Department for Transport

TRAFFIC ADVISORY LEAFLET 1/06

Part 2 of 4

General Principles of Traffic Control by Light Signals Part 2 of 4

This document is Part 2 of Traffic Advisory Leaflet 1/06. It should be read in conjunction with Parts 1, 3 & 4. The Reference section is in Part 1.

SIGNAL SEQUENCES

The signal sequence at junctions in GB is red, red +amber, green, amber, red. The standard period during which an amber signal is displayed is fixed at three seconds and the red + amber signal at two seconds (see TR 2500[22], "Specification for Traffic Signal Controller" for tolerances).

The duration of the green signal will depend on the method of control. See later references to "vehicle actuation", "MOVA", "UTC", "SCOOT" and "linking".

Traffic signal controllers in GB make use of "stages" and "phases". Controllers select stages. The timings and demands are, however, phase based. The controller philosophy is designed to select the duration and the order of the stages to give right-of-way to phases in an optimum manner.

Understanding "stage" and "phase" is important. The two concepts are defined in BS 6100:1992[23], "Building and Civil Engineering Terms" and illustrated in Part 4, which shows the traffic movements permitted in each step of stage control for hypothetical junctions.

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Traffic Advisory Unit

Stage

The BS definition is: "indication by traffic signals during a period of the signalling cycle that gives right of way to one or more particular traffic movements". Stages usually, but not always, contain a green period. They are arranged to follow each other in a pre-determined order. However, some stages can be omitted, if not demanded, to reduce needless delay. Also, stage changes can be disallowed in the specification, normally for safety reasons. Only one stage can exist at one time.

A stage may be considered as starting at the point at which all phases that will have right-of-way during the stage have been set to green, and all others have been set to red. The stage may be considered to end at the point at which the first phase loses right-of-way. Therefore stages may be considered as being separated by interstage timing periods during which phases lose and gain right-of-way to establish a new stage. Provision is made for phases to receive right-of-way only when demanded e.g. left turn arrows. Such phases do not affect the definition of the stage.

Stages are defined by numbers, normally starting at either 0 or 1 as the "all red" stage, the stage numbers incrementing upwards with their appearance in the normal signal cycle. See TAL 5/05[4] for examples.

Parallel Stage Stream

The definition is a control scheme in which two or more separate stage streams run in parallel. The controller thus has the effect of two or more smaller controllers. Examples can be found in TAL 5/05[4].

This is a very useful facility but care needs to be exercised. Parallel stage streams can require strict conditioning to ensure that potential conflicts are avoided. Designers should be wary of using facilities just "because they are there"!

Phase

The BS definition is "set of conditions that fixes the pattern of movement and waiting for one or more traffic streams during the signalling cycle". Where two or more streams are always signalled to proceed simultaneously then they may share the same phase. However, it is now conventional that opposing traffic streams that always run together in the signal cycle are controlled separately by the controller. Although in traffic engineering terms the opposing streams share the same phase, in the controller they are treated separately. This must be recognised in the specification of the controller and on the layout plan where signal heads are lettered according to the phase to which they belong. This allows for the red lamp monitoring of individual approaches. Two or more non-conflicting phases may overlap in time.

Phases are defined by letters, with vehicular phases starting at A. The start point is often the southbound approach, although many designers start with the next "main road" approach. In both cases the designation continues clockwise round the junction. Many designers start with the main road, then the side roads, followed by the pedestrian phases. See TAL 5/05[4] for examples. In other European countries, "signal group" is often used instead of "phase".

Dummy Phase See Part 4.

Control strategy

(See CONTROLLER SETTINGS for explanations of intergreen, interstage, minimium and maximum green and extension.)

The stage sequence, start of green period and length of green period can be varied to match prevailing traffic conditions by one or more of the following methods.

Permanently FIXED TIME operation, where the timings and order of stages are not varied to meet changing conditions, is rarely satisfactory. The delays are usually unacceptable and driver frustration leads to disobedience. The control is usually varied by:

- vehicle responsive instructions, known as vehicle actuation. Includes "MOVA" and "CMOVA";
- instruction from an integral group, cableless link facility (CLF);
- instruction from an associated junction controller (cable-linked);
- instruction from central computer, known as Urban Traffic Control (UTC); includes "SCOOT", or
- integral time switch.

Each of these methods is described in the succeeding paragraphs.

Vehicle Actuation (VA) Method

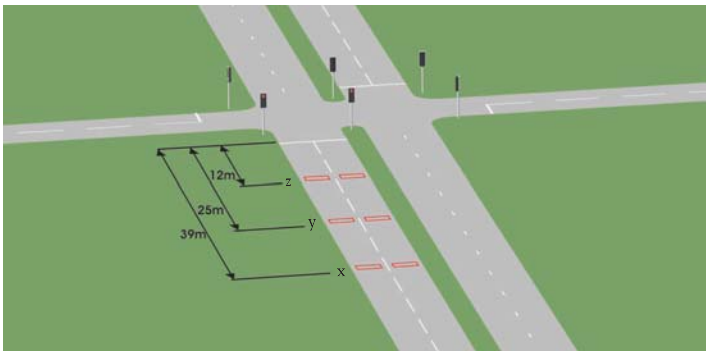
VA has considerable merit compared with fixed-time signal control. It is still probably the most common form of control for isolated junctions.

A vehicle approaching a red, or amber, signal will be detected and register a demand for a green. This demand is stored in the controller, which will serve allowed stages in cyclic order omitting any stages for which no demand has been received. Where it is essential that one stage must always follow another, the appearance of the first stage will automatically insert a demand for the second. When a stage loses right-of-way having reached the maximum green time, a demand is inserted for a reversion to that stage – to be implemented after other demands have been met.

Once a green signal is displayed, the duration may be extended by vehicles detected moving towards the signal. On expiry of the last extension and with no more vehicles detected, the controller will answer a demand for another stage, either at the end of the minimum green period, or immediately if this has already expired. If vehicles continue to extend the green period and a demand exists for another stage, the green signal will be terminated on expiry of a preset maximum period after the demand has been received. If there are no demands for another stage the signals will normally not change. However, in the absence of demands, they can revert to a pre-determined stage, say, the main road, or an all-red, see also TAL 5/05[4].

There are two standard methods of detection used:

i) Buried "loop" detectors consist of a cable taken from the kerb edge, coiled several times to produce an inductive component of a detector circuit and returned to the kerb edge. The loop "tails" are then jointed to a cable that returns to the controller. A vehicle passing over the loop changes the parameters within the detector and this change is used to give a "1" or "0" to the controller circuit.



A system (known as "System D") was developed in the 1960s to replace pneumatic detectors and is still used. There are normally three loop detectors in system D, although fewer can be used. The furthest, at 39 metres from the stop line is normally nominated as "X". Traditionally this demands the green if the signals are on red and otherwise extends the green. The next two are "Y" and "Z" and traditionally only extend the green. However, all three can demand and there may be good reasons for specifying this. For example, there may a minor side road/private access, or a bus stop at less than 39 metres.

In these cases, at quiet times, anyone turning out of the side road/access, or a bus pulling away after the signals have turned to red may not be detected. Details can be found in MCE 0108C[24], including the spacing for the three loops and other variations. Loop detectors can be uni-directional and also used for queue management and selective vehicle detection.

At advanced stop lines (ASLs) drivers must stop at the first stop line they reach if so required by the signals, with the normal proviso for the amber signal. If they pass the first line before the signal requires that they stop but do not reach the second they must stop between stop lines, again with the normal proviso. Consequently the XYZ detectors are measured from the second stop line to be reached and the clearance times will be unchanged.

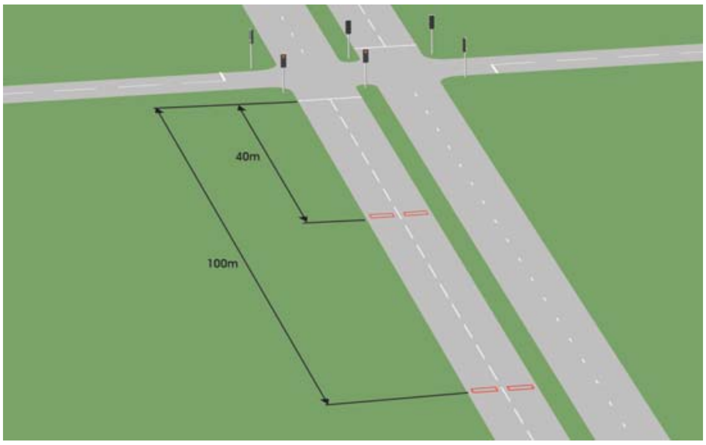
If the 85th percentile approach speeds are above 35mph the designer should read TAL 2/03[5] "Signal-control at Junctions on High-speed Roads" which introduces the

subject of special detection for these applications.

ii) Above Ground Detectors (AGDs) can be used effectively instead of loop detectors. Information can be found in TAL 16/99[25], "The Use of Above Ground Vehicle Detectors". AGDs are being developed further and the designer should check with the Highways Agency in Bristol for an up-to-date approval list for the application being considered. There are basically two types of AGD currently used: dynamic – detecting moving vehicles (e.g. microwave) and static – detecting stationary vehicles, including equestrians, (e.g. infra-red detectors). Both give the same output to the controller of a "1" or "0". Installation of both types is important as unlike the loop detector, which is fixed, AGDs can be moved by vandalism and high winds. Secure fixings and regular checks are therefore essential.

MOVA (Microprocessor Optimised Vehicle Actuation)

The following is an extract from TAL 3/97[26], "The MOVA Signal Control System" and TAL 2/03[5] "Signal-control at Junctions on High-speed Roads". Anyone contemplating installing MOVA should read both of these documents and



those referenced in them.

Although VA is responsive, it "is prone to extend the green phase ineffectively, particularly when there are long queues waiting at red signals. It is also difficult to set maximum greens effectively. This can seriously degrade performance if they are poorly related to the balance of opposing flows. Thus, if performance is not to deteriorate by ageing, it is necessary to measure traffic flows at regular intervals in order to reset maximum greens. This places a considerable burden on traffic engineers and is often neglected. In the mid-eighties TRL developed a control strategy to overcome these problems - MOVA.

"MOVA maintains the green whilst the flow is maintained at, or above, saturation flow rate as determined by the standard MOVA detector layout; once the end of saturation flow has been detected a delay optimisation process begins. If one or more lanes are oversaturated, MOVA uses a capacity-maximising algorithm instead of the delay-optimising process.

"MOVA is now the general standard on all new and modified trunk road sites, see TD 35[27], "All Purpose Trunk Roads MOVA System of Traffic Control at Signals" unless (exceptionally) site circumstances dictate otherwise, for example in a UTC system."

CMOVA

A potential barrier to the implementation of MOVA at low speed sites (where the 85th percentile speed is less than 35 mph) is the requirement to have vehicle 'IN-detectors' positioned at a relatively long distance from the junction compared with VA. The requirement for IN detectors presents cost and maintenance difficulties, especially in urban areas where the cost of ducting under the footway can be prohibitive. 'Compact MOVA' is a new facility provided in MOVA M5 which allows MOVA to be installed without the use of the more distant 'IN-detectors' on all or selected low-speed approaches. Trials have shown that, although not quite as effective as full MOVA, Compact MOVA is capable of reducing delay compared with traditional VA and is particularly effective during congested periods.

Linking

A linked system usually requires each controller to be functioning on identical or submultiple cycle times of the key intersection and the co-ordination determines the start or finish of certain stages.

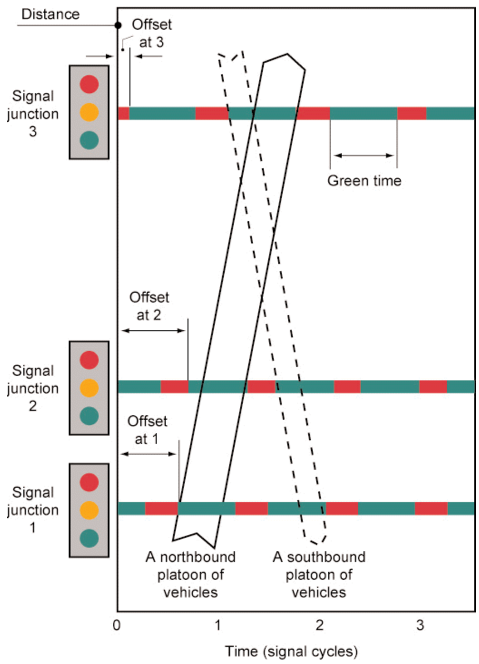
There are several ways to derive signal settings for co-ordinated junctions and crossings. Originally all calculations were carried out using time and distance diagrams, see Traffic Advisory Leaflet (TAL) 7/99[28] "The SCOOT Urban Traffic Control System".

However, in the late 1960s TRL developed the TRANSYT (Traffic Network Study Tool) program that reduces much of the work involved and is now the basis for most linking. TRANSYT is an off-line computer program for determining and studying optimum fixed-time co-ordinated traffic signal timings in any network of roads for which the average traffic flows are known.

i) Cableless

Using cableless linking units, two or more junctions or crossings can be linked by synchronisation with the mains supply frequency. Different combinations of stage timings, cycle times and stage off-set periods between junctions can

An idealised time-distance diagram showing signal co-ordination with a fixed time plan



be selected according to the time-of-day and day-of-week to cater for variations in overall traffic flows.

Demand dependent stages can be incorporated, which can be selected by a vehicle, or pedestrian demand. If such a stage is not demanded then the time is added to the preceding or succeeding stage.

Correctly set and synchronised this method offers reduced delays to road users by signal co-ordination. As the plans are fixed, apart from the use of demand dependent stages, it presupposes that the variation in flow for a particular period is small.

ii) By cable

This uses information passed between two or more controllers to arrange that the commencement of a selected stage at one intersection (termed the key intersection) shall control the beginning or the end of any selected stage or stages at other intersections (known as controlled intersections). This arrangement provides for the controlled displays to operate simultaneously or separated by a time interval. It is also possible for the control arrangement to provide for selected stages to be synchronised with those at other intersections when they run concurrently. The linking can be disconnected, say, by a time switch to allow each controller to operate in an isolated mode.

The method was popular but because of the capital and maintenance costs involved, has largely been superseded by the cableless linking system. However, it is more flexible and if junctions are close together then this vehicle responsive co-ordinated system is worth considering. If the problems associated with cable were overcome then it could have considerable advantages.

iii) Urban Traffic Control (UTC)

Signal-controlled junctions and crossings are connected back to a central computer.

Earlier systems were fixed time, dating from the late 1960s onward. Traffic plans, which are usually generated from historical data, control the cycle time, start and length of green period and therefore the offset between stages on adjacent controllers. Plans are normally selected according to time-of-day and day-of-week. The problem with fixed time systems is that they are only as good as the last survey. These surveys are very time consuming and periods between surveys become extremely lengthy. With changes to traffic patterns within towns and cities being often rapid, plans become out of date far quicker than they can be updated.

Not only do general patterns change but day-to-day flows can alter considerably, due to road works, broken down vehicles, delivery of site equipment to developments within the conurbation etc.

To tackle both the short and long term problems associated with fixed time UTC the SCOOT (Split, Cycle, Offset, Optimisation Technique) system was developed jointly by the Department, TRL and industry. The principles are set out in Traffic Advisory Leaflet (TAL) 7/99[28]. Three other TALs cover specific uses: 7/00[29] "SCOOT Gating", 8/00[30] "Bus Priority in SCOOT" and 9/00[31] "SCOOT Estimates of Emissions from Vehicles".

Master Time Clock Switch

The master time clock switch is available on controllers and is based on a precision real time clock and calendar from which timing information is derived.

The Master Time Clock System provides the facilities necessary for the controller to be integrated into a cableless link system or to allow the controller to be operated in a fall back mode of operation in an Urban Traffic Control Scheme.

The Master Time Clock System may additionally be used to achieve time-controlled switch facilities, such as alternative timings, or stage structure, or the control of secret signs.

The Master Time Clock System is used to change to and from British Summer Time.

Part Time Operation

In most situations there is no need for part time operation and if used there may be an increase in accident potential. If the junction is working efficiently on vehicle actuation during off-peak periods, unnecessary delays are minimised and the advantages of control, especially for the more vulnerable users retained. See CSS publication, A Review of Signal-controlled Roundabouts[32]. A TAL on signalised roundabouts is in preparation.

Hurry Calls

It is often important to move quickly to a particular stage in the cycle. This can be achieved by using a Hurry Call registered via a selective vehicle detector, or a switch, say, in a fire station.

Controller Settings

The controller periods that have an important effect on safety are: the intergreen, interstage, minimum green and extension. (See TR 2500[22], "Specification for Traffic Signal Controller" for timing ranges.)

Intergreen Period

The BS definition is: "the period between the end of the green signal giving right of way for one phase, and the beginning of the green signal giving right of way for the next phase".

The intergreen period can be extended but never curtailed by external control.

The normal minimum is 5 seconds, made up of 3 seconds amber after one green and 2 seconds before the next. The intergreen can be fixed at a longer period, say, because of conflict distances, or made variable, say, because of a high-speed detection requirement, see TAL 2/03[5].

Intergreens can be extended by buried inductive "loop" detectors, or by above ground detectors (AGDs). This is typically on a shuttle working length. It is important that all-red extending detectors are remotely monitored as a faulty detector will mean that the intergreen will extend up to the maximum set, which over time will bring the signals into disrepute and encourage disregard of the red signal.

A short intergreen period is potentially dangerous but equally a period that is too long leads to delay, frustration and disobedience, again bringing the signals into disrepute.

A guide to calculating the intergreen period is illustrated in "Determination of Intergreen Times" in Part 4.

Interstage Period

This is defined as "the period between the end of one stage and the start of the next stage" (TR 2500[22]). This period is best explained by the diagrams in "Phases and Stages" in Part 4.

Minimum Green

The minimum green time is fixed, starting at the commencement of the green signal. The minimum green cannot be overridden by demands, whether emanating from vehicles, manual control devices, central computers, or linked controllers.

Under vehicle actuation, the minimum green allows those drivers in front of the demand (X) loop detector to clear the junction, or to allow the moving queue to reach the minimum speed for AGDs. Otherwise a vehicle can become trapped in front of the stop line with no means of registering a demand for another green period. The minimum also gives the signals credibility by not changing too quickly and allowing a vehicle just outside the detection zone to register an extension.

With the exception of the cases mentioned below, the shortest minimum green period normally used is seven seconds but site conditions may require a longer period. Typically this will be where large numbers of heavy vehicles have difficulty in starting away from the stop line or the approach is on a steep gradient, but see also “Determination of Intergreen Times” in Part 4 . Where pedestrians and traffic share the same stage the green signal is governed by the period given in TAL 5/05[4] “Pedestrian Facilities at Signal-controlled Junctions”. On early cut off and late start stages the minimum may be as low as three seconds.

Extension Times

Where vehicle actuation is employed, a vehicle detected on the approach during the display of a green signal will, within certain limits, extend the time the green signal is displayed. The purpose of extensions is to permit the vehicle to pass the stop line before expiry of the green period. Detectors should respond to all vehicles, including bicycles.

Extensions at junctions equipped with inductive 'loop' detectors are given at each of, normally, three detectors. Each will extend the green by, say, 1.5 seconds. However, if the vehicle arrives at the third detector 2 seconds after passing over the first, the total extension period will be 3.5 seconds (2 + 1.5) and not 4.5 seconds.

See TAL 2/03[5] for junctions on high-speed roads. High speed for this purpose is defined in that publication.

The extension periods required for each type of detector are given in TR 2500[22].

Maximum Green Times and Cycle Time

The maximum green period is calculated using a combination of layout and traffic flow parameters. (The maximum green normally starts on the receipt of a demand for an opposing stage but see Dummy Stage in Part 4.) Early work was carried out by Webster & Cobbe in the 1960s and still forms the basis of signal calculations carried out today, mainly by computer programs such as LINSIG and OSCADY. A brief preview of each is given in Part 3.

The sum of the maximum green periods for each stage, plus the sum of the intergreen periods between each stage in cyclic order will give the maximum cycle time for the intersection. The BS definition of “cycle” is “one complete sequence of the operation of traffic signals”.

Relatively short cycle times are beneficial to overall good traffic management and they should be matched to actual demand. It is not recommended that cycle times in excess of 120 seconds be used.

Details of Traffic Advisory Leaflets available on the DfT website can be accessed as follows: www.dft.gov.uk
From the DfT homepage, click on Roads and Vehicles, then Traffic and Parking Management and then Traffic Advisory Leaflets.

The Department for Transport sponsors a wide range of research into traffic management issues. The results published in Traffic Advisory Leaflets are applicable to England, Wales and Scotland. Attention is drawn to variations in statutory provisions or administrative practices between the countries.

The Traffic Advisory Unit (TAU) is a multi-disciplinary group working within the Department for Transport. The TAU seeks to promote the most effective traffic management and parking techniques for the benefit, safety and convenience of all road users.

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