6.1 Parallel crossing, no pedestrian demand

If any of the left-turn lanes are shared with other movements or there is an opposing right-turn filter and there is no pedestrian demand, the left-turn green arrow is permitted to overlap through the intergreen. However, the left-turn green arrow is blacked out as soon as the full green aspect is displayed as shown in Figure 7.23.

**Figure 7.23 Signal display for shared left-turn lane or opposing right-turn filter and no pedestrian demand.**
If all the left-turn lanes are exclusive to the left turn movement, there is no opposing right-turn filter movement and the parallel pedestrian movement is not demanded, the left-turn green arrow is permitted to overlap through the intergreen. The left-turn green arrow is then displayed with the full green aspect as shown in Figure 7.24.

### 7.5.6.2 Parallel crossing, pedestrian demand

When a left-turn green arrow is followed by a full green aspect and the parallel pedestrian movement is demanded, the left-turn green arrow is not permitted to overlap through the intergreen. The left turn is stopped using a left-turn yellow arrow, followed by a left-turn red arrow as shown in Figure 7.25. The left-turn red arrow is then held for a pre-determined period as described for pedestrian protection in Section 7.9. At the end of this period, the arrow is blacked out and left-turn traffic may proceed with care on the full green signal.

The left-turn green arrow may be introduced at the conclusion of the pedestrian clearance period if:

- None of the left-turn traffic shares a lane with other movements.
- There is no opposing right-turn filter in that phase.
- There is at least six seconds of green time remaining for the adjacent full green display as dictated by the SCATS Z5 signal under Masterlink.
### 7.5.6.3 No parallel marked foot crossing

The rules under Section 7.5.6.1 also apply when there is no parallel marked foot crossing. In this case, a five-aspect display is sufficient as no left-turn red arrow is required. When the left-turn green arrow is not followed by a full green aspect, the left-turn movement is stopped as shown in Figure 7.26.

![Figure 7.26 Signal display for five-aspect lantern when green is not next](image)

### 7.6 Late start

There are four standard uses for the late start interval as described in specification TS-TN-019. The standard uses are:

- To delay the introduction of the through movements in a trailing right turn when there was an opposing right-turn filter in the previous phase, see Section 7.3.3.
- To delay the introduction of a right-turn filter when it was controlled by a right-turn green arrow in the previous phase, see Section 7.3.3.
- To delay the introduction of a left-turn green arrow when the left-turn movement has been held during the intergreen because it is in a shared lane which was controlled by a full green in the previous phase, see Section 7.5.6.
- To delay the introduction of a left-turn green arrow when the left-turn movement has been held during the intergreen because of an opposing right-turn filter in the previous phase, see Section 7.5.5.

The late start may also be used for special situations. An example of this is given in Section 15.6 of Special Situations.

### 7.7 Early cut-off

The early cut-off interval is used to terminate one movement before another within the same phase. A typical application is at intersections with double stop lines such as staggered T-junctions. An example of this may be found in Section 15.4 of Special Situations.

### 7.8 Early start and green on yellow

Early start and green on yellow allow some movements to commence earlier than others within the same phase. This is usually associated with the early cut-off interval of another phase. An example of this, using early start, may be found in Section 15.4 of Special Situations.
7.9 Pedestrian movements at intersections

When a signalised marked foot crossing is provided at a signalised intersection, the pedestrian movement normally runs in association with the parallel vehicle movement. When this occurs, care must be taken to avoid unsafe sequences. For example, if a pedestrian demand is received after the parallel vehicle green aspect is displayed, it would be unsafe to introduce the pedestrian movement due to the conflict with left-turning or right-turning traffic as shown in Figure 7.27.

![Figure 7.27 Unsafe introduction of parallel pedestrian movement](image)

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

Where there are no conflicts between vehicle and pedestrian movements (due to one-way streets or corner islands), the pedestrian movement may be re-introduced or late introduced while the parallel vehicle signal group is green. This re-introduction feature is described in Traffic Signal Operation – No: RTA – TC - 106 and specification TS-TN-021 and should be utilised whenever the conditions permit it.

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

The general design principles for pedestrian movements at SCATS controlled intersections are contained in specification TS-TN-021.

7.9.1 Auto-introduction of pedestrian phase

At some intersections it may be an advantage to automatically introduce the pedestrian phase without relying on pedestrians to activate the walk signal. Such situations may be in areas of very high pedestrian activity, ie urban CBDs, or locations where correct pedestrian usage cannot be relied upon, eg alcohol affected pedestrians exiting licensed premises.

The following criteria should be taken into account when considering the introduction of an automatic pedestrian phase:

- There are short parallel marked foot crossings that have clearance times at or below the intergreen time for the phase that they run in; OR
- There is high pedestrian activity, such as regional and urban CBDs. It has been observed that the higher the number of pedestrians wishing to use a crossing the less is the likelihood that the pedestrian push button will be activated; OR
- There is a high level of alcohol/drug affected pedestrian activity ie near licensed or recreational venues, and there is a history of vehicle/pedestrian crashes.
In these circumstances auto-introduction of all or selected features of the pedestrian phase may be introduced by a combination of adaptive engineering and integration with SCATS. It may also be introduced to operate at a particular time of day for particular needs. These strategies may alleviate concern about pedestrian safety at these sites. However, continual automatic introduction of the pedestrian phase may cause noise disturbance at some locations in close proximity to housing, especially at night, due to the audio/tactile feature of the push-button detector. This would need to be considered prior to its introduction and timed usage may be a solution. Notwithstanding the advantages of introducing an automatic pedestrian phase at selected locations, this feature must not be introduced without first seeking advice from the Principal Manager Network Operations.

### 7.9.2 Scramble crossings

A scramble crossing is a specific type of exclusive pedestrian phase in which crossings on all legs of the intersection operate simultaneously including diagonal crossings (See Section 2.6 in Warrants, Section 6.4 in Pavement Markings and Section 10.6 in Signs).

Scramble crossings eliminate all vehicle/pedestrian conflicts at an intersection and provide the highest level of safety for pedestrians, but they have several disadvantages:

- Pedestrian clearance times need to be longer as they must take account of the extra distance of the diagonal crossing.
- The reduced proportion of vehicle green time may lead to driver frustration, particularly in off-peak periods when drivers are unable to perceive why they are delayed for the sake of perhaps a single pedestrian crossing an approach parallel to their movement.
- The reduced proportion of vehicle green time may cause over saturation in peak periods.

Despite the disadvantages, scramble crossings have been found to be beneficial at certain sites in central business districts and busy shopping centres where heavy, consistent pedestrian movements would otherwise cause excessive conflicts with vehicular traffic. For example on a two lane approach, where the left turn and/or right turn filter movements are not banned, the through movement can be blocked by turning vehicles which must give way to pedestrians where the controlled crossings are being used. Cyclists can ride across scramble crossings provided bicycle signal faces are mounted adjacent to pedestrian signal faces.

Scramble crossings must not operate part-time because pedestrians having already crossed diagonally could mistakenly cross diagonally again immediately after crossings revert to normal parallel use (ie diagonal crossing becomes unsafe).

### 7.10 Pedestrian protection

Protection for pedestrians must be considered for every marked foot crossing at new and reconstructed traffic signals. The degree of protection provided depends on the circumstances and may be:

- 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. This is not to be used where the signal operation for opposing traffic directions is non-identical and an opposed right turn movement is permitted to filter.
- No protection.

Protection for pedestrians should be provided whenever pedestrians are placed at an unnecessarily high risk by the introduction of the pedestrian movement. Pedestrian protection may be either full protection or timed protection as described below.

7.10.1 Full protection

Full protection must be used when any of the following conditions apply:
- Sighting to the pedestrian crossing is restricted.
- The speed of the turning traffic is high.
- There are two lanes of vehicles turning left or right through the pedestrian movement, where those turning vehicles are opposed.
- There are three or more lanes of vehicles turning left or right through the pedestrian movement.

7.10.2 Timed protection

Timed protection must be used as the default setting at all marked foot crossings unless a higher level of pedestrian protection is being implemented or you are able to justify no pedestrian protection. Timed protection is adequate when:
- There are two lanes of vehicles turning left or right through the pedestrian movement, where those turning vehicles are unopposed. *
- Left or right arrow displays are present and there is an associated conflicting pedestrian movement.

There is a high volume of turning traffic and low pedestrian flow. * Flashing yellow arrows must be used after the expiry of the red arrow during the pedestrian clearance interval.

Timed protection should be considered when:
- The flow of pedestrians is high.
- There is a high proportion of children, elderly, or people with disabilities.
- The length of the crossing results in a long clearance time.

The length of the timed protection depends on the type of pedestrians using the crossing, the flow of pedestrians and the flow of the conflicting vehicles. However, a minimum of four seconds is required to allow pedestrian movements to be established before vehicle movements begin. The length of timed protection can be varied by the time of day such as at school entry and exit times and where protection is determined by which pushbutton is pressed. Where timed protection is being provided for left turning vehicles and the right turning vehicles opposing the left turn, the right turn protection must exceed that for the left turn.
7.10.3 No pedestrian protection

No pedestrian protection requires approval from the Principal Manager Network Operations. Pedestrian protection may be unnecessary when all of the following conditions are met:

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

Pedestrian protection may also be unnecessary at one-way out roads.

Examples of pedestrian protection operation may be found in Traffic Signal Operation – No: RTA – TC - 106.

7.10.4 Flashing yellow arrows at signalised marked foot crossings

Flashing yellow arrows may be installed to provide additional pedestrian safety. The provision of flashing yellow arrows is twofold. They are intended to:

- Remind drivers of their obligation to ‘give way’ to pedestrians who are still completing their crossing.
- Allow vehicles to proceed, if a crossing is clear, during the flashing red ‘Don’t Walk’ clearance period of the pedestrian phase of traffic signals; (see section 2.4.1 in Warrants for warrants and application).

7.10.5 Pedestrian protection due to heavy vehicle turning movements

Pedestrian protection must be provided at any intersection where B-doubles turn left or right as part of a designated B-double route.

Pedestrian protection may also be provided at any intersection where it is considered that there is an increased risk to pedestrians due to the number of left or right turning heavy vehicles.