# 10

## chapter 10 Traffic signals

# 10.1 Introduction

Traffic signals were first used in London at the end of the 19th century with the first set of signals installed in Ireland in 1938 at the intersection of Clare Street/Merrion Square, in Dublin.

Traffic signals are often the best form of junction control where road space is limited and there is pedestrian crossing movement. It is possible to link traffic signals and co-ordinate their timings along a route or throughout an area to ensure that there are no queues back through important links. It is generally cheaper to introduce traffic signals than to construct a conventional roundabout with the same capacity.

In the past, specific warrants for the use of traffic signals were contained in RT.181 – the NRA's Geometric Design Guidelines[1]. However, current practice is to rely less on absolute figures within warrants and to rely on engineering judgement within an overall transport strategy to decide whether or not traffic signals are the correct form of junction control.

Within an overall transport strategy, traffic signals can be introduced as a positive means of managing and controlling traffic for a wide variety of reasons:

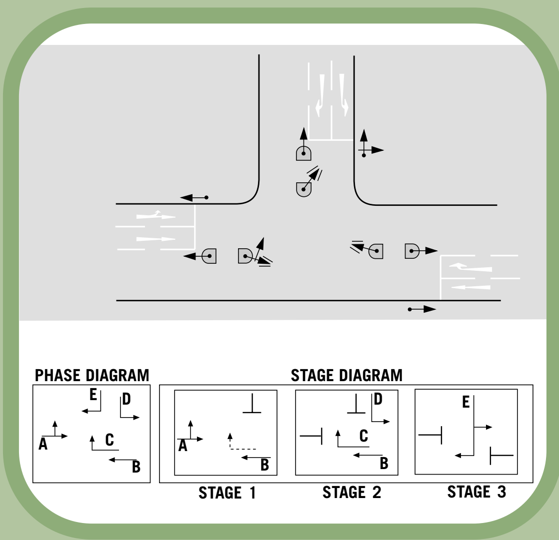
- managing congestion
- improving safety
- providing facilities for pedestrians and cyclists
- providing priority for public transport including light rapid transport (LRT)
- providing priority for emergency service vehicles
- limiting traffic flow by demand management
- improving air quality
- reducing speeds

### Traffic signals can also have disadvantages:

- they can increase off peak delays for all road users
- they are not always good at dealing with right turning movements
- they are not suitable for high speed roads (85% speeds of 65mph and above)

Traffic signal junction

Diagram 10.1 Phase and stages



This chapter gives general information and advice on the use of traffic signals, which can be used to improve existing signal junctions and help to design new signal junctions. A full traffic signal design guide is beyond the scope of this manual. Chapter 9 of the Traffic Signs Manual[2] and TD50/99[3] and NRA amendment give advice on the use of traffic signals and a number of references for more detailed information on geometric layout, signalling strategies etc. are given in 10.14.

## 10.2 Definitions and terminology

Some of the most common terms used by traffic signal engineers are outlined below.

### Cycle Time

The cycle time is the time taken for one complete sequence of the traffic signals. For example, from the start of green for one approach to the next time the green starts for the same approach is known as the cycle time. Cycle times are generally between 40 seconds and 120 seconds. Cycle times in excess of 120 seconds are not recommended as drivers and pedestrians can get frustrated with delays and can be tempted to take risks. **Shorter cycle times (90 seconds or less) should be provided in urban areas in order to minimise delays to pedestrians, cyclists and vehicles.** However, cycle times in excess of 120 seconds are acceptable in the context of restricting side road access onto a main road so long as drivers are informed by signage.

### Phase

The signal sequence for one or more streams of traffic (or pedestrians) that receives an identical signal display (see Diagram 10.1). They are the various separately signalised movements in a junction.

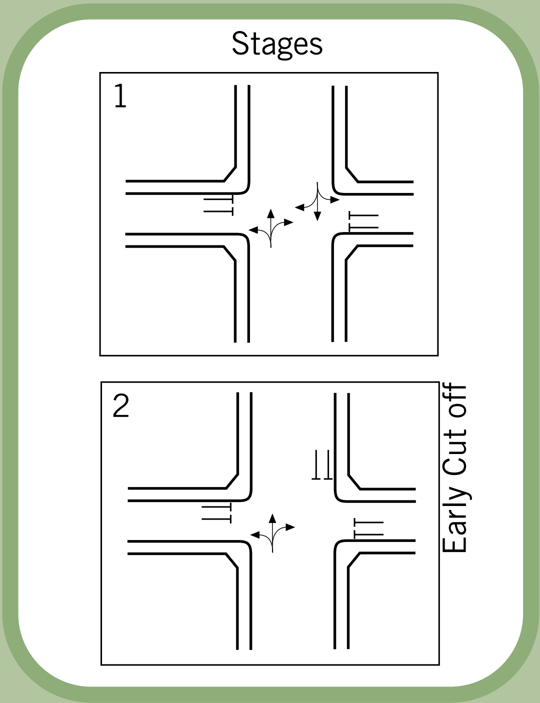
### Stage

A period when a particular combination of phases are displayed (see Diagram 10.1).

### Phase and stage intergreen

The time between the end of the green for one phase or stage and the start of green for the next phase or stage. The length of the intergreen period varies (see Chapter 10.3).

Diagram 10.2 Early cut-off




Shorter cycle times (90 seconds or less) should be provided in urban areas in order to minimise delays to pedestrians, cyclists and vehicles.

## Early Cut-Off

A sequence where one phase is terminated to facilitate another conflicting phase, whilst allowing other associated phases to continue. A common use is where a phase is terminated early to allow an opposing right-turn phase (see Diagram 10.2). These are useful to clear right turn queues at locations where separately signalled right-turn stages cannot be justified or would increase peak hour delays too much. A closely associated secondary signal should be used in this arrangement (see 'secondary traffic signals').

## Late Start

A sequence where a phase is released later than other phases. This can be used to hold traffic on an opposing approach whilst a conflicting right turn is allowed to take place (see Diagram 10.3). This is generally used when there is insufficient stacking space for right-turning vehicles on an approach. A few right-turning vehicles would effectively block other vehicle movements so they are allowed to go first to clear any potential blockages. Care is needed with the use of a late start as it can confuse the drivers whose phase is held and released late. It can cause conflict with pedestrians who may not be expecting these traffic streams to start at different times.

## Primary traffic signals

There must be at least one primary signal at each stop line. The primary signal is normally sited on the nearside (footpath side), between 1m and 5m beyond the stop line. Additional primary signals should be sited on the offside in one-way streets or on dual carriageways and at locations with a splitter/pedestrian crossing island in the centre of the road. On faster roads or roads with 4 or more approach lanes, high mounted or overhead additional signals should be considered. Similarly if visibility of the signal heads is restricted by a crest in the alignment, then high mounted or overhead additional signals (6m) should be considered.

Signals should be visible within the stopping sight distance of the junction. Neither parking/loading nor street furniture should block the approach view of the signals, (e.g. within 50m of the signals).

Diagram 10.3 Late start

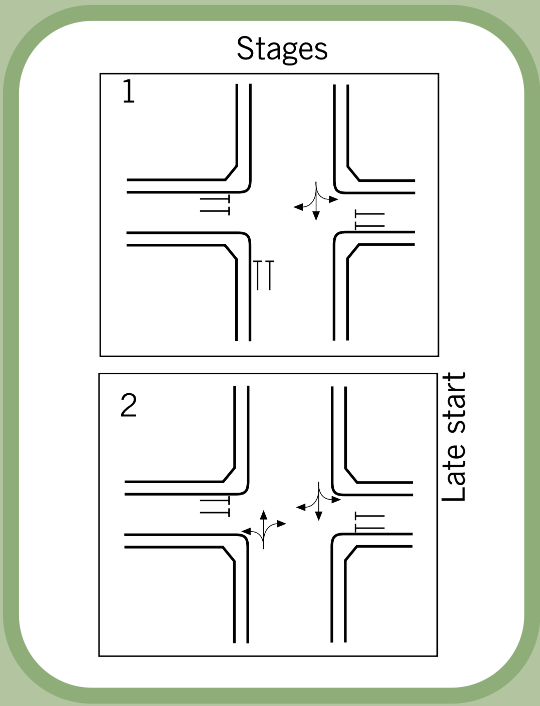
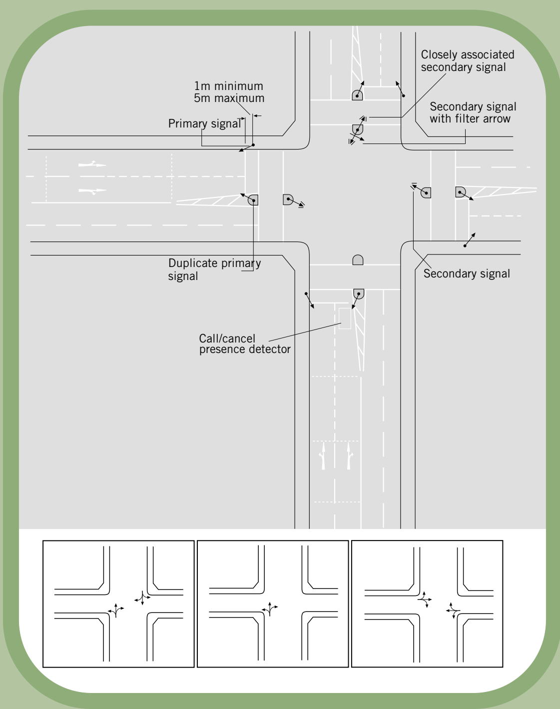



Diagram 10.4 Primary and Secondary traffic signals



### Secondary traffic signals

Generally there should be at least one secondary signal associated with every stop line, except for bus gates where it may not be feasible to install one. The secondary signals are normally sited on the opposite side of the junction where they can be seen easily by drivers waiting at the stop line.

Where a vehicle is waiting to turn right at a junction and there is an opposing right turn movement with an early cut-off facility, drivers could be confused when the secondary signal for their movement turns to red. The driver would normally expect oncoming traffic to stop and would use the intergreen period to complete their turn. However, when an early cut-off phase operates then the opposing traffic continues to run. This has resulted in accidents at some junctions. This confusion can be avoided by locating the secondary signals on the same side of the junction as the stop line (but beyond the primary) so that drivers who have crossed the stop line and are waiting to turn right cannot see it. These are termed closely-associated secondary signals (see Diagram 10.4).

### Eye-height signals

In certain circumstances, eye-height signals can be effective, especially where the primary or secondary signals are not visible. These eye-height signals must be used in addition to (not replacing) primary and secondary signals.

## 10.3 Principles of traffic signal control

At a junction there are demands for movements which conflict with each other, for example turning traffic, minor road traffic, pedestrians etc. Traffic signals are designed to minimise the various conflicting manoeuvres at a junction by allocating time and road space to vehicle and pedestrian movements in a sequence. They should provide good facilities for all road users including cyclists, pedestrians and mobility-impaired users (see Section E).

Traffic signal design aims to give adequate time to each traffic stream and road user while keeping the overall cycle time as short as possible. There are various methods of control for stand alone traffic signal junctions:

- Vehicle actuated – the timings of each phase/ stage are varied between the pre-set minimum and maximum times, according to the demands indicated by the vehicle and pedestrian detection systems. It is possible to miss out or cut short certain phases/stages of the cycle if no demands are registered for these. Vehicle actuation offers significant benefits at stand-alone signal junctions. It adjusts the signal timings to suit the traffic flows at the time and if properly set up and maintained keeps overall vehicle delays to a minimum. All stand-alone signals should operate with vehicle actuation as their normal mode of operation.

- Fixed time – the timings of each phase/stage and the overall cycle time are predetermined and activated by a time clock within the controller. A number of different time plans (for example am peak, pm peak, off-peak and overnight) can be programmed. No vehicle detection systems are required for this type of operation but demand dependant stages (for example pedestrian stages) can be incorporated into these. The main disadvantages of this method of operation are the longer delays to vehicles off-peak (most of the day) and that the plans can quickly become out of date as traffic flows change. Fixed time control should only be used where the signal installation is part of a network of linked signals or as a back-up when there is a fault with the vehicle actuation at stand alone signals
- Manual control – The timings can be operated manually in special circumstances such as special events, usually by An Garda Siochana.

Traffic signals can also be controlled in a manner which co-ordinates their operation with adjacent signals (see Chapter 10.11).

## Traffic signal equipment

Each signal installation includes (see Diagram 10.5):

- A controller – a microprocessor and other control equipment e.g. detector pack, power supply etc. normally contained within a 'large grey cabinet'. The equipment controls the operation of the signals. In particular the phasing and staging of the junction and the time allocated to each are programmed and stored within the controller's memory
- Signal poles and heads – a number of primary, secondary and where necessary pedestrian and cycle signal heads, together with poles
- Detection equipment – vehicle, cycle and pedestrian detection equipment of various types (see section on detection systems)
- Other street furniture such as traffic signs etc.
- Road markings – including stop lines, lane markings and arrows

Each of the primary, secondary and pedestrian signals together with the detection systems are connected to the controller by cables. These allow the controller to receive information from the detection systems and change the signal displays accordingly. The cables are generally run through ducting which runs underneath the carriageway and footway. Older installations may have cables buried directly in the carriageway. Care will be needed when deciding the routes of ducting to ensure that there is no conflict with any other utilities or cables.

The controller is pre-programmed with information about the permitted phase and stage combinations that can operate at the junction. The minimum and maximum phase and stage times together with the intergreen times are pre-programmed.

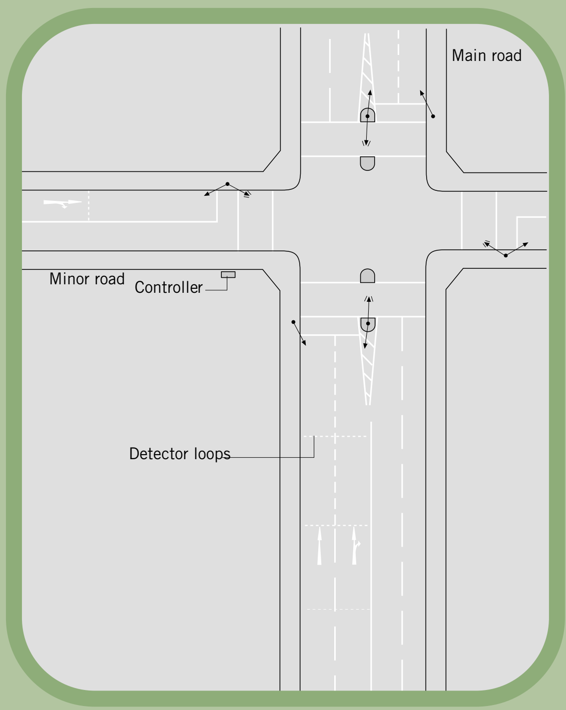
## Sequence of signal displays

In Ireland, in common with many other countries, the signals change directly from red to green. In the UK, there is a two second period when red and amber show together before the green signal shows. This additional period is thought to reduce the lost time between stages and improve safety but there does not seem to be any definitive research in the area.

## Determining minimum and maximum phase/stage times

At stand-alone sets of traffic signals the timings should be determined in a real-time method by detecting traffic approaching the junction (vehicle actuation). The minimum stage

Diagram 10.5 Traffic signal equipment



time is usually set at around 7 seconds (4 seconds for filter arrows) and is extended in units of around 1.5 seconds up to the pre-set maximum time. The maximum setting is pre-determined and programmed into the controller. When installing new traffic signals or updating timings, computer models (Chapter 10.5) can be used to assist in determining the most efficient settings. The timings can be fine-tuned after observing traffic conditions on site. Signal controllers can store a number of different maximum greens so that the timings can be set to suit traffic flows at different times of a day.

## Determining intergreen times

Intergreen times allow streams of traffic or pedestrians in a phase to clear the junction before a conflicting phase commences. The layout of the junction is examined to determine how long is required between each phase or stage change (the intergreen). The intergreen times can vary between 5 seconds for compact junctions and 10 seconds or more for junctions with a long distance between entries and exits. Particular care is needed when pedestrian phase follows a traffic phase. In this case the intergreen time should allow vehicles (including right-turning vehicles that will use the intergreen to complete their turn) to clear the crossing point before the pedestrian phase starts. A method for estimating the required intergreen times is given in TA16/81[4]. The timings can be fine-tuned after observing traffic conditions on site.

## Detection systems

Detection systems are used to call or extend phases in the signal sequence. The main forms of detection in use are:

**Inductive loop detectors** are loops buried in slots cut into the road surface and connected to the controller. They work by detecting the passage or presence of vehicles over the loop. A number of different layouts can be used depending on the function of the loop. The three main types are:

- A 3 loop system (X, Y, Z loops referred to as 'System D') to call/extend a particular phase. The loops are situated 39m, 25 m and 12m respectively from the stop line on the approach.
- Presence detectors that call or cancel demand for a specific phase (for example a filter arrow for a queue of right turning vehicles). These should be positioned where the vehicle in the queue that would require the phase to be called is located.

Diagram 10.6 Signal Timings

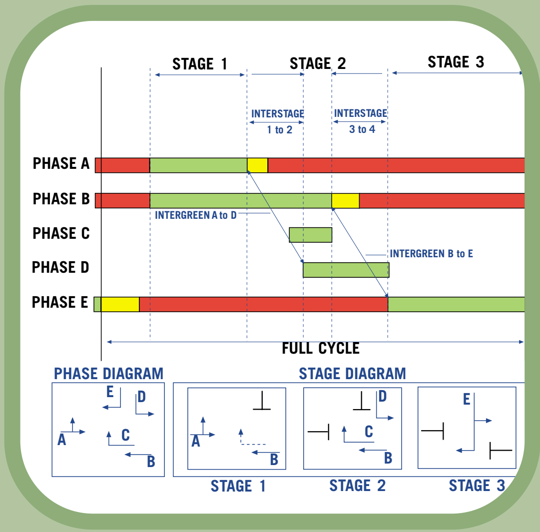
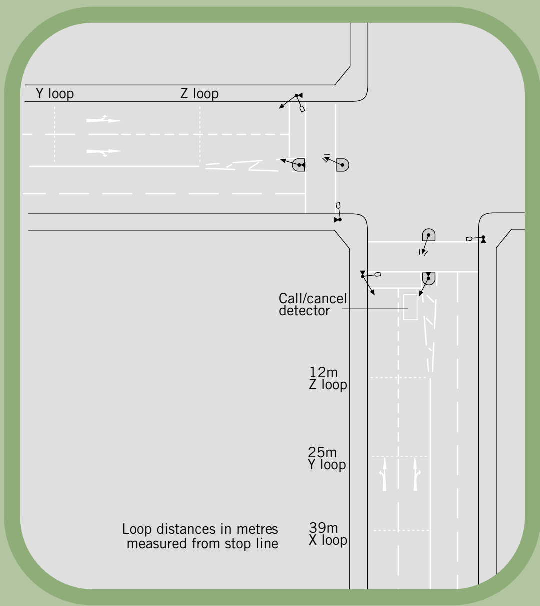



Diagram 10.7 Loop detection



- Speed discrimination/assessment loops for roads with 85% approach speeds over 45mph.

One disadvantage with loops is the cost of maintaining them and the frequency with which they can be severed by other organisations working on the road.

Other loop detection systems are used in association with adaptive UTC systems such as SCOOT and SCATS (see Chapter 10.11). Another system called MOVA[5] has been developed and used in the UK, for semi intelligent and isolated junctions.

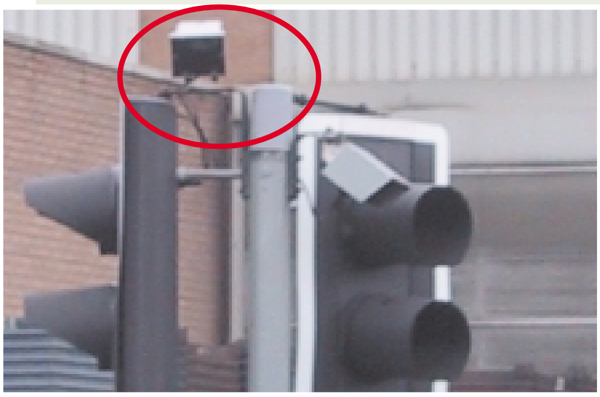
**Rear Queue detection loops** are positioned on important links to alert that the queue back from a junction has exceeded the desired maximum queue length.

**Microwave vehicle detectors (MVDs)** detect movement and are used in two main ways. The most common use is to detect traffic on the approaches (vehicle actuation). They cover the length of the approach within 40m of the stop line, performing the same function as the X, Y, Z loops. The other use of MVD's is at signalled pedestrian crossing points to detect pedestrians on the crossing. They are used to extend the crossing time for slow moving or large groups of pedestrians. It is imperative that such detectors are regularly checked for proper beam direction.

**Infra red detectors (IRDs)** detect presence rather than movement and are used in two main ways. The first is as kerb side detectors to detect the presence of pedestrians waiting to cross. The IRD is often used a supplement to a push button unit. If the pedestrian crosses before the pedestrian phase arrives then it will cancel the demand so that drivers are not delayed unnecessarily. The second use is as an additional detector at a stop line to ensure that slow moving vehicles such as cycles are detected and the required phase is called.

## Push buttons

Push buttons are used to call pedestrian phases and can incorporate tactile indicators for blind or partially sighted people. Audible bleepers should be used where possible but only when there is a full pedestrian stage and all traffic is stopped. This avoids confusion for blind or partially sighted pedestrians who might hear a bleeper relating to a partial pedestrian stage elsewhere in the junction and step out into traffic.



MVD

IRD

Pedestrian Push Button unit

Push button units should be located close to the point where pedestrians will cross (ideally 0.5m from the kerb and 0.5m from the edge of the crossing guidance lines). Push button units should be mounted at a height of 1m to the bottom of the push button unit.

Two types of push-button unit are now commonly used in new installations in Ireland:

The first is a unit where the entire electronic front panel area acts as a push-button. A direction indicator on top of the unit should point in the direction of travel for the pedestrian. A vibrator is located under the direction indicator and allows blind or partially sighted pedestrians to know when to cross.

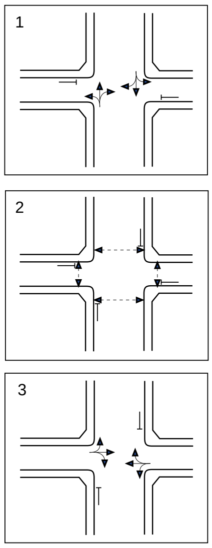
The second type has a large push-button, a small flashing light and audible indicator. The audible indicator "ticks" slowly whilst a red pedestrian aspect shows. It then ticks more quickly and vibrates when a green pedestrian aspect shows.

An earlier type of push-button unit was subject to vandalism in some areas but some of that type are still in use.

Additional push-button units should be provided on any central islands in the signal layout. This is to cater for slower moving pedestrians who may be unable to cross the full road width in the time allocated.

Pedestrian Push Button

Diagram 10.8 Typical 3 Stage Control




## 10.4 Traffic signal layouts and design issues

This section describes some typical traffic signal layouts and associated design issues. Whilst standard layouts are useful on new roads, it is often difficult in urban areas to achieve ideal layouts and compromises may need to be made. Chapter 9 of the Traffic Signs Manual2 gives examples of many different layouts. Advice on the geometric design of traffic signal junctions is given in TD50/993 and NRA addendum.

## Signalled cross-roads – 3 Stage

A simple form of traffic signal control is at a cross-roads junction as shown in Diagram 10.8. This layout includes a pedestrian stage and relies on drivers using gaps in traffic and the intergreen period to complete right-turning movements. All red pedestrian stages are generally associated with compact junctions (eg islands)

## Signalled cross-roads – 4 Stage with early cut-off facility

If one of the right-turn movements is high (say more than 100 vehicles per hour) then an additional stage may be required as shown in Diagram 10.9. This will help to clear the queue of right- turning vehicles and reduce the potential for accidents associated with this movement. This staging arrangement is known as an "early cut-off". In this layout, a right-turn filter arrow is provided on the secondary traffic signal head to indicate to drivers that they will be unopposed during the "early cut-off" stage.

## Providing for right-turning vehicles

Right-turning vehicles are often the most difficult stream of traffic to deal with at a traffic signal junction. Their movement is often in conflict with opposing straight-ahead traffic and left turns. Opposing right-turning vehicles can often make the turn more difficult. At most signal junctions vehicles have to use gaps in opposing traffic or the intergreen period to complete their manoeuvre. At busy times there may not be gaps in opposing traffic and therefore only 1 or 2 vehicles will be able to turn per cycle (using the intergreen period). Long queues of turning vehicles can form which can block the junction for other traffic.

There are a number of specific facilities which cater for higher numbers of right turning vehicle including early cut-off and late release (see Chapter 10.3). For higher volumes of right-turn vehicles and junctions with approach speeds over 45mph, separately signalled right-turn stages should be provided.

The proposed signal staging options for catering for right-turn vehicles should be modelled to see which produces the most efficient layout for the traffic flows at the site (see Chapter 10.5).

Diagram 10.9 Typical 4 Stage Control

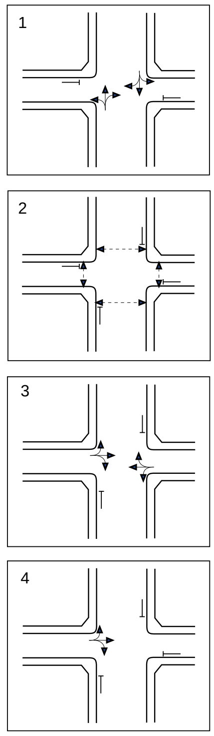



Diagram 10.10 Separately signalled right turns

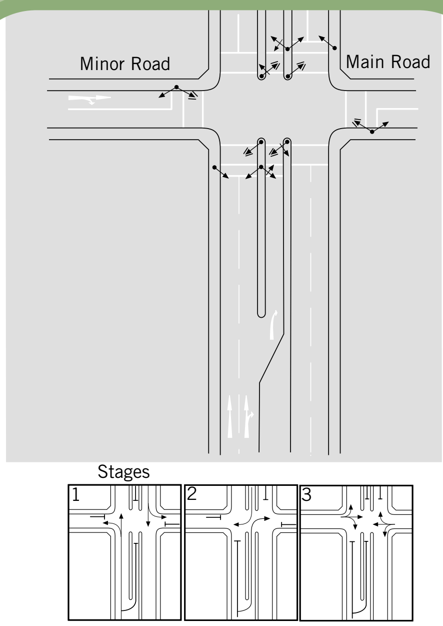


Diagram 10.10 shows an example of a separately signalled right-turn stage.

## Lane widths

Lanes on the approaches to traffic signals in an urban area should generally be 3m wide (see Diagram 10.11). This can be reduced to 2.4m in special circumstances.[2] At simple junctions, local widening of the road can help to provide a length of right turning lane. The length should be equivalent to the expected peak hour queue lengths (this depends on signal timings) to avoid blocking of other movements. If this cannot be achieved a shorter length or narrower width may still be beneficial.

## Turning circles and swept paths

The turning circles and swept paths of all vehicles likely to use the junction should be catered for where possible. Where no special provision is made for large goods vehicles, minimum corner radii of 6m in urban areas and 10m in rural areas are recommended. Where large goods vehicles are to be accommodated, minimum corner radii of 10m in urban areas and 15m in rural areas are recommended. The proposed layout should be checked using templates of swept paths (or computer simulations) for a range of long vehicles. If their swept paths cannot be accommodated without crossing other lanes or overrunning the footway, it may be necessary to set back the stop lines and provide tapers at the junction.

## High-friction surface

If speeds cannot be reduced through the use of narrow lanes and other measures, then high-friction surfaces should be considered for the approaches to traffic signal junctions. This minimises the risk of accidents involving skidding on a wet road surface. Accident studies in the UK have shown that the use of high-friction surfacing at traffic signals can reduce accidents by up to 68%. Where used, high-friction surfaces should be provided for a distance of at least 50m (on 30mph roads) back from the crossing walkway edge line (beyond the stop line). On faster roads greater lengths of high-friction surfaces should be provided.

## Visibility

Vehicles approaching the signals require good visibility of the signal heads. The minimum visibility distance required for different approach speeds is set out in Table 10.2.

### TABLE 10.1 SELECTING APPROPRIATE RIGHT-TURN FACILITIES AT SIGNAL JUNCTIONS

| PEDESTRIAN FACILITY | COMMENTS |
|---|---|
| Early cut-off | These work best when the one right turn movement at a junction is dominant and opposing right-turns can be cleared within the intergreen period. The volume of right-turning vehicles that would benefit from this facility varies from junction to junction depending on the layout. It is best to model the traffic flows using one of the computer models described in Chapter 10.5. Generally around 2 right-turning vehicles per cycle can clear a junction during the intergreen period. It is worth considering this type of facility if there are significantly more vehices than this. |
| Separately signalled right-turn stages | These should be considered when there are significant numbers of right-turning vehicles on opposing arms or 85%ile approach speeds exceed 45mph. It is best to model the traffic flows using one of the computer models described in Chapter 10.5. |

## Symbols

A number of different signal symbols are used on plans to indicate the type of signal heads/aspects and detection systems used in a layout. Some of the more common ones are shown in Diagram 10.12.

## Cowls

Cowls are used on signal heads to reduce the effect of bright sunlight, which can make the signal aspects difficult for drivers to see. New light emitting diode (LED) signal heads are much brighter and can overcome problems with sunlight. Cowls also prevent drivers from other approaches seeing the wrong signal. Longer cowls are generally used on secondary signals as their location makes it easier for drivers on other approaches to see them.

Cowls with louvres are also available for use in locations where normal cowls would not be sufficient. Examples of where these are used include:

- where signal heads that can show different lights for different movements have to be located next to each other. Drivers could be confused about which one applies to them
- where pedestrian facilities have been displaced from the junction and drivers could see through to the green light at the displaced facility rather than the red light that applies to them
- where pedestrians using a staggered crossing facility might see a green pedestrian aspect not applicable to them.

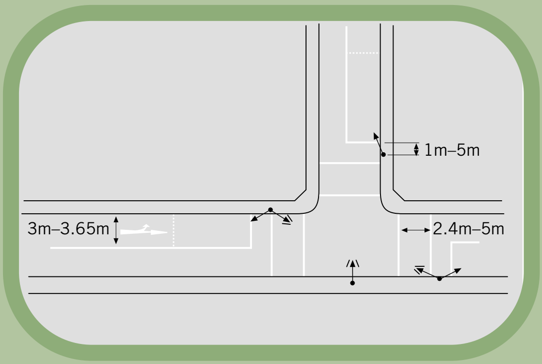
## Dimmers

Signal intensity should automatically diminish at night time to prevent glare, In the absence of dimmers, it can be difficult to discern filters in particular

# 10.5 Capacity issues and computer models

An efficient signalling regime will maximise the safe movement of persons through a junction. Green times should be sufficient to clear queues and the "lost time" (that part of the intergreen period where traffic is stopping or starting) between stages should be kept to a minimum having due regard to safety (see

Diagram 10.11  Lane Widths




High-Friction surface

Table 10.2 Minimum visibility distances

| 85% APPROACH SPEED km/h | MINIMUM VISIBILITY DISTANCE |
|---|---|
| 40 | 40m |
| 50 | 70m |
| 60 | 90m |
| 80 | 145m |
| 100 | 215m |
| 120 | 295m |

Chapter 10.4). Delays to pedestrians and cyclists should be considered in addition to motor vehicle delays. The capacity of a set of traffic signals is determined for the junction as a whole rather than for individual approaches as with roundabouts. Capacity is generally increased by providing more entry and exit lanes. However the wider an approach or exit is the more time that will be required for pedestrians to cross it safely. Strategies for providing pedestrian phases are dealt with in Chapter 10.7.

Signal junctions are generally modelled using a computer program. These computer models are able to handle more complicated junctions and evaluate options more easily.

## Computer models

There are two commonly used computer programmes for analysing vehicle movements at "stand alone" traffic signals.

OSCADY is a program developed at the Transport Research Laboratory (TRL) in the UK. It can be used to analyse traffic signal junctions with up to five arms and can be used to predict accidents on four-armed single carriageway junctions (UK based experience only). The program can be set to optimise cycle times and green times and calculates queues and delays for a given traffic flow.

LINSIG is a program that was developed at Lincolnshire County Council in England. Like OSCADY, the program can optimise cycle times and green times and calculates queues and delays for a given traffic flow.

The programs require the following inputs:

- traffic flows including turning proportions together with proportions of trucks, buses, cycles and motorcycles
- junction geometry including entry lane widths, numbers of lanes, flare length and gradient
- permitted turning movements
- phasing and staging details
- mode of operation – VA, fixed time

TRANSYT is another program that models signal operation but is used for networks of linked signals. Linked signals are dealt with in Chapter 10.11.

Diagram 10.12 Signal equipment symbols

CONVENTIONS

- Signal mounting on existing structure or pole
- Signal post

VEHICLE SIGNAL HEADS

- Primary signal fitted with shallow cowls
- Secondary signal fitted with deep cowls
- Fitted with special cowls
- Fitted with green arrow lens
- Fitted with green arrow filter unit

PEDESTRIAN SIGNAL HEADS

- Three light signal
- Two light signal

GENERAL

- SP Pedestrian push button unit on a short pole
- Pedestrian push button unit
- Control unit or equipment cabinet
- Detector kerbside equipment housing
- Cable duct
- Presence detector
- Passage detector
- Signal head offset, or bracket mounted
- Double headed signal
- Guard railing


Countdown Display

## 10.6 Safety issues

Traffic signals can offer a safe means of junction control. Some of the more common safety issues that need to be considered when designing traffic signals are:

- Has the design been safety audited?

  *All traffic signal designs should be subject to a series of road safety audits during the design and construction process (see Section A, Chapter 2).*

- Have conflicting traffic movements (particularly right-turns) been adequately catered for?

  *Accidents involving right-turn movements are common at signal junctions. The provision of adequate intergreen times and facilities such as early cut-offs and separate right-turn stages can help to reduce these (see Chapter 10.4).*

- Have pedestrians and cyclists been adequately catered for?

  *Pedestrian facilities should provided at urban traffic signal junctions (see Chapter 10.7). Consideration should also be given to the provision of advanced cycle stop lines and feeder lanes (see Chapter 10.8).*

- Has the risk of red light infringements been minimised?

  *The provision of red light cameras can help to discourage infringements. However their use has resource implications for An Garda Siochana and therefore needs their support. Before resorting to the use of cameras, the visibility of signal heads, intergreen times and vehicle detection should be checked for adequacy in relation to the approach speeds of vehicles.*

- Do drivers and pedestrians have good visibility of their signals?

  *Drivers approaching the signals should be able to see the primary signal heads from a distance in which they can comfortably stop their vehicle if required. Visibility distances for various approach speeds are outlined in Chapter 10.4. Signal heads should be positioned so that trees, planting and signs do not obscure them. If pedestrians are using a staggered crossing in a central island they may be able to see pedestrian aspects that do not apply to them (see Chapter 10.4 'Cowls'). This can lead to pedestrians crossing at the wrong time into the path of vehicles.*

- Has high-friction surface been provided on the approaches to the signals?

  *When a road surface is wet vehicles need a longer distance to stop. The risk of skidding increases when the road surface is wet and this can result in collisions with other vehicles or pedestrians. These types of accidents are common at traffic signals. Studies in the UK have shown that high-friction surfacing can reduce accidents by up to 60%.*

- Has guardrail been provided on Primary Distributor roads to guide pedestrians to the designated crossing point?

  *Pedestrians can be guided to the safest place to cross at traffic signals, where appropriate. High visibility guardrail should be used (see 10.7)*

- Are the intergreen times sufficient for vehicles to clear both the junction and any pedestrian crossing points?

  *Adequate time for vehicles to clear the junction must be provided in order to avoid collisions with other vehicles or pedestrians. These should always be checked on site to ensure that they are adequate.*

- Does the position of signal poles and clearance of signal heads (including pedestrian aspects) cause any problems?

  *Signal aspects should be mounted a minimum of 2.4m high (to the bottom of the lower lamp) so that they can easily be seen by drivers and do not* *present a hazard to pedestrians. Signal poles should be located so that signal heads (including side mounted ones) have a minimum clearance of 450mm from the edge of carriageway. This minimises the risk of them being struck by the wing mirror of trucks or buses. In some locations it is difficult to achieve this clearance without the pole obstructing the footway. Cranked poles (where the top of the pole is cranked inwards to get clearance) can help with this problem (see Section E).*

- Are the traffic lanes well marked and easy to understand?

  *On Distributor roads, it is important that drivers can get into the correct lanes as early as possible to avoid turbulence and any conflicts with other drivers. This is particularly important when there are 3 or more lanes on an approach and it may be necessary to supplement the road markings with lane use signs at such locations.*

- Has the controller been located correctly?

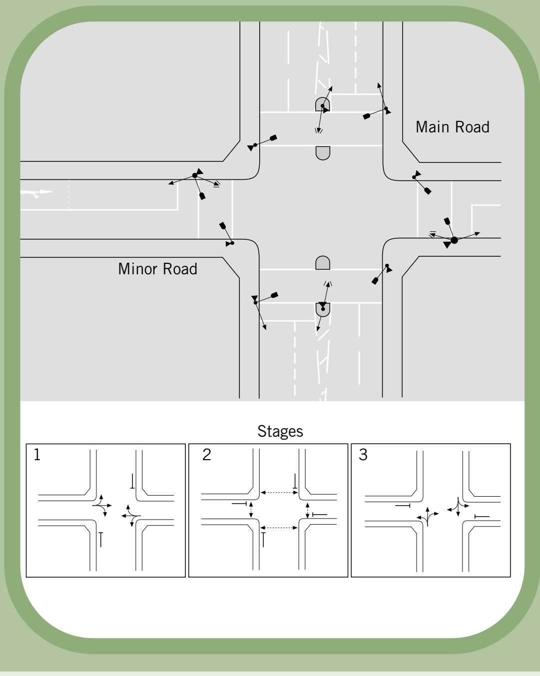
  *The controller should be located where a maintenance engineer can get easy access and can see each approach. This position should not obstruct pedestrians using the footway or visibility of pedestrians crossing or about to cross the road. It should be located at the back of the footway (away from the kerb edge) where it is less likely to be damaged by passing or errant vehicles.*

- Have the pedestrian detection, dished crossings and tactile indicators been provided and located correctly?

  *If a pedestrian phase is provided then consideration should be given to placing push button units at all four corners of each crossing point. The units should incorporate tactile indicators. Dished crossings and tactile paving should be provided at signalled crossing points (see Chapter 10.4).*

Missed opportunity to provide pedestrian signals on all junction arms during all red phase

Diagram 10.13 Full pedestrian stage



## 10.7 Providing for pedestrians

There are a number of ways in which pedestrians can be catered for within a traffic signal junction. Pedestrian facilities should always be provided. They are particularly useful for the more vulnerable pedestrians such as children and people with a mobility/sensory impairment. Sometimes it can be difficult to provide adequate signalled facilities for pedestrians without having adverse effects on peak hour traffic queues and delays but this does not justify the exclusion of pedestrian facilities.

### Crossing width

A minimum crossing of 2.4m width in front of the stop line should be provided with an additional 0.5m for every 125 pedestrians per hour above 600 (averaged over the main 4 hours of pedestrian use) up to a recommended maximum width of 5m.

### Delays to pedestrians

Delays to pedestrians should be minimised and should be accounted for in the selection of the most appropriate type of pedestrian facility and design. Pedestrians are sensitive to the time they have to wait at the kerbside and if this waiting time is too long pedestrians will cross the road without waiting for a green signal. To minimise pedestrian delays it is important that overall cycle times are kept as short as possible. In some instances it is possible to include the pedestrian phase twice during one cycle of the signals (double cycling). In the climate of encouraging walking as part of sustainable transport, justification for pedestrian facilities should be considered more in terms of the needs of pedestrians[7] (in particular the delays and difficulties experienced in crossing a road) than in always maximising traffic flows. Guidance on the justification for a pedestrian stage at a set of traffic signals is given in TA 15/81[6] and for pedestrian crossings in Local Transport Note 1/95[7]. The 1970 Foras Forbartha system of warrants contained in "Warrants for the installation of Pedestrian Crossing Facilities" is now over 30 years old and is superseded by the recommendations in this document.

### Guardrail (for Primary Distributor Roads only)

On Primary Distributor roads, guardrails can help to guide pedestrians to cross at the correct place. High visibility guardrail should be used at these locations because the vertical bars of

Diagram 10.14 Walk with traffic

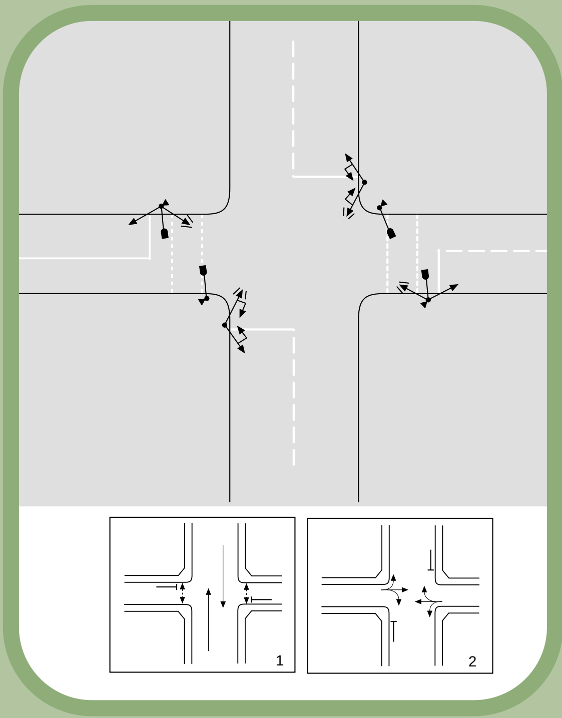
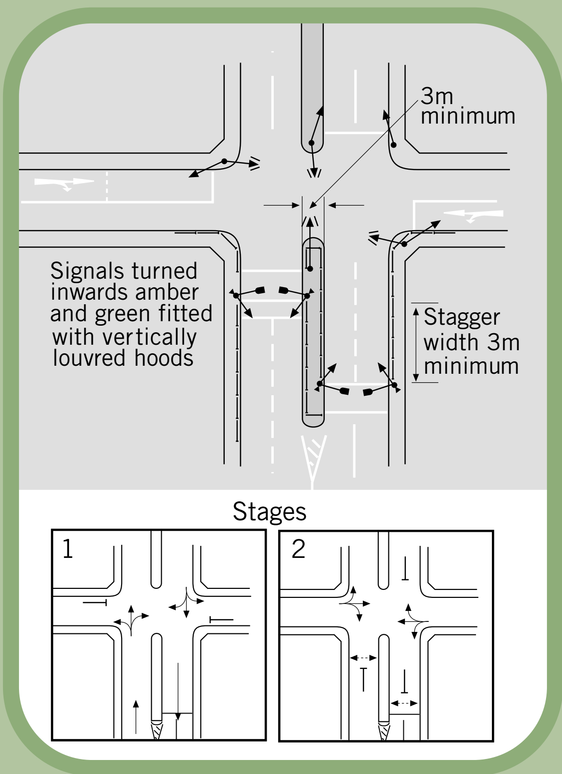



Diagram 10.15 Staggered pedestrian facility



more traditional guardrails can block intervisibility between drivers and child pedestrians. The length of guardrail used should be kept to a minimum to reduce its environmental impact.

Flashing amber for turning vehicles

## Dished crossings

Dished crossings should be provided at locations where pedestrians will cross regardless of the provision of a pedestrian phase. The crossings should be ramped or dished at a slope of 1 in 20 where possible. In many urban locations this is not possible so a compromise of 1 in 12 is a more practical maximum slope (see Diagram 13.1).

The upstand between the dropped kerb and the road is an important issue for wheelchair users. Even relatively small upstands can cause the front wheels of wheelchairs to turn and present users with difficulties. Ideally the road surface should be level with the kerb at the dished crossing but the maximum upstand should be 6mm.

Appropriate tactile paving should be provided at all crossing points (see Chapter 13).

## Full pedestrian stage

A full pedestrian stage (all-red to vehicular traffic) is the simplest method for pedestrians as they can cross any of the approaches during the stage. However, the introduction of a full pedestrian stage can increase traffic delays considerably, particularly if the approach roads are wide (because of the extra time required for pedestrians to cross) or the junction is near to its capacity. Push button units should be included on signal poles on islands (see Diagram 10.13). Appropriate audible bleepers should be incorporated into the signal equipment (see Chapter 13.4).

## Parallel pedestrian stage ("Walk with traffic")

It is sometimes possible to provide a parallel pedestrian stage, known as a "walk with traffic" system. This involves providing a controlled crossing for pedestrians across part of the junction whilst some of the traffic movements (not in conflict with the pedestrian movement) are allowed to run at the same time Diagram 10.14 shows a layout incorporating ‘walk with traffic’ where turning movements are banned. This facility has the advantage of having less effect on traffic capacity. However there is a tendency to install these facilities where they won't cause problems with traffic rather than where they are most needed by pedestrians. These facilities can be used with banned turning movements and across the exit from one-way streets.

### Staggered pedestrian facility (Primary or District Distributor roads only)

In this arrangement a wide central island is provided and the crossing of the road takes place in two separate movements. The crossing walkways are staggered to emphasise that the crossings are separate (see Diagram 10.15). A minimum stagger distance of 3m is recommended. Where possible it is good practice to have the stagger orientated so that pedestrians on the island are walking towards oncoming traffic. This was not possible in Diagram 10.15 where storage is provided in advance of the pedestrian lights for vehicles turning left and right from the minor road. The island must have adequate room for the number of pedestrians that are likely to use it at peak pedestrian times. A minimum island width of 3m is recommended. This allows for a 2m wide walkway, pedestrian guardrail and adequate clearance from the road. Increasing the stagger distance and width of the crossing walkways can help to cater for more pedestrians.

In signalised staggered t-junctions, it may be more appropriate to bring up the pedestrian phase after the main road, and in advance of the side road movements, to avoid car-pedestrian conflicts.

### TABLE 10.3 SELECTION OF APPROPRIATE PEDESTRIAN CROSSING FACILITIES AT TRAFFIC SIGNAL JUNCTIONS

| PEDESTRIAN FACILITY | COMMENTS |
|---|---|
| Full pedestrian stage "All-red" to traffic | This is the most common type of pedestrian crossing facility and the simplest for all road users to understand. Should be provided wherever there is available capacity |
| Parallel pedestrian stage "Walk with traffic" | This provides an opportunity to introduce pedestrian crossing phases whilst allowing traffic movements (that do not conflict with the pedestrian phases) to continue. They can be introduced at sites where the provision of a full pedestrian stage would result in unacceptable delays to traffic. These are often introduced in conjunction with banned turning movements or one-way streets |
| Staggered pedestrian facility (Distributor roads only) | This allows pedestrians to cross wide roads in two separate movements using a wider elongated central island. Traffic movements that do not conflict with the pedestrian phase are allowed to run at the same time. These offer the advantage that overall pedestrian delay can be reduced and pedestrian safety improved |

## 10.8 Providing for cyclists

Cyclists are vulnerable at all junctions. At traffic signals many cyclists will try to squeeze past lines of queuing traffic to get to the front of the queue. Narrow lanes or multiple lane approaches and the absence of cycle tracks make them particularly vulnerable. Cyclists are at risk from turning traffic.

Cycle tracks can be provided either off-road or on-road. Additionally there will be locations where there are no specific cycle facilities on the approaches to the signals, but cyclists will use the signals. To cater for cyclists at signalised junctions, signal times should be less that 90 seconds.

Most cycle facilities at traffic signals will cross cyclists through the junction on the road.

An advance stop line (see Diagram 10.16) creates an area in front of the normal stop line, to enable cyclists to get in front of other traffic when the signals are red. This allows them to get into a more prominent position. The reservoir area should be about 4m long. It is important to provide cycle "feeder" lanes on the approach to the advance stop lines.

"Provision of cycle facilities, the National Manual for Urban Areas",[8] deals with the provision of facilities for cyclists at traffic signal junctions in detail.

## 10.9 Providing for buses

Traffic signals can give priority to buses in a variety of ways. The simplest way is to design the signals to give more time to the approaches with bus routes. Alternatively, the buses can be equipped with transponders, which can call and extend the signal phase for the approaching bus. These can only give limited priority to buses unless there is sufficient capacity at the junction to allow bus lanes to continue up to the signal stop line. However the latter may not be possible where left turning vehicles must be accommodated at the junction. Such left turning vehicles can be accommodated either by having a separate left turn lane or by terminating the bus lane in advance of the junction and permitting only left turn traffic and buses in the inner lane from that point to the junction. As a minimum this latter level of priority should be provided on Quality Bus Corridors.

Diagram 10.16 Advanced cycle stop line

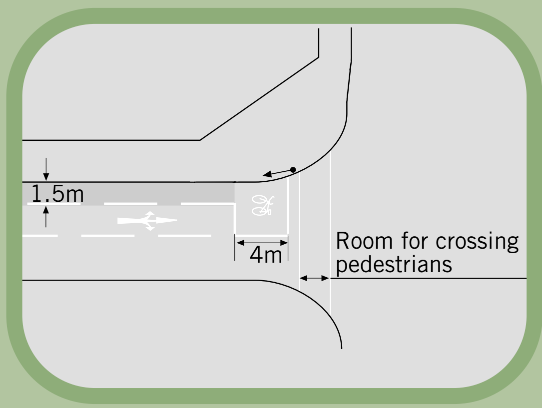
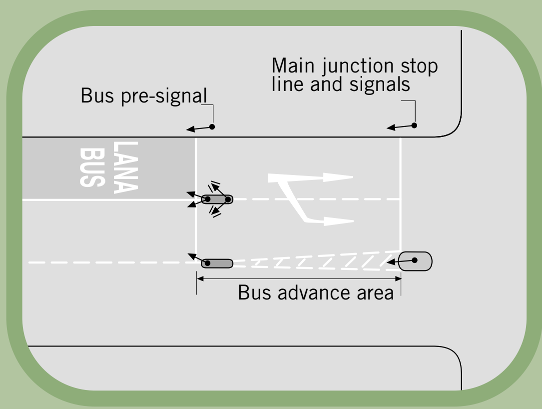



Diagram 10.17 Bus Advance Area which facilitates right turn for buses



## Bus lanes and Pre-signals

Where separate lanes can be provided for buses (often on wider roads) there are a number of ways in which buses can be given priority.

- Bus advance area (Diagram 10.17) – which uses a bus pre-signal to allow buses to advance into an area of road that is clear of traffic, before general traffic is allowed to flow. Pre-signals are located prior to the main signals on the approach. The pre-signal holds general traffic on red while the buses are allowed to enter the advance area. The main signal turns to green and traffic flows as normal. This facility allows buses to get to the front of the queue or in position to make a right turn without being held up by the other traffic. This provides a higher degree of bus priority without affecting capacity significantly because the manoeuvring between the pre-signal and signal takes place whilst other traffic phases at the junction continue as normal.
- Bus gate (virtual bus lane, Diagram 10.18) – use separate traffic signals to 'gate' general traffic whilst buses proceed unhindered into a normal traffic lane without having to filter in. These help to reduce delay to buses at locations where the road reduces in width and the separate bus lane has to be terminated. The section of road beyond the signals is then referred to as the 'virtual bus lane'. This area should be kept as "free flowing" (through the use of rear queue detection where necessary)

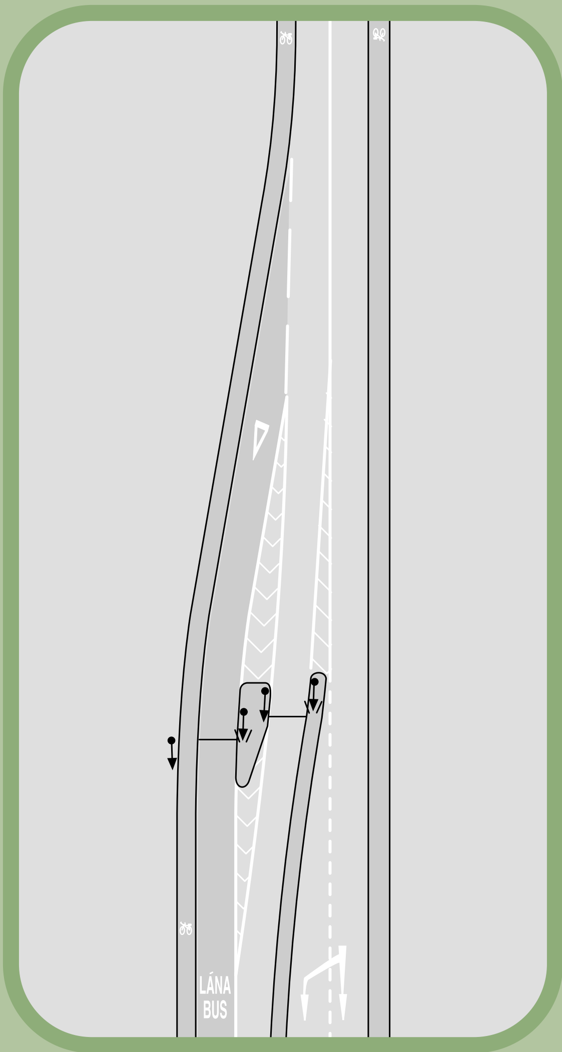
Where left-turning traffic would have to cross a bus lane at a signal controlled junction the bus lane marking can be broken to allow vehicles to do this.

## Other bus priority measures

If a bus lane can be continued to the stop line, separate phases can be introduced specifically for buses. When buses are detected, priority can be given to the phase that allows their movement. Selective Vehicle Detection (SVD) can provide a facility for buses to call a phase, which gives them priority. It can also omit or shorten other phases. There are a variety of ways in which this can be achieved. The most common types in use involve either bus-mounted transponders or separate detection loops.

Priority for buses can be provided within linked signals in an UTC system in certain circumstances. This can be achieved by weighting links with significant bus flows in the time plans.

Diagram 10.18 Bus Gate (virtual bus lane)




Bus Priority Measure

Adaptive systems such as SCOOT and SCATS can also give priority to buses within their operation.

Quality Bus Corridors (QBCs), contra flow bus lanes and other forms of bus gates can provide benefit for buses. These are dealt with in Section F, Chapter 15.

Quality Bus Corridor

## 10.10 Traffic control strategies

Traffic signals can be used as a powerful traffic management tool and can be used to achieve a wide range of traffic management objectives. If the network is overloaded, there is an immediate loss of network capacity, with unpredictable journey times, and random queueing and traffic jam events. If access to the network is metered, the network will have spare capacity to allow other strategies to take place, such as the following:

- Bus priority – to give buses priority over other vehicles and reduce delays for buses (see Chapter 10.9).
- Pedestrian and Cycle priority – to give pedestrians and cyclists better facilities particularly when crossing junctions. A reduction in delays and improvement in safety can be achieved (see Chapters 10.7 and 10.8).
- Emergency vehicle green waves – to give emergency service vehicles such as fire appliances and ambulances a sequence of green lights along a particular route or through an area. This can help to reduce response times when attending emergency calls.
- Encourage or discourage particular traffic movements – maximum green times can be varied to influence sensitive traffic movements at particular locations or times of day.
- Incident and special event management – signal timings and phase allocation can be altered to cope with incidents such as road accidents. Special events can generate unusual traffic flow patterns or involve temporary road closures.
- Parking management – parking management systems can be incorporated into adaptive co-ordinated signal systems such as SCATS. These can direct traffic to particular car parks.
- Air quality management – this is becoming increasingly important with the need to improve air quality in certain areas as part of the sustainable approach to transport management.
- Queue re-location and Gating – queue re-location provides for the re-distribution of traffic queues away from sensitive links where they could cause problems, for example where blocking of a link with insufficient stacking space could cause other

junctions to lock. Gating is a more sophisticated form of queue relocation that involves predefined limits for links sensitive to queuing. It gradually reduces flow into those links by adapting the green times to allow queues to build up at other junctions where the consequences are not so problematic.

The co-ordination of traffic signal junctions along routes or in areas is required for the effective operation of many of these strategies. This is dealt with in Chapter 10.11.

## 10.11 Urban Traffic Control (UTC)

UTC systems involve the co-ordination of adjacent traffic signals along a route or in an area. If the junctions are linked together, their timings can be co-ordinated to reduce overall vehicular delay. This offers significant benefits and can allow the introduction of a number of traffic control strategies (see Chapter 10.10).

### Co-ordination

Co-ordination is achieved by adopting common cycle times for each set of traffic signals. The amount of green time allocated to each movement will vary. It is possible to have some junctions operating two full cycles (double cycling) in the same time that the remaining junctions operate one full cycle. The time difference between a stream of traffic receiving a green light at one junction and the next one is called the offset. By varying the offset it is possible to co-ordinate the sequence of green lights that a stream of vehicles receives and control progress through the network. UTC systems aim to co-ordinate the interaction of all traffic streams in the network with a minimum of delay overall. If some links within the network are sensitive to queues or it is necessary to provide priority for buses etc. along them, weightings can be given to these links to reduce delays on them. Co-ordination can be achieved by the operation of fixed time plans or traffic responsive control systems.

"Green waves" assume all road users are travelling at uniform uninterrupted speeds. This is generally not the case, except perhaps on some primary distributor roads.

### Fixed time systems

These operate by implementing fixed time plans for various times of day for example AM peak, PM peak, off-peak, overnight etc. The plans are generally co-ordinated by use of very accurate time clocks within the signal controllers or by links with a central computer. The signals operate in accordance with the time plans, which can be prepared manually or using computer programs such as TRANSYT. If vehicle detection is provided at the junctions, then the fixed time plans can be switched off overnight (when traffic flows are light). The junctions can run in vehicle actuated mode which is more responsive to off-peak traffic patterns.

Fixed time systems offer significant benefits over operation without co-ordination. However, some of the main problems with fixed time plans are:

- they can become out of date quickly and need a lot of traffic survey work and analysis to keep them up-to-date
- the clocks can get out of synchronisation
- they cannot respond easily to variations in traffic flow

### Advantages of co-ordinated systems

The main advantages of adaptive systems are:

- improved monitoring of the signal equipment and any faults
- active bus priority
- special event management
- pedestrian priority

On Primary Distributor roads, they can provide the following benefits under certain conditions:

- savings in journey time
- reduction in the number of stops improving fuel economy and reducing pollution

- reduced journey time for emergency vehicles through "green waves"
- reducing driver delays and frustration

### Disadvantages of co-ordinated systems

- expensive to install and operate
- requires expert hands-on management
- benefits are limited in a congested network

### Traffic-responsive systems

A variety of traffic-responsive systems are in use around the world. These systems monitor traffic flows on the network using detectors and change the signal settings accordingly.

SCATS (Sydney Co-ordinated Adaptive Traffic Systems) was developed in New South Wales and is now used to manage many of the traffic signals in Dublin City and in Waterford City. A central computer communicates with individual signal controllers using a modem and dedicated phone lines. Detectors at each intersection measure traffic volumes and flows. These relay information in a real time manner to the central SCATS computer. The SCATS software adapts the signal timings, offsets and phasing in the system as a whole to respond to traffic flows. SCATS seeks to optimise the operation of each individual junction and its co-ordination with others in the network. The system does not require traffic surveys for updating fixed time plans and can provide traffic flow information for other traffic management purposes.

### SCOOT

Split Cycle Offset Optimisation Technique (SCOOT) is an adaptive UTC system developed jointly by the Transport Research Laboratory (TRL) in the UK in collaboration with some of the traffic signal system suppliers. The aims of the system are broadly similar to the SCATS system but the detection systems used and optimisation process used are different. SCOOT is used in Cork, Belfast and widely throughout the UK with very good results. The benefits of SCOOT are widely documented.[9]

## 10.12 Maintenance and fault monitoring

To keep traffic signals operating safely and efficiently it is necessary to have a good maintenance system. Traffic and pedestrian counts should be updated regularly and signal timings updated accordingly after running one of the available computer models (Chapter 10.5).

Detailed records of all signal timings, phases, stages and equipment are generally stored in the maintenance control centre with a copy in the signal controller cabinet. While faults are often reported by An Garda Siochana and members of the public a road authority should be pro-active in detecting faults. Regular inspections should be carried out to ensure that the signals are operating as designed and that any faults are identified and corrected quickly.

Signal maintenance is a specialist area and should only be undertaken by suitably qualified and experienced staff. If an authority does not have this facility then an arrangement with a specialist contractor should be considered. The following issues should be examined:

- a fault reporting and logging system
- a priority rating system for different types of fault
- agreed times for attending faults of different priorities
- a method of monitoring attendance times
- temporary arrangements if the lights are out of commission or have to be switched off for repair
- a schedule of rates for correction of common faults (e.g. bulb out)
- an agreed way of dealing with problems that require longer to correct
- an annual or six-monthly inspection of the condition of the signal equipment condition and programme of routine maintenance.

UTC systems connected to a central computer can monitor and report faults with the signals. Signal junctions in more isolated areas can also be connected to a central remote monitoring system. A fault monitoring system in the maintenance control centre is connected to the signal controller by a phone line. This periodically interrogates the controller and identifies any faults logged. This allows regular monitoring of faults and facilitates corrective action.

## 10.13 Signalled roundabouts and gyratories

The introduction of traffic signal control at large roundabouts and gyratories can help to:

- improve capacity
- balance queues between approaches
- reduce traffic speeds
- improve safety (particularly for cyclists)
- provide controlled crossings for pedestrians and cyclists
- provide priority for public transport including LRT

The junction can be considered as a number of two-stage traffic signals linked together. The first step in the design is to analyse each approach and associated internal stop line as an individual junction. Then, linking the sets of signals is considered. Traffic models (see Chapter 10.5) are needed to assist in this process. One of the main design limitations when considering the introduction of traffic signal control of a roundabout or gyratory is the available queuing lengths within the roundabout itself. If these block then the junction can lock up. It is important to keep cycle times short (no more than 60 seconds) to keep queue lengths to a minimum. It is easier to signalise larger junctions because of this.

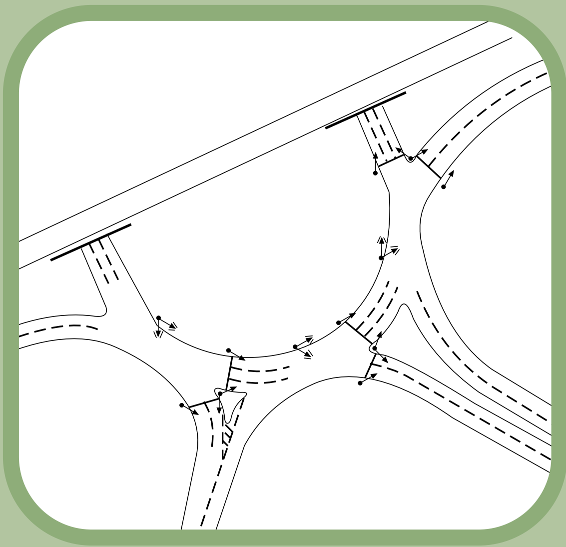
An alternative approach that is becoming more popular on complex junctions is to signalise only some of the arms and allow others to work on a yield to traffic from the right basis.

Diagram 10.19 shows an example of a signalled roundabout layout.

## 10.14 References

1. RT.181 Geometric Design Guidelines (Intersections at Grade) – National Roads Authority, St Martins House, Waterloo Road, Dublin 4

Diagram 10.19 Signalled Roundabout



2. Traffic Signs Manual – Department of the Environment. (Available from Government Publications Sale Office, Sun Alliance House, Molesworth Street, Dublin 2, or by mail order from Government Publications, Postal Trade Section, 51 St. Stephen's Green, Dublin 2, Tel 01 6476879; Fax 01 6476843)

3. TD50/99 and NRA Amendment – NRA Amendment available from NRA, St Martin's House, Waterloo Road, Dublin 4, Ireland. Tel 01 660 2511 Fax 01 668 0009. TD50/99 available from The Stationery Office, Telephone orders +44 870 600 5522, Fax orders +44 870 600 5533

4. Advice Note TA 16/81, General Principles of Control by Traffic Signals – Available from The Stationery Office, Telephone orders +44 870 600 5522, Fax orders +44 870 600 5533

5. Traffic Advisory Leaflet 3/97, The "MOVA" Signal Control System – (Available from the Traffic Advisory Unit, Zone 3/23, Great Minister House, 76 Marsham Street, London SW1P 4DR Tel +44 20 7944 2478 e-mail: tal@dft.gsi.gov.uk)

6. Advice Note TA15/81, Pedestrian Facilities at Traffic Signal Installations – Available from The Stationery Office, Telephone orders +44 870 600 5522, Fax orders +44 870 600 5533

7. Local Transport Note 1/95 – The Assessment of Pedestrian Crossings, Department of Transport UK. Available from The Stationery Office, PO Box 276, London SW8 5DT. Tel +44 870 600 5522

8. Provision of Cycle Facilities, National Manual for Urban Areas – DTO/DoELG. (Available from Government Publications Sale Office, Sun Alliance House, Molesworth Street, Dublin 2, or by mail order from Government Publications, Postal Trade Section, 51 St. Stephen's Green, Dublin 2, Tel 01 6476879; Fax 01 6476843)

9. Traffic Advisory Leaflet 7/99 – The 'SCOOT' urban traffic control system. (Available from the Traffic Advisory Unit, Zone 3/23, Great Minister House, 76 Marsham Street, London SW1P 4DR Tel +44 20 7944 2478 e-mail: tal@dft.gsi.gov.uk)