Department for **Transport**

TRAFFIC ADVISORY LEAFLET 1/06

Part 1 of 4

General Principles of Traffic Control by Light Signals Part 1 of 4

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

INTRODUCTION

The primary purpose of traffic control by light signals is to separate conflicting traffic by the division of time, within the available road space, in a safe, efficient and equitable manner. The term "traffic" includes all road users: vehicles, (including cycles), pedestrians and equestrians. Conflict at a junction is manifested as an increase in delay and/or accident rate.

At a signal-controlled junction, vehicular traffic is permitted to flow in a strictly controlled manner. The traffic flows, available road space, layout and stage sequences will all affect delay. The successful installation will impose the minimum delay on all traffic, consistent with safety.

The designer should have a firm grasp of the relevant current legislation and advice/guidance. The "umbrella" document is TA 84[1], "The Code of Practice for Traffic Control and Information Systems", which encourages consideration and documentation of the various safety aspects. Traffic Advisory Leaflet (TAL)[2], "Traffic Light Signals - Relevant Publications", lists both those documents directly associated with the subject and others which practitioners should have knowledge of.

General layout matters are covered in TD 50[3], "The Geometric Layout of Signal-controlled Junctions and Signalised Roundabouts". This takes the designer

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through the early considerations, such as the intervisibility, lane widths, swept paths of vehicles etc. TD 50[3] was written for trunk road junctions and although the advice given will also be applicable to many other junctions, there will be exceptions. For example, some junctions are signal-controlled because there is poor intervisibility, which cannot reasonably be improved and a priority junction would not be safe. Therefore, some of the advice given in TD 50[3], on subjects such as intervisibility needs to be considered pragmatically. Decisions may be justified because of the existing/desired topography, or to help deliver a desired design speed. The Manual for Streets, currently in preparation, is developing this approach, adopting a different approach to road design by creating environments which dictate the prevailing speed of vehicular traffic rather than try to accommodate it.

This document follows on from TD 50[3], considering the detail. It is necessary to read TAL 5/05[4], "Pedestrian Facilities at Signal-controlled Junctions" with this document and there are others, such as TAL 2/03[5], "Signal-control at Junctions on High-speed Roads", which should be referred to as necessary.

Compared with other western countries Great Britain (GB) has a good accident record at signal-controlled junctions. This is certainly in part, if not mainly, due to a consistent system of signalling for a given circumstance. It is important that all displays must be clear and unambiguous.

Signal posts

The standard signal head is mounted on a post, within the height limits set in the Traffic Signs Regulations and General Directions (TSRGD)[6]. However, because of poor sight lines caused by the geometry of the approach, or by high vehicles blocking visibility at some point on the approach, designers may need to consider a supplementary signal. This could be either by using a tall post, with a second signal above the standard one, or by installing a mast arm signal over the carriageway. However, the aim should be a sufficiency of signals, not a surfeit. As in all traffic management, a proliferation of signs/signals can lead to confusion and ambiguity. Tall post signals need authorisation if they are above the maximum height in TSRGD[6]. The designer needs to check that the posts to be used are structurally approved for the specific design (see TAL 2/03[5]).

Designers should consult TA 89/04[7], "Use of Passively Safe Signposts to BS EN 12767[8]". BS EN 12767[8]: Passive safety of support structures for road equipment - Requirements and test methods, is voluntary and provides a means of classifying items of roadside equipment in terms of the likely severity of injury they might cause if a vehicle collides with them.

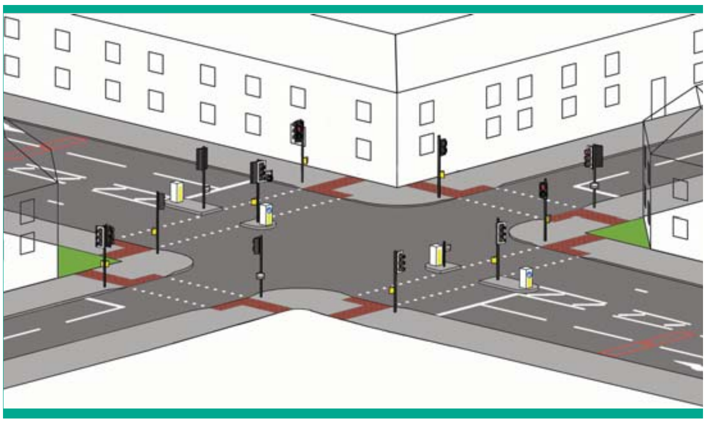
Sockets are available for posts so that they can be removed easily for wide loads, ceremonial occasions etc. The socket arrangements come complete with electrical plug/socket connections.

It is normal to number posts, at least on the design drawing. A standard convention should be adopted, say, starting at the controller and working clockwise.

Signal displays

Traffic signal displays are provided under powers contained in the Road Traffic Regulation Act[9]. They must comply with TSRGD[6] which calls for some equipment to be approved and the relevant specifications are listed in MCS 206[10] "List of Drawings, Specifications and Instructions". MCS 215[11] "Traffic Signal Equipment on all Purpose Roads - Summary of Approval Status" gives details but advice on individual approvals can be sought from the Highways Agency. Any use of signals not specifically covered by the above documents is unlawful unless specifically individually approved/authorised as appropriate.

Traffic control is by means of red, amber and green light signals, supplemented by additional green arrow light signals and regulatory signs as necessary (but see section on wig-wag and tram signals). Individual elements in a signal head are known as "aspects". In Europe the term used is more often "optical unit". (NOTE the colour "yellow" referred to in European Standard (ES) EN 12368:2000[12] is known in GB as "amber".) TSRGD[6] gives details of the performance level within the ES[12] for signal heads. TSRGD[6] requires all junctions to have at least two signal heads per approach.



One signal head is normally placed on the nearside and is known as the primary signal. Each approach has a transverse stop line associated with the primary signal indicating the place at which vehicular traffic must stop. The signal must be beyond the stop line, as seen for an approaching vehicle and before pedestrian crossing studs if provided. The minimum distance from stop line to studs is 3 metres, with the post to studs distance set so that pedestrians can easily reach the push button, normally 0.5 metres. Although there is no legal maximum at junction signals, care must be taken not to jeopardise intervisibilty, or confuse road users. There can be a second primary signal, sometimes known as the duplicate primary. These are on the offside, possibly on an island.

Signal heads beyond the junction are known as secondary signals. The displays must have the same information as the primary and may have additional information, which must not conflict with that shown on the primary. In certain circumstances it may be undesirable, or impracticable, to position the secondary signal beyond the junction. On these occasions the secondary may be on the entry side of the junction, beyond the stop line and primary positions and preferably on the offside. This is known as a closely associated secondary.

There must always be a primary signal but the required second signal can be any of the other types described. The important test for sufficiency of signal heads is to be found in Local Transport Note 1/98[13],"The Installation of Traffic Signals and Associated Equipment". Other references can be found in TAL 2/03[5], "Signal-control for high-speed junctions" and Local Transport Note (LTN) 2/95[14], "The Design of Pedestrian Crossings".

Signal heads may be provided with a black backing board, known in parts of Europe as a background screen, which enhances the conspicuity of the signal, especially if there are background distractions: advertisements, street lighting, general shop front "noise" etc. Legislation allows for a white strip around the backing board. Previous backing boards extended the width of the signal significantly, potentially causing problems at constricted sites. Legislation now permits white borders to be fitted directly to signal heads. The white strip alone will help to enhance the definition of the signal head. If the signals are not working for any reason this is particularly important. A reflective white border is particularly helpful in the case of a local power failure, or in areas with no street lighting.

In the context of this document, an arm is one road forming part of the junction; an approach is that part of the arm which carries traffic towards the junction and a traffic stream consists of vehicles in one or more lane, on the same approach, which, when they have right of way, will move in the same direction.

Green arrow light signal displays

The significance of a green arrow is that drivers can proceed only in the direction of the arrow (assuming no other green signal) and continue through the junction in that direction. See TSRGD[6] for the legal definition. If there are other green signals these will have separate meanings.

When green arrows are used, drivers have come to expect an exclusive right of way. It is therefore strongly recommended that when green arrows, especially for turning traffic, are displayed there should be no conflicting movements.

Substitute Green Arrow Signal

A green arrow can be fitted in place of the full green in a three-light signal head. It may indicate any movement through 180^0 above the horizontal. A green arrow in this position must always be preceded by a red + amber and terminated by amber, or full green.

Additional Green Arrows

Additional green arrows may be fitted in any of the positions indicated in TSRGD[6].

A filter arrow is a green arrow displayed on its own, normally a left hand arrow, with an associated red signal. It is not preceded by a red + amber and is followed by a full green. These are commonly run in parallel with a non-conflicting right turn from the opposing approach.

An indicative arrow is a green arrow displayed with a full green, conventionally displayed only in the secondary position. It is preceded by a red + amber, or full green and followed by a full green, or amber. A typical use would be an early cut-off sequence, see later reference.

Amber Arrows

Some drivers can have problems at sites where a common stop line is shared by lanes, which are being separately signalled with green arrow signals. It is thought that they anticipate that an amber signal preceding, say, a green arrow for a straight ahead movement is that for a right turn. The driver may then move off, unlawfully, against the amber signal and turn right, a movement which may endanger both that driver and others.

Research was carried out with replacing the amber signal with one showing an amber arrow. However, although this did reduce the number of incidents involving the red/amber period, at some sites it increased the number of drivers failing to stop during the amber period.

An Intelligent Amber Arrow, a signal showing an amber arrow before the green arrow but a full amber before the red was developed and tried at a number of sites. This did reduce the number of drivers failing to stop during the amber period. However, the future of this development is unsure and potential users should contact the Department before incorporating amber arrows in their design. Site authorisation for the use of amber arrows would also be needed.

Signals for light rapid transit systems (LRTS or trams)

Trams are now well established in a number of towns and cities. The Railways Inspectorate (HMRI) should be contacted at an early date if a system is being considered.

For trams at signal-controlled road junctions, signals to one of the variants of diagram 3013 of the TSRGD[6] are used. The tram signals are often mounted alongside standard signal displays as shown in TSRGD[6]. Facilities for pedestrians crossing at signal-controlled junctions and elsewhere on the system need to be considered at the start of the project.

Although signals are not now required to be type approved, specification TR 2514[15] does give the requirements for light signals for the control of trams. The specification shows the lines in diagram 3013 as a sequence of discrete "spots". This arrangement does not need authorisation.

Other tram signals used on the system are not necessarily seen by vehicle drivers. However, if they are, signals such as "point indicators" will need authorisation, as they are not prescribed in TSRGD[6]. Advice on the procedure for authorisation can be obtained from the local Government Office.

Wig-wag signals

Signals to diagram 3014 in TSRGD[6] are prescribed "for the control of road traffic at level crossings, swing or lifting bridges, tunnels, airfields or in the vicinity of premises used regularly by the fire, police or ambulance service vehicles". The signal heads need to be ES compliant, as specified in regulation 39 of TSRGD[6]. A TAL specifically on the use of wig-wags will be published shortly.

It is important to note that although some specified vehicles may pass a red signal displayed by an assembly in the diagram 3000 series, there are no exceptions for drivers to pass a red signal displayed by one to 3014.

The specification is TR 2513[16] "Performance Specification for Wig Wag Signal Control System."

For level crossings, the HSE publication "Railway Safety Principles and Guidance, Part 2, Section E, Guidance on level crossings"[17] is the source document. The Railways Inspectorate (HMRI) must be consulted if any work is planned near level crossings.

There are situations where the standard 3014 signal cannot be used because of a lack of space. A narrower version can be used but will need authorisation. A drawing NP 3015 is available from the Traffic Signs Technical Advice Branch of the Department. It is essential that signals used display the same layout as diagram 3014 and not a three-in-line assembly as in the diagram 3000 series.

Signals for the exit, say, from a fire/ambulance station show blue, or white with amber aspects. These are not visible to the public highway. See TR2513[16] for details of this and call out switches etc.

Signing

A review of the existing signing should always be part of the new/modified signal layout design. Careful combination of signs onto a common background, for example, will cut clutter and give a clearer message.

Regulatory

There is no requirement for erecting a sign to diagram 606 where an exclusive traffic movement is required at the signals, as indicated by a substitute green arrow. However, if there is a Traffic Regulation Order (TRO) associated with the junction it must be signed. Regulatory signs may be used in conjunction with signal displays to indicate movements that are restricted. TSRGD[6] refers to the type, illumination requirement and position of the signs.

Prescribed subplates in TSRGD[6] can also be used to indicate exceptions listed in the TRO. These are circular and allow fitting in a standard signal housing. However, the size of lettering on some is smaller than would otherwise be used.

To give drivers every opportunity to comply, the lettering size (x height) should be commensurate with the 85th percentile speed, as shown in Chapter 3 of the Traffic Signs Manual[18]. If it is not possible to use this size in the signal display, other methods should be used instead, or in addition.

One method is to use advance signing, say, to Diagram 818.2, TSRGD[6] and a standard plate sign at the junction.

Informatory and Warning

Signs on the approach to and at the junction are an important part of the overall design. Regulatory signs have already been mentioned. Informatory and warning signs also need careful consideration:

- Signals work by allocating time but often the design also allocates space, say, by providing separate lanes for left and/or right turning vehicles. To maximise the junction capacity it is important to provide informatory signs to get drivers into the correct lane. This also reduces lane changing near to the junction with the associated accident potential.
- Warning signs (see individual guidance in Chapter 4[19] of the Traffic Signs Manual) can be needed for the signals themselves, diagram 543 or a 584/584.1, or for other potential problems, such as diagram 530 for a low bridge ahead, or a combination of diagrams 520 and 521 where a dual carriageway ends after the junction.
- Road markings - see Chapter 5 of the Traffic Signs Manual.

Apart from the possibility of signs directly associated with the installation, such as to diagram 543.1, there should be no other signs mounted on the signal post. Other signs would inevitably attract a driver's attention and it is important that this is concentrated on the signal displays.

Street lghting

Signal-controlled installations will only work efficiently if treated as a part of the whole and not as a separate entity. When introducing signal-control, the introduction of, or alteration to the street lighting should be considered as part of the design. If there are pedestrian facilities street lighting is essential.

The type of street lighting should be considered. Low pressure sodium, with its yellow source is unsuitable if it acts as a backdrop for the amber (yellow) signal. High pressure sodium, which has a white light, gives better contrast.

BS 5489[21], Road Lighting is a general starting point for design, which should be undertaken by a qualified lighting engineer.

References

All the listed HA specifications will be replaced and renumbered in the near future. Designers should refer to the HA.

1 TA 84, The Code of Practice for Traffic Control and Information Systems, Design Manual for Roads and Bridges (DMRB), Vol. 8, Section 1. TSO.
2 Traffic Advisory Leaflet (TAL), Traffic Light Signals - Relevant Publications. DfT.
3 TD 50/04 The Geometric Layout of Signal-Controlled Junctions and Signalised Roundabouts, DMRB, Vol. 6, Section 2. TSO.
4 TAL 5/05, Pedestrian Facilities at Signal-controlled Junctions. DfT.
5 TAL 2/03, Signal-control at Junctions on High-speed Roads. DfT.
6 The Traffic Signs Regulations and General Directions 2002. ISBN 0-11-042942-7. TSO.
7 TA 89/04, Use of Passively Safe Signposts to BS EN 12767, DMRB, Vol 8, Section 2, TSO.
8 BS EN 12767, Passive safety of support structures for road equipment - Requirements and test methods, BSI.
9 Road Traffic Regulation Act 1984. TSO.
10 MCS 206, List of Drawings, Specifications and Instructions. HA.
11 MCS 215, Traffic Signal Equipment On All Purpose Roads.
12 European Standard EN 12368:2000. BSI.
13 Local Transport Note 1/98, The Installation of Traffic Signals and Associated Equipment. TSO.
14 Local Transport Note (LTN) 2/95, The Design of Pedestrian Crossings. TSO.
15 TR 2154, Light Signal for Control of Tramcars. HA.
16 TR 2513 Performance Specification for Wig Wag Signal Control Equipment. HA
17 Railway Safety Principles and Guidance, Part 2, Section E, Guidance on level crossings. HSE
18 Chapter 3 of the Traffic Signs Manual. TSO.
19 Chapter 4 of the Traffic Signs Manual. TSO.
20 Chapter 5 of the Traffic Signs Manual. TSO.
21 BS 5489, Road Lighting. BSI.
22 TR 2500, Specification for Traffic Signal Controller. HA.
23 BS 6100:1992 Building and Civil Engineering Terms. BSI.
24 MCE 0108C, Siting of Inductive Loops for Vehicle Detecting Equipment at Permanent Road Traffic Signal Installations. HA.
25 TAL 16/99, The Use of Above Ground Vehicle Detectors. DfT.
26 TAL 3/97, “The MOVA Signal Control System”. DfT.
27 TD 35/91, “All Purpose Trunk Roads MOVA System Of Traffic Control At Signals”. DMRB Vol.8, Section 1, Part 1. TSO.
28 TAL 7/99, “The SCOOT Urban Traffic Control System”. DfT.
29 TAL 7/00, SCOOT Gating. DfT.
30 TAL 8/00, Bus Priority in SCOOT. DfT.
31 TAL 9/00, SCOOT Estimates of Emissions from Vehicles. DfT.
32 “A Review of Signal-controlled Roundabouts”, Traffic and Safety Committee, Traffic Management Working Group. CSS.
33 LINSIG. JCT Consultancy.
34 OSCADY Optimised Signal Capacity and Delay. TRL.
35 ARCADY Assessment of roundabout Capacity and Delay. TRL.
36 PICADY Priority Intersection Capacity and Delay. TRL.
37 Road Research Technical Paper No. 56 - Traffic Signals, Webster and Cobbe, HMSO, out of print.
38 TRL Report RR67 The prediction of saturation flows for road junctions controlled by traffic signals. TRL

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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Scottish Executive

Within Scotland enquiries should be made to:
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Department, Transport Division 3, Zone 2-F,
Victoria Quay, Edinburgh, EH6 6QQ,
Telephone 0131 244 0847
e-mail: roadsafety2@scotland.gsi.gov.uk

Llywodrath Cynulliad Cymru
Welsh Assembly Government

Within Wales, enquiries should be made to:
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Transport Directorate, 2nd Floor, Cathays Park,
Cardiff, CF10 3NQ
Telephone 02920 826444
e-mail: keith.alexander@wales.gsi.gov.uk

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TRAFFIC ADVISORY LEAFLET 1/06

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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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.

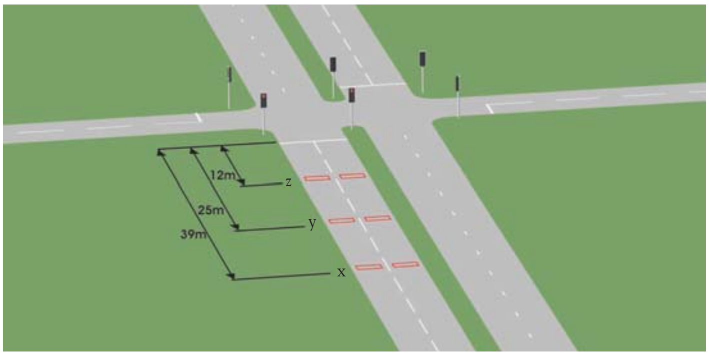
A vehicle approaching a red, or amber, signal will be detected and register a demand for a green. This demand is stored in the controller, which will serve allowed stages in cyclic order omitting any stages for which no demand has been received. Where it is essential that one stage must always follow 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.

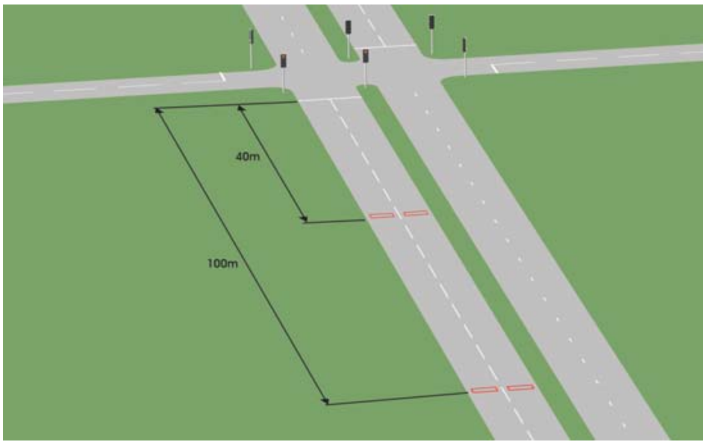
If the 85th percentile approach speeds are above 35mph the designer should read TAL 2/03[5] "Signal-control at Junctions on High-speed Roads" which introduces the

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.

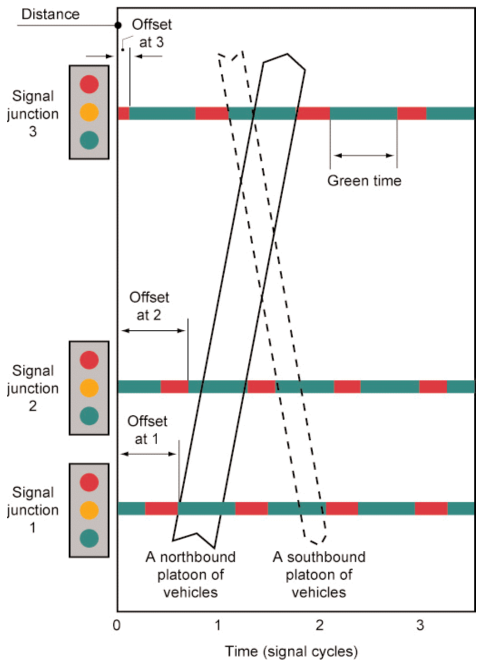
There are several ways to derive signal settings for co-ordinated junctions and crossings. Originally all calculations were carried out using time and distance diagrams, see Traffic Advisory Leaflet (TAL) 7/99[28] “The SCOOT Urban Traffic Control System”.

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

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



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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TRAFFIC ADVISORY LEAFLET 1/06

Part 3 of 4

General Principles of Traffic Control by Light Signals Part 3 of 4

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

TRAFFIC ENGINEERING AT SIGNAL-CONTROLLED JUNCTIONS

Signal-controlled junctions can reduce accidents by allowing certain traffic movements to proceed whilst holding others that would be in conflict. To allow each movement separately will remove all conflicts but is not normally satisfactory since delays to all traffic will be high and effective capacity of the junction will be low. For example, at a simple crossroads, with a pedestrian stage, there would be five stages and the probable delays unacceptable to all road users.

The art of designing an installation is in reducing the delay and increasing the capacity while still maintaining a high degree of safety.

Reduction in total delay and improvement in capacity can be achieved by:

- normally using the lowest number of conflicting phases and practicable stages in any signal cycle;
- ensuring that each vehicular approach is capable of carrying the maximum predicted flow for that approach;
- allocating time to each phase/stage appropriate to the actual traffic flow and
- if appropriate, co-ordinating control of adjacent junctions to maintain traffic platoons.

The aim is always to keep as much traffic moving as practicable at the same time. Techniques may be employed, singly or in combination. For example:

- a right-turn on full green, with an opposing straight ahead movement, can be acceptable as long as it can be executed safely with the exercise of due care;
- Traffic Regulation Orders (TRO's), e.g. banning turns, can be employed to regulate other conflicting movements and
- the provision of "walk with traffic" pedestrian facilities can be used rather than an exclusive pedestrian stage.

The following are examples chosen to illustrate the above principles at a four-arm junction.

Two Vehicular Stages

i With all movements permitted

This is a very common junction and two stage operation forms the basis of signalling techniques. Red, Amber, Green (RAG) signal heads are used. Vehicles on opposite approaches have a green signal whilst those on the other two approaches have a red. When an all-round pedestrian stage is introduced, all vehicular movements are stopped, see TAL 5/05[4].

Each approach may have one or more lanes, a shared stop line and simultaneous discharge. Right-turning traffic may impede vehicles wishing to proceed over the junction if an offside lane is shared, or even worse there is only a single lane.

ii With right-turn traffic prohibited

Where there is a relatively minor right-turn flow the capacity of the junction is reduced by the road space occupied by the vehicle waiting to turn right and by the time which has to be provided to this movement in the cycle. If the right-turn manoeuvre is removed then reduced delay and improved capacity can be expected. Where one exists, an alternative route can be indicated to traffic before the junction is reached.

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The main alternatives are to:

- turn left before the junction, make two right-turns to appear at the junction on the left-hand arm (known as a 'g' turn).
- pass through the junction, turn left and make two further left-turns to appear at the junction on the left arm (known as a 'q' turn).

In the latter case the diverted traffic will pass through the junction twice and may adversely affect the expected improvements. If the diversion routes are residential the additional through traffic may be unacceptable.

The staging can be applied to a single lane approach and the signal display is a three-light with a full green signal and a sign to diagram 612 in TSRGD[6] mounted on the signal head.

iii With both left-turn and right-turn prohibited

This results in exclusive movements; Red, Amber, Green Arrow (RAGA) signal heads are used. See SIGNING section in Part 1 for the use of regulatory signs to diagram 606 (TSRGD)[6]. If both opposing arms operate this way, the opportunity can be taken to run parallel pedestrian phases (walk with traffic), see TAL 5/05[4].

Dealing with right-turning movements

Without special provision, some right-turning vehicles will turn in gaps in the opposing flow but if this is not possible they will complete their movement in the intergreen period.

A typical junction will have space for two or three vehicles beyond the stop line. With, say, a 70 second cycle time this means that between 100 and 150 vehicles an hour will turn right in the intergreen . With a longer cycle time this "free" right-turn capacity decreases.

If the number of right-turners exceeds the number that can clear the junction in gaps, or during the intergreen, special provision will be probably be required. Note that if right-turners are left in front of the stop line after a change to another stage, not only will the driver feel in a vulnerable position but the presence of the vehicle may obstruct pedestrians wishing to cross.

There are three basic choices. If only one approach has a right-turn flow justifying special provision, typically an early cut-off can be used. However, if the right-turning movements from opposing directions both justify a right-turning stage then a staging with concurrent exclusive right-turning movements may be appropriate. The third option is to run the opposite arms separately but this normally has serious capacity problems.

Three Vehicular Stages

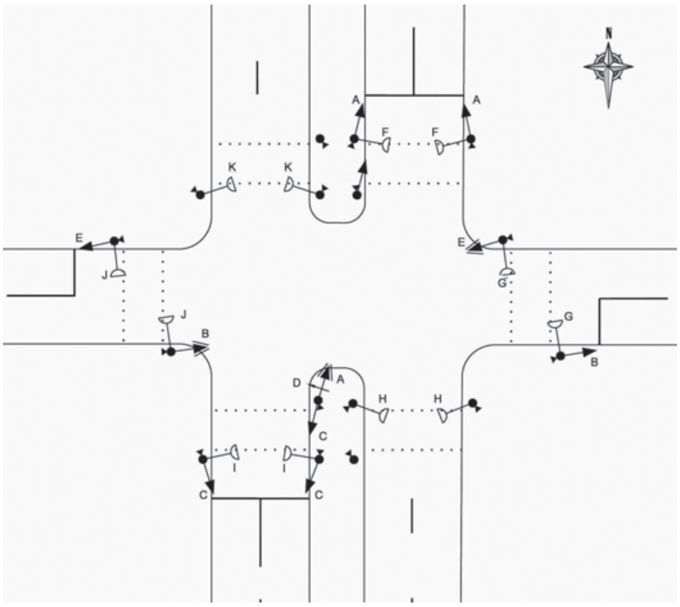
Early Cut-off

The definition is "a condition in which one or more traffic streams, that were running during the preceding stage, are stopped whilst one or more other traffic streams are allowed to continue moving". The arrangement is shown in Diagram 4, Part 4.

It allows opposing arms to run together on the first stage but only one to proceed on the next. This will permit right-turning vehicles to discharge without conflict and to allow any other vehicles, which have been delayed by the right-turn traffic, to clear.

With early cut-off signalling, one straight ahead movement has more green time (because it runs in two stages) than the opposing straight ahead movement. If this is roughly equivalent to the balance of straight ahead flows then this arrangement is likely to be efficient. The facility should not be applied if the arm has only a single lane approach and a separate stage should be considered.

The signal display, on the arm that loses right of way at the end of the first stage, should be sited with care. If a secondary signal is to be used it must be "closely associated", that is on the same side of the junction as the primary signal. Farside secondary signals in this situation are potentially dangerous and should not be used.



The only exception is at a junction where there is no right-turn from the approach losing right-of-way, the westbound approach in the diagram. The southbound approach will have a three-light primary and a secondary, which is always

placed beyond the junction, with an additional right-turn arrow illuminated during Stage 2, see Diagram 4, Part 4. If the right-turn, from phase C, is still thought to be a problem the designer may consider a TRO to ban the movement.

It is not normally recommended that the second stage (green arrow) be allowed to mature in the absence of a demand for the third stage for side road traffic. This is because of confusion and danger to drivers on the main road due to the rapid reversion to stage 1, which would otherwise occur.

If traffic demand is sufficient, it is possible to show an additional left-turn green arrow to the side road traffic on stage 2. The requirements under “Additional Green Arrows” must be adhered to and care must be taken to avoid danger to pedestrians from the left-turn traffic. Such traffic must be provided with its own independent lane. The display will have a standard signal head with the additional green arrow on the primary. During the second stage a red signal will be displayed together with the green arrow. The green arrow will be extinguished when the full green signal appears at the start of the third stage.

Late start

The definition is: “a condition in which one or more traffic streams are permitted to move before the release of other traffic streams which are permitted to run with them during the subsequent stage”.

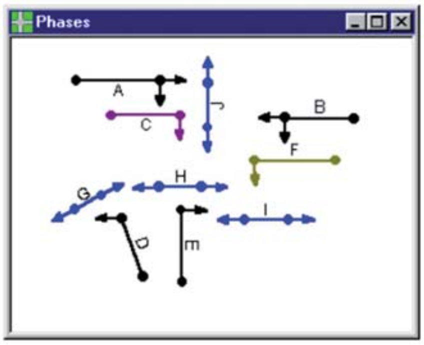
This method of operation is not recommended. It displays an indicative arrow to one approach whilst delaying the start of the opposing traffic. The two problems are: once a dominant flow has been established, those drivers having been initially shown a green arrow assume an unopposed exclusive movement and for the right-turning driver on the opposing flow, it is difficult to make the movement and unnecessary risks are taken.

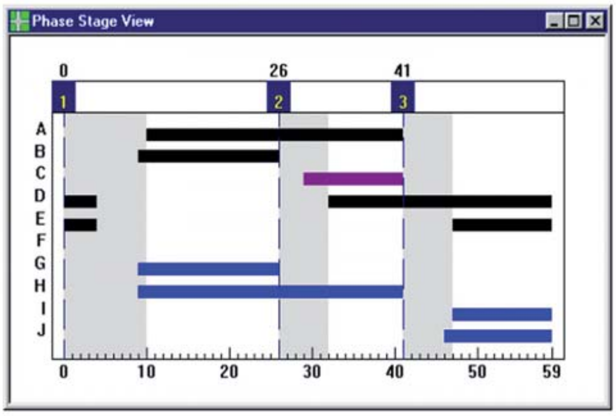
Concurrent Exclusive stages

Where both right-turn movements are heavy a better solution can be to hold them against a red signal whilst the ahead and left-turn vehicles flow unhindered. They are then stopped before the right-turn vehicles are released simultaneously on the same stage. This requires separate right-turning lanes and signal displays. These are often separated from the other lanes by traffic islands, this method should be employed on high-speed roads, see TAL 2/03[5].

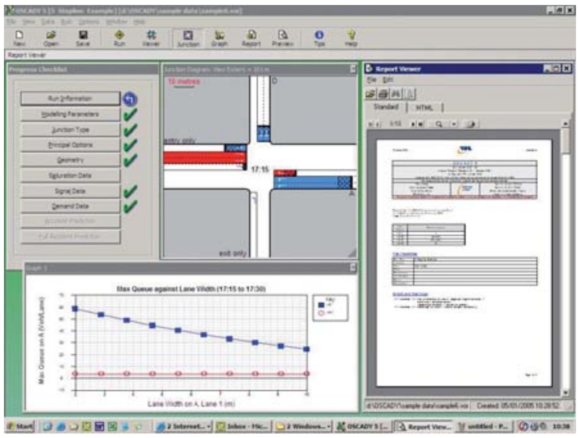
Design for traffic signal control

The analysis of a traffic signal junction to provide details of optimum timings and predicted performance in terms of capacities, delays and queues is best performed by the use of specialist software packages such as LINSIG[33], or OSCADY[34] (Optimised Signal Capacity and Delay), perhaps the two best known in GB. These packages require the user to input not only the geometrical details of the junction and traffic flow information but also the proposed control method in terms of phasing and staging.





LINSIG[33] provides an output compatible with the TR2500[22] form used to specify the phasing, staging, timings etc for the controller (see Part 4). The latest version models parallel stage streaming and progression through multiple stop lines. OSCADY[34] was developed by TRL as one of a suite of three programs. The other two are ARCADY[35] (Assessment of Roundabout Capacity and Delay) & PICADY[36] (Priority Intersection Capacity and Delay). OSCADY[34] is often used to assess schemes at the initial planning stage as various methods of control, ie signals against roundabout can be assessed together.



Both LINSIG[33] and OSCADY[34] are Windows-based programs and provide the user with user-friendly screen information.

It is possible to submit a wide range of staging arrangements for individual analysis by the software. However, there are advantages in carrying out a manual preliminary assessment to identify the preferred staging or a limited number of staging arrangements for detailed analysis. The manual method will give a general indication of whether the

junction would operate comfortably or close to its capacity limit. This is very valuable in interpreting the output from the software packages and identifying any unrealistic results which would indicate errors in the input data.

Drawing Symbols

An example of drawing symbols can be found in Part 4. Many practitioners have developed others. If you are not sure check with the design authority concerned.

Manual Preliminary Assessment

Before investigating any special staging requirements it is worth checking that the main vehicular flows do not exceed the overall junction capacity potential.

A preliminary assessment can be carried out using the basic concepts of the analysis developed by Webster and Cobbe[37]. This is based on the assessment of y values.

y value is defined as the ratio of the demand to the saturation flow - the proportion of time a signal has to be green to allow the demand flow to pass. The

critical y value is the highest value for each stage in the cycle.

A flow of 1000 pcu/h crossing a stop line with capacity 2000 pcu/h needs a signal which is green for at least 50% of the time, a y value of 0.5. (To convert a mix of vehicles into pcu's, or passenger car units, the following figures are used: Car or light goods – 1, medium light goods – 1.5, HGV – 2.3, Buses and coaches – 2, Motor cycle – 0.4, Pedal cycle – 0.2.)

Note that y values need to be assessed using a realistic assessment of the saturation flow. Site conditions will often mean lower saturation flows than expected from an inspection of a two dimensional plan. Some can possibly be changed by TRO, for example parked vehicles but some such as a steep incline will have a permanent effect. Some layouts will also affect the consistency of the saturation flow. A flared approach, or an exit merge will not give a constant saturation flow. If there is a very lightly trafficked stage it will have to run for at least the minimum green of, say, 7 seconds. With a cycle time of 70 seconds this will mean assigning it a y value of at least 0.1.

Y is the summation of the y values for all the stages in the cycle. If Y is >1 then the junction has insufficient capacity whatever timings are applied. In Webster and Cobbe[37] "a practical capacity maximum of 90% of this maximum possible flow" is recommended.

Y_{pract}- the maximum practical value of Y.

Y and Y_{prac}. can be calculated using Webster and Cobbe[37]:

$Y = 1 - \frac{L}{c}$ and $Y_{prac} = 0.9\ (1 - \frac{L}{c})$

Where:

c is the cycle time and

L is the lost time, the total cycle time which is not effective green, often taken as the total interstage period* minus 1 sec. for each individual interstage period*. Note that lost time does vary from site to site and the figure given is only an approximation.

(in Webster and Cobbe the example given uses a maximum cycle time Cm of 120 seconds:

$Y = 1 - \frac{L}{Cm}$, therefore Y = 1 – 0.0083L and Y_{prac} = 0.9 – 0.0075L)

Broad approximations are sometimes necessary but sufficient for preliminary assessment where the detailed analysis is to be later undertaken using LINSIG[33] or OSCADY[34].

In practice, Y values as high as 0.9 could indicate a short life for an installation before remedial action is necessary to return the junction to an efficient level of working. 0.8 is often taken as a more practicable value to start indicating potential capacity problems.

As can be seen from $\mathbf{Y = 1 - \frac{L}{c}}$, Y falls off markedly with increasing values of L and decreasing values of c. To take an extreme example, operating a junction with (say) an L of 30 seconds and choosing a cycle time of 50 seconds would result in an available Yprac of as little as 0.4.

It is therefore useful to calculate a reasonable cycle time:

C_{min}, the minimum cycle time – the cycle time which is theoretically just long enough to pass the traffic through the intersection is given by:

$$C_{min} = \frac{L}{1 - Y}$$

This minimum cycle time will produce excessively long delays. In practice it will be appropriate if the minimum cycle time chosen is such that the installation is loaded to 90% of its capacity, i.e.

C_{prac}., the practical minimum cycle time is:

$$C_{prac} = \frac{0.9L}{0.9 - Y}$$

To obtain a measure of "fit for purpose" and life expectancy.

Webster and Cobbe[37] give:

Percentage Reserve Capacity as: $\frac{100(Yprac - Y)}{Y}$

*Note: for more complex junctions, stages may not be defined at this early stage and groups of conflicting phases are used instead. With simple junctions it will often be easy to identify a single set of conflicting phases. However, more complex junctions will have more than one set of conflicts and basing assessments on stages could be misleading. For the preliminary assessment therefore it would be necessary to identify each group of conflicting phases, testing them for practicality by substituting their 'Y values' and related lost time (L), using relevant intergreens, into the relevant equations.

Right-turning Movements

These are often the critical factor in determining a staging arrangement for a junction. For the purpose of a preliminary assessment, the choice is between an overlap arrangement, like an early cut-off, a concurrent exclusive method and separate stages for each of the opposing arms.

Pedestrian and bicycle facilities, see also TAL 5/05[4]:

The staging arrangement for a junction will have implications for how pedestrian and cycle facilities are provided. An exclusive pedestrian stage will typically require 20 seconds of the cycle time and will increase the lost time L disproportionately. L for a simple junction could increase from, say, 12 ((2 x 7) – 2) to 32 seconds and the cycle time would increase proportionately. This preliminary analysis will indicate whether an exclusive pedestrian stage is feasible, or desirable, for either vehicular, or pedestrian traffic. Longer cycle times will increase waiting times for pedestrians as well as vehicular traffic. In this case the staging and layout of the junction will require walk with traffic pedestrian facilities where required. Separate bicycle facilities would be considered in the same way.

Summary

The preliminary analysis is not intended to produce a definitive staging arrangement for a junction but it is helpful in ruling out ideas which are not practicable. It can indicate situations where traffic signals are not appropriate, or suggest that carriageway widening may be necessary to obtain the required capacity. Any 'marginal' arrangements should be tested by detailed analysis.

Worked example for a crossroads with two lanes on each of the southbound and northbound approaches but single lanes on the others. (Note: This is not the example given under 'Three vehicular stages'.)

Approach	pcu/movement		
	Left	Straight ahead	Right
Southbound	25	700	25
Westbound	140	100	28
Northbound	50	800	400
Eastbound	30	100	12

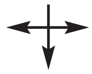
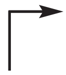
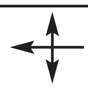
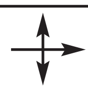
It is estimated that there is storage space for two right turning vehicles from the main road in each direction and one right-turning vehicle from the side road. Apart from the northbound right-turn, it is estimated that there is sufficient "free" right-turning capacity to clear the right-turning vehicles in the intergreen.

The separate traffic streams have been identified and saturation flows estimated using the method set out in TRL Report RR 67[38] "The prediction of saturation flows for road junctions controlled by traffic signals" but see earlier warning on realistic saturation flows. In this case saturation flows have been assumed as 1900 pcu/lane for straight ahead flows and 1650 for turning flows. Lanes with mixed movements have been interpolated between these.

Using the measured flows and the estimated saturation flows from RR 67[38], the y values for each traffic stream were calculated. (Saturation flows can be measured on site by counting vehicles in free flow conditions during a saturated period, say, after a few seconds into the green until there is a reduction in flow. Special packages are available to assist.)

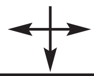
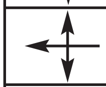
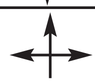
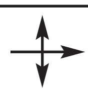
Two different staging arrangements were tested and a Y value obtained for each. L values were considered with and without exclusive pedestrian arrangements. For an initial analysis the interstage periods have been set at 6 seconds each. The practicable arrangements would then be subject to detailed analysis.

First assessment (Using an early cut-off arrangement).

Stream	Flow (pcu)	Sat. flow (pcu)	stage	y value	Critical y?
	750	3750	1	0.20 (750/3750)	-
	850	1900	1 and 2	0.45	0.45
	400	1650	2	0.24	-
	268	1800	3	0.15	0.15
	142	1800	3	0.08	-
				Y	**0.60**

Y is estimated at 0.60. (Note, at this level of approximation there is little point in calculating y values to more than two significant figures) and L would be 15 seconds. The resultant Cprac. indicates that this arrangement is likely to be practicable. However, when an exclusive pedestrian stage is added, L will rise from 15 to somewhere nearer 35 seconds giving a Cprac. of over 100 seconds.

Second assessment (Using separate staging for each direction on the main road)

Stream	Flow (pcu)	Sat. flow (pcu)	stage	y value	Critical y?
	750	3600	2	0.21	0.21
	268	1800	3	0.15	0.15
	1250	3550	1	0.35	0.35
	142	1800	3	0.08	-
				Y	**0.71**

Y is estimated as 0.71 but L would still be 15 seconds as staggered pedestrian facilities could be provided across the main road within the Cprac. cycle time.

This staging does not allow for protected pedestrian facilities across the side roads. The staggered movements across the main road would be less convenient for pedestrians but the cycle time would be shorter and the waiting time for a pedestrian may well be reduced.

There would be more spare capacity than the early cut-off plus exclusive pedestrian stage arrangement but costs and visual impact would be higher because of the additional equipment needed and the necessarily larger refuges.

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76 Marsham Street, London, SW1P 4DR.
Telephone 020 7944 2478
e-mail: tal@dft.gsi.gov.uk

Scottish Executive

Within Scotland enquiries should be made to:
Scottish Executive, Development
Department, Transport Division 3, Zone 2-F,
Victoria Quay, Edinburgh, EH6 6QQ,
Telephone 0131 244 0847
e-mail: roadsafety2@scotland.gsi.gov.uk

Llywodrath Cynulliad Cymru
Welsh Assembly Government

Within Wales, enquiries should be made to:
Welsh Assembly Government,
Transport Directorate, 2nd Floor, Cathays Park,
Cardiff, CF10 3NQ
Telephone 02920 826444
e-mail: keith.alexander@wales.gsi.gov.uk

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TRAFFIC ADVISORY LEAFLET 1/06

Part 4 of 4

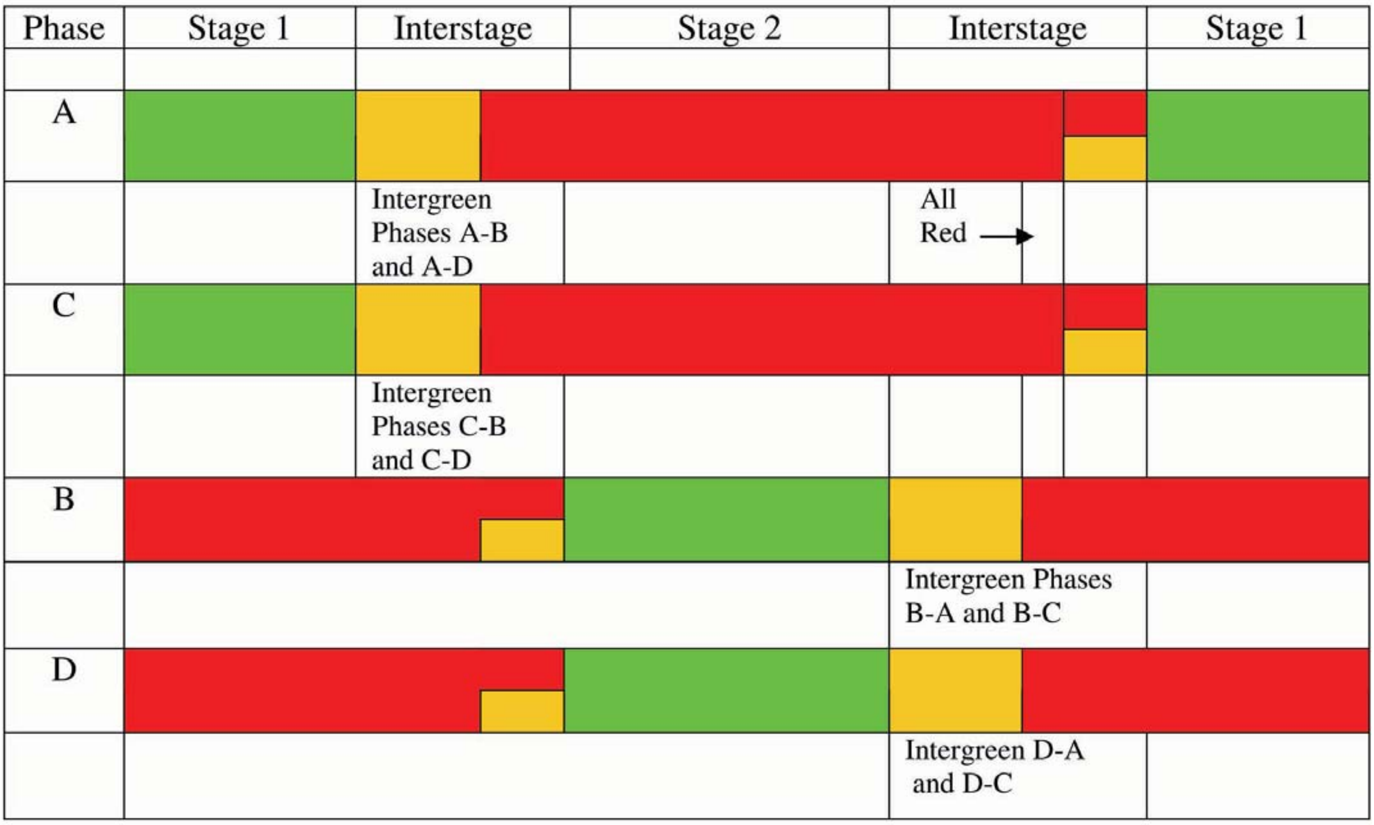
General Principles of Traffic Control by Light Signals Part 4 of 4

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

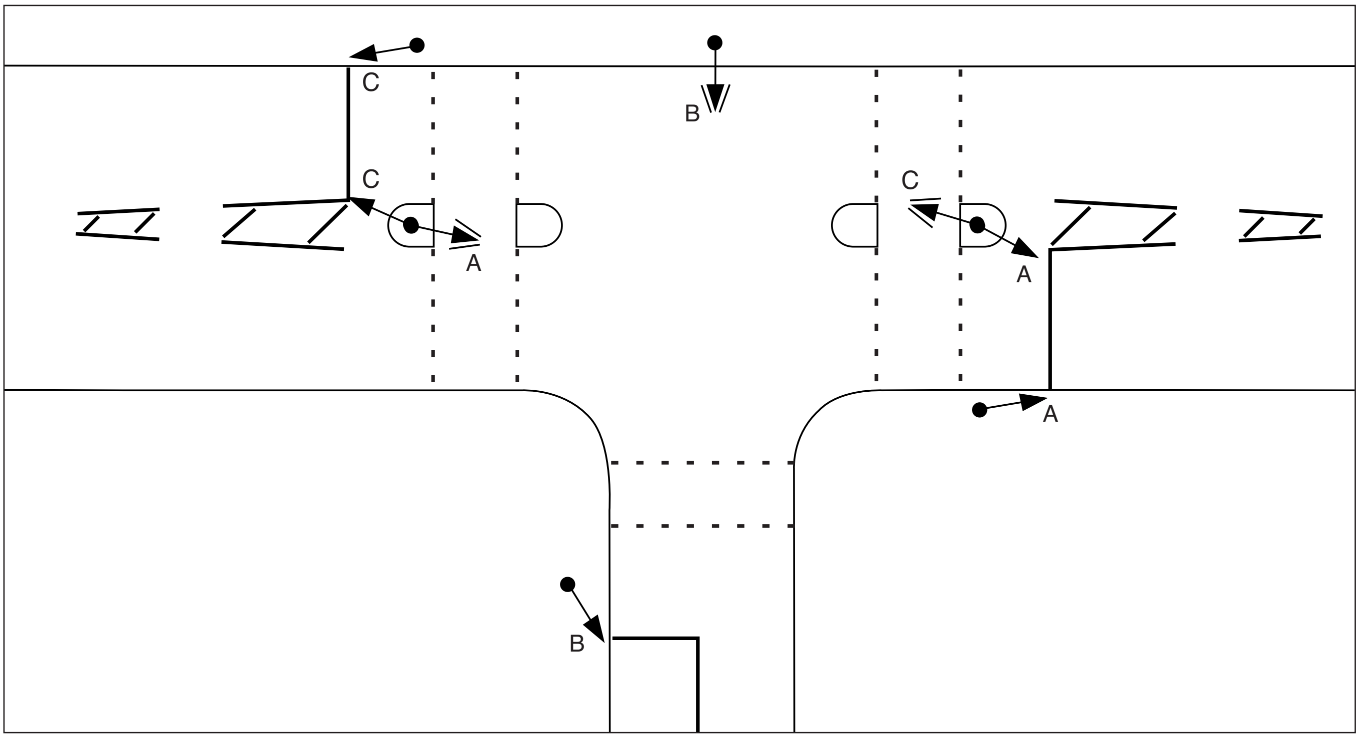
PHASES AND STAGES

Example of simplified 4 approach crossroads, with 4 phases and 2 stages. Phase A southbound, Phase B westbound, Phase C northbound and Phase D eastbound. Note: it is conventional to notate phases clockwise round the junction. Interstage 1-2 has a 5 second interstage, made up of a 3 second amber and a 2 second red/amber. The timings for amber and red/ambers are obligatory, with a tolerance of plus or minus 250 milliseconds. The interstage 2-1 is shown with a 1 second all red, making it 6 seconds. The intergreens A-B, A-D, C-B and C-D are the same as the interstages 1-2 and the intergreens B-A, B-C, D-A, D-C are the same as the interstages 2-1.

Diagram 1



March 2006
Traffic Advisory Unit



Losing and gaining right of way

The two following examples illustrate Phase Change Delays. This might be a “T” junction, with Phase A being the Westbound main road, Phase B the Northbound side road and Phase C the Eastbound main road. Here only one intergreen in each change is the same as the interstage.

Diagram 2

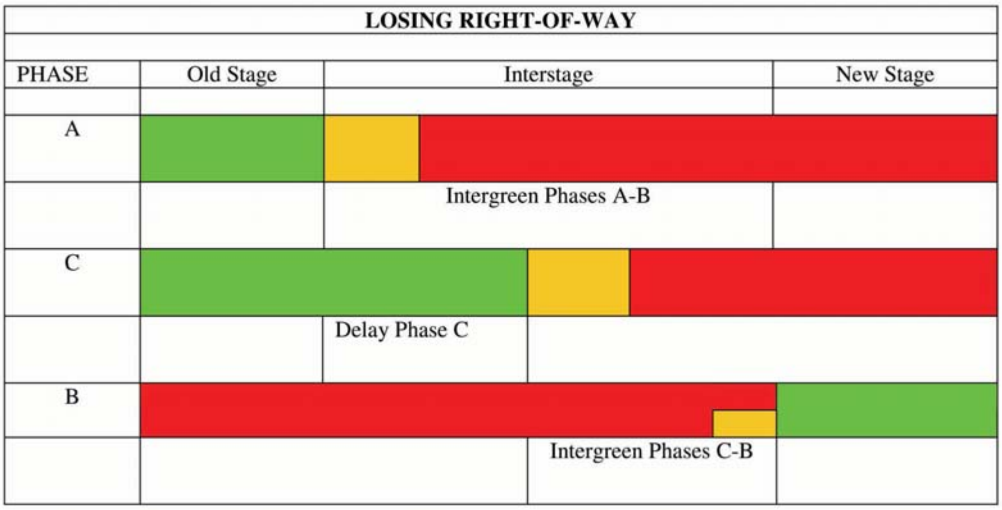
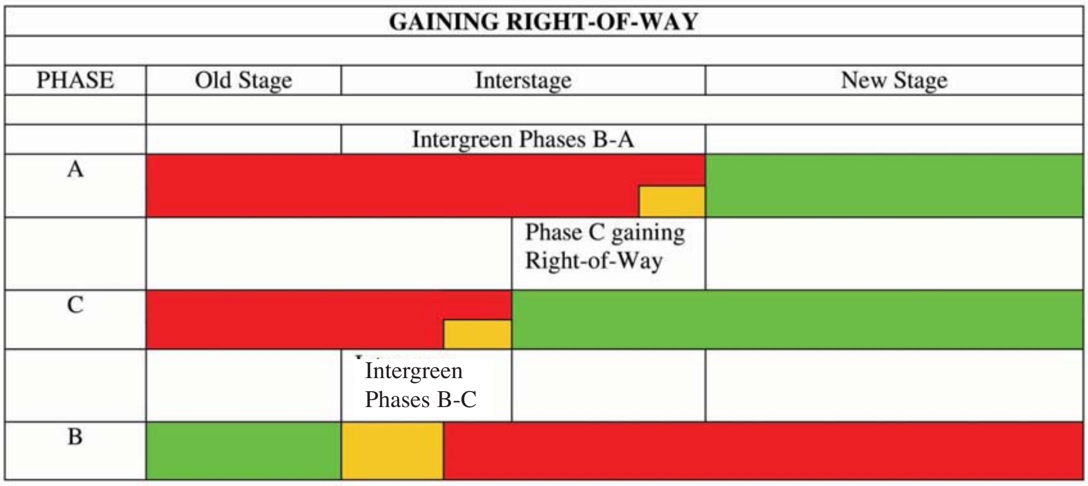


Diagram 3



Early cut-off

Below represents a simple crossroads, Phase A - southbound, Phase B - westbound, Phase C - northbound, Phase D - right turn overlap using an early cut-off of Phase C (see Part 3 of this Traffic Advisory Leaflet), Phase E - eastbound. Here the intergreen between phases A and D does not have a red/amber component. It is common to have a 3 second intergreen but the start of Phase D can be held off by additional red time to give a longer intergreen.

Diagram 4

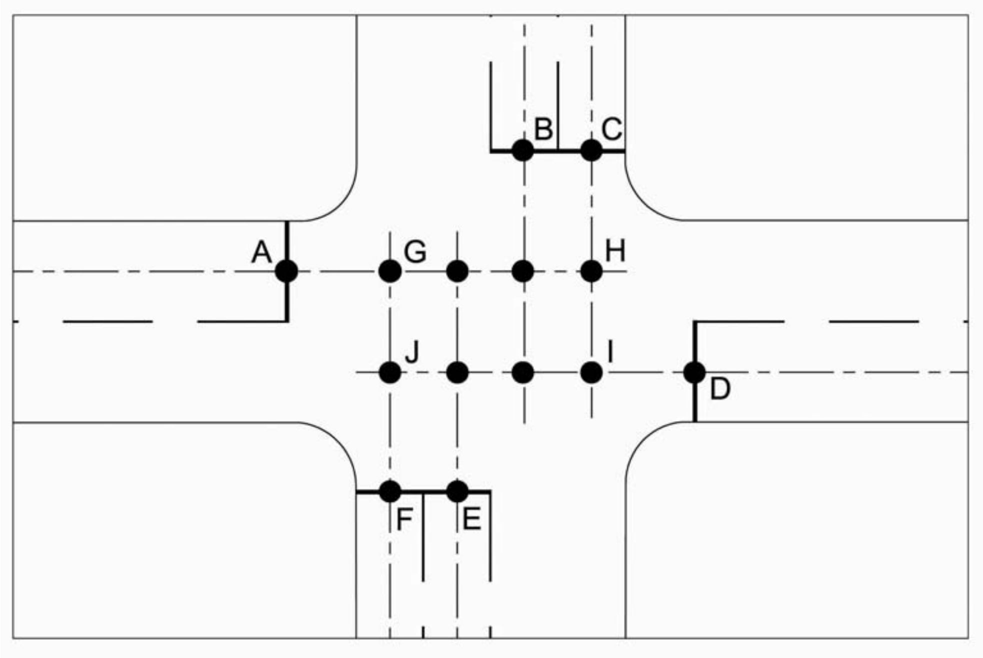
Dummy phases

The preceding diagrams illustrate "real phases". There are also "dummy" phases. The definition is: "A software device, within a controller, which may be used to control traffic movements which are not separately signalled. It does not have any associated traffic signals."

Typical uses are where:

- there are phases which continue across from one stage to another.
  i) There may be a requirement to make the second stage a priority. A dummy phase can be assigned to this stage as the priority phase. A demand for the dummy phase is inserted when priority is required.
  ii) There may not be a set minimum green for the second stage, or it may be zero. Under UTC control a zero length stage will not be detected and an error will be reported. This can be prevented by allocating a dummy phase to the second stage with an assigned minimum green, say, of 2 seconds.
- on UTC, a "G" bit is required to continue through the interstage period. By linking the "G" bit, the dummy phase and associated stages, the "G" bit can be allocated to a nu mber of sequential stages.
- a pedestrian phase runs parallel to a vehicular phase within the same stage but only when called by a push button. A dummy phase can be used as the alternative when a call is not present. If the stage initially starts without the pedestrian signal but a demand is received during the stage the dummy phase is terminated and replaced by the pedestrian phase. This saves the pedestrian waiting another cycle before receiving a green man signal. (See TAL 5/05[4])
- shuttle working is being used.
  i) Detectors can be used to optimise the all-red. Using a dummy phase for the extendable period allows for a settable interstage at the end of the all-red.
  ii) If 'revert to red' is used, the same dummy phase can be used for intergreens between each of the opposing flows. The controller is instructed to revert to the dummy stage in the absence of demands. If demands for green are received for both opposing stages during the all red the controller will choose the next stage green to the one it closed previously and not the same one.
- it is necessary to vary an intergreen because of the presence of slower, or specific vehicles. A dummy phase can be introduced by detectors, time-of-day, or day-of-week. This could, for example, be because of a steep incline on one approach. An all-red stage could be used with its own dummy phase. The dummy phase can be allocated a different extension time to give longer extension periods.
- a more responsive move is needed at a VA junction on receipt of a demand from an opposing stage. Normally, the change to an opposing stage is made following the last extension from the running stage, or at its maximum green. The maximum green starts at the receipt of the demand for the opposing stage. So the running stage could have run for a matter of minutes before the

Diagram 5
Potential collision points



maximum timer starts and the arriving vehicles still have to wait a considerable time, even though the running stage will be likely to be running fairly light. A dummy phase can be used so that its maximum green can start with the minimum green. This then works like the pre-timed maximum, say, at a Puffin.

Determination of intergreen times

Probable Collision Points

The intergreen period can be approximated by considering the relative transit times to the probable collision points. It is assumed that vehicles enter the junction at a constant speed and that the probable collision points are at the intersection of the centre lines of the swept paths, (see TD 50[3]). In practice, of course, there will be collision areas rather than collision points, since vehicles have width and length. Drivers will also take action by swerving, or braking/accelerating to avoid a collision. To take account of all these and other factors would be impracticable. The calculation on the assumptions quoted has been found to give a good basis for the initial settings but it must be stressed that on-site observation is essential and adjustments should be made if necessary.

The probable vehicular collision points for a typical junction are shown in diagram 5. Following the east-west stage those of concern are J and H. G and I are the collision points of concern following the north-south stage.

To calculate the clearance periods, measure the extra distance travelled to the probable collision points by vehicles losing right-of-way compared with those gaining right-of-way and call the longest distance x. For example if AH – CH = 6m and DJ – FJ = 8m then x = 8m.) If x is up to 9m then the minimum intergreen period following the east-west phase should be satisfactory but for distances over 9m the times given in the Table should be used. Repeat for every possible phase* change.

The distance x may be negative and intergreen times lower than that shown in the Table can be used with caution. The following advice applies in either case.

If vehicle speeds on the phase losing right-of-way are substantially less than on the phase gaining right-of-way, possibly because of a steep incline on the approach or a predominance of slow-moving vehicles, the intergreen should be increased. An example may be in determining an intergreen involving opposed right turning vehicles, which are normally slower and may be late starting. This is particularly important when the move is followed by a pedestrian phase. In such cases, after measuring the difference in swept path length and applying the guide below, it is normal to add 1, or possibly 2 seconds.

* See definitions for intergreen and interstage in Part 2 and explanation in the phasing diagram in this part.

Distance "x" (metres)	9	10-18	19-27	28-37	38-46	47-55	56-64	65-73
Intergreen (seconds)	5	6	7	8	9	10	11	12

Table for Calculating Intergreen Times

Note: Where the following stage is a pedestrian stage, the distance 'x' should be determined from the position of the pedestrian crossing. Where pedestrians are losing right of way, the figures in Traffic Advisory Leaflet 5/05[4], "Pedestrian Facilities at Signal-controlled Junctions", should be used to calculate the clearance.

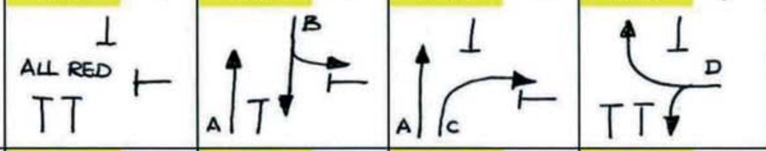
Example of a TR2500 Form

Traffic Signal Data Sheet

Controller	
Manufacturer	Fireball
Type	XL5

Ref No	24/10	Site	A613 Main Road / Side Road	Town	Any Town

STREAM 0	N02C1	STAGE 0	STAGE 1	STAGE 2	STAGE 3	STAGE / STAGE
STREAM 1		STAGE	STAGE	STAGE	STAGE	STAGE / STAGE
STREAM 2		STAGE	STAGE	STAGE	STAGE	STAGE / STAGE



PHASE	APPROACH	MIN	EXT	PBT	MAX	MBX	MCX	MDX	MEX	MFX	MGX	MHX	DEMANDED BY DET NAME	EXTENDED BY DET NAME
A	A613 N/Bnd Ahead	7	1.6		60	40	60	40					AX 1 & 2	AXYZ 1 & 2
B	A613 S/Bnd	7	1.6		60	40	60	40					BXZ 1 & 2	BXYZ 1 & 2
C	A613 N/Bnd R/T	7	2.0		10	7	10	7					P1	P1
D	Side Road	7	0.2		16	10	16	7					DX & MVDD9	DX & MVDD9
E														
F														
G														
H														

Phase Intergreen Times

FROM \ TO	A	B	C	D	E	F	G	H	I	J	K	L
A				6								
B			8	8								
C		7		6								
D	7	6	7									
E												
F												
G												
H												
I												
J												
K												
L												

FT Stage Sequence

Stage	Green Time

Optional Standard Features

	Y	N
Dimming	✓	
LMU	✓	
CLF Plans	✓	
RLM		✓
Time Tables	✓	
FT to MAX	✓	
SA / SD	✓	
VA	✓	
TS from Centre	✓	
TS from Rugby		✓
MOVA		✓
Part Time		✓

Additional Phase Delays

NO	Delay Phase	From Stage	To Stage	By (Secs)

Input / Output Port Details

IOP	7	6	5	4	3	2	1	0
6	AYZ1,2	AX1,2	BSA2b	BSA2a	BSA1b	BSA1a	ASA1b	ASA1a
7				MVDD9	DX	P1	BY1,2	BXZ1,2
2			DX1	D3	D2	#F3	#F2	F1
3			TS					
4	RR	CF	DF	DR3	DR2	G3	G2	G1
5			CC			MC	LF	

Hurry Calls

HC	Stage	Demanded By	Call Delay (Seconds)	Hold (Seconds)	Prevent (Seconds)
0					
1					

Manual Control

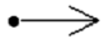
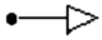
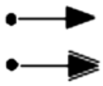
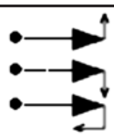
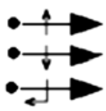
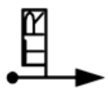
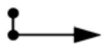
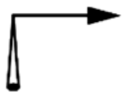
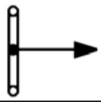
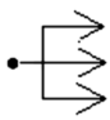
PB	1	2	3	4	5	6	7	0
Stages	1	2	3					0

NOTES

THIS SITE IS PART TIME DIAL UP U.T.C.

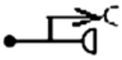
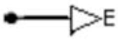
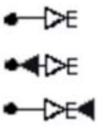
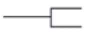
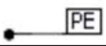
Commissioned	16/12/2004
EPROM Identity	BFR 209-215
Data Prepared	07/03/2005
File reference	
Specification Issue No.	24/10 / Issue 1
Date of Issue	11/11/2004

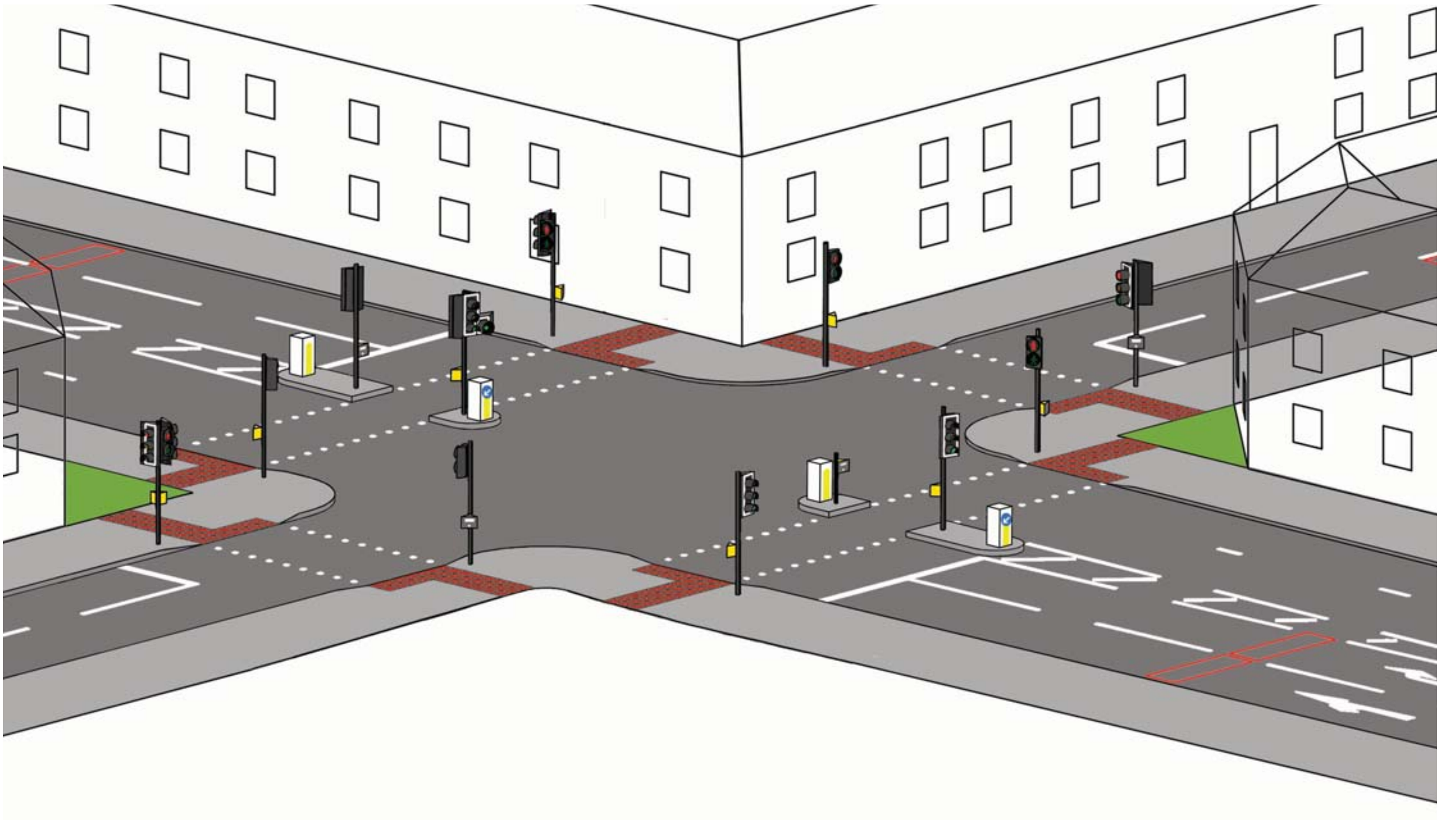
Traffic signal symbols part 1

	SYMBOL	APPEARANCE OR DIAGRAM NO. FROM TSRGD[6] AND DESCRIPTION
SIGNALS FOR VEHICLES		Single aspect signal
		Two aspect signal
		3000 with primary visor 3000 with secondary visor** — Three aspect signal
		3000.8, 3000.10 Three aspect primary signals with substitute green arrow signals
		3000.7, 3000.9 Three aspect primary signals with additional green arrow signals
		Three aspect primary signal with box sign. TL-Turn left, TR-Turn right, AO-Ahead only, NLT-No left turn, NRT-No right turn, NUT-No "U" turn Note: TL and NLT normally fitted on left of signals TR and NRT on right
		Bracket mounted three aspect primary signal
		Three aspect primary signal mounted on mast arm support
		Three aspect primary signal mounted on gantry
		Two three aspect signal heads, one at standard height, one at high level
		3000.2 Three aspect primary signal with cycle symbols for amber and green
		3014 Wig-wag signal
		3013 – 3013.5 Tramcar signal

**Secondary visors have a much reduced field of vision compared to the primary. This is to shield the signal from opposing vehicular traffic, or pedestrians in some cases. However, primary visors can be used in the secondary position, for example at a stand-alone pedestrian crossing, where ahead visibility is paramount. It is important to ensure that this is clear to the supplier/installer. Drawing MCX 0402, Traffic Signal Visors, is available through the Highways Agency, giving details of the two types. All the signals above can have primary or secondary visors, as appropriate.

Traffic signal symbols part 2

	SYMBOL	APPEARANCE OR DIAGRAM NO. FROM TSRGD[6] AND DESCRIPTION
SIGNALS FOR PEDESTRIANS, CYCLISTS AND EQUESTRIANS		4003, 4003.3, 4003.6, and part of 4003.1, 4003.4, 4003.7 Push button (p.b)
		4002.1 Two aspect farside pedestrian signal
		**Two aspect nearside pedestrian signals** 4003.1 without p.b. with restricted field of view 4003.1 with combined p.b. 4003.1 with separate p.b.
		4003.5 Farside Toucan signal (cycle symbol can be to right or left)
		**Nearside Toucan signal (cycle symbol can be to right or left, see TSRGD[6])** 4003.7 without p.b. 4003.7 with combined p.b. 4003.7 with separate p.b.
		4003.2 Two aspect farside Equestrian signal
		**Two aspect nearside Equestrian signals** 4003.4 without p.b. 4003.4 with combined p.b. 4003.4 with separate p.b.
DETECTORS		Inductive loop vehicle detector
		Inductive loop MOVA vehicle detector
		Above ground vehicle detector
		Above ground stop line vehicle detector
		On-crossing detector
		Kerbside detector
		Tactile area used as surface kerbside detector
		Photo-electric cell
		Tactile paving
		Guardrailing
		Controller or other equipment housing



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Telephone 020 7944 2478
e-mail: tal@dft.gsi.gov.uk

Scottish Executive

Within Scotland enquiries should be made to:
Scottish Executive, Development
Department, Transport Division 3, Zone 2-F,
Victoria Quay, Edinburgh, EH6 6QQ,
Telephone 0131 244 0847
e-mail: roadsafety2@scotland.gsi.gov.uk

Llywodrath Cynulliad Cymru
Welsh Assembly Government

Within Wales, enquiries should be made to:
Welsh Assembly Government,
Transport Directorate, 2nd Floor, Cathays Park,
Cardiff, CF10 3NQ
Telephone 02920 826444
e-mail: keith.alexander@wales.gsi.gov.uk

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