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# Operation of Traffic Signals during Low Demand Periods

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# Executive Summary

**Objectives**

It is not uncommon for criticisms to be made of highway authorities that the operation of traffic signals during periods of Low Demand (LD), for example overnight, causes unnecessary delays. In addition to building driver frustration, this leads to increased fuel consumption and the level of particulate emissions, resulting in an increased carbon footprint.

Comparison is frequently made with practices overseas, where various techniques are applied to 'demote' signalised junctions to priority mode of operation, for example the flashing amber on main road/flashing red on minor road employed in some States of the USA. This study has been commissioned by the Department for Transport to investigate, assess and recommend potential alternative techniques that could be applied at signal-controlled junctions in the UK during periods of LD.

The objectives of this desktop study are to investigate options for signal controlled installations that will help

- reduce unnecessary delays to traffic, hence minimising overall vehicle delays and emissions;
- reduce the energy consumption of signal installations; and
- maintain or enhance levels of safety, especially for vulnerable road users.

**The Study**

The methodology was divided into 5 key stages:

**1 Review of Current Practice**

Twelve local authorities in the UK participated in a review of current practice, and were asked to provide a response to potential LD options. This exercise highlighted a number of issues which would require mitigation before alternative methods of operation could be considered.

The key concern was the safety of pedestrians and other vulnerable road users, in that traffic signal control provides pedestrians with an opportunity to cross safely, with priority over vehicles for a period of time Methods to revert junctions to priority mode of operation, albeit with signals to warn highway users, would reduce or remove an element of that pedestrian priority.

In addition, driver comprehension and education was noted as a potential area of concern. Alternative LD operation has historically been used in other countries where drivers are aware of the appropriate rules and regulations. Introducing a new form of control to motorists in the UK would require funded campaigns to raise driver awareness of any changes and ensure sufficient understanding.

The Department for Transport has stated its position on traffic signal control, the stance being that that technologies should be used to minimise unnecessary delays to traffic, using more responsive vehicle actuated systems.

The practices of a number of overseas countries were reviewed in respect of the operation of traffic signals in LD periods. It is apparent that all countries under review utilise intelligent methods of operation, using Urban Traffic Control (UTC) or Vehicle Actuation (VA) to optimise signal timings for prevailing traffic conditions.

The alternative methods of control in Europe generally consist of flashing amber operation and in Germany only, turning the signals off. In the United States, flashing amber/red operation is used where appropriate to reduce delays in LD periods.

However, with advancing traffic signal technology in Vehicle Actuated control, e.g. Microprocessor Optimised Vehicle Actuation (MOVA)) and more responsive UTC, the need for flashing signals is diminishing; vehicle actuated traffic signals are able to adjust their operation during LD periods and modify the signal timings as required to minimise delay.

Nevertheless, priority mode of operation in LD periods (utilising flashing signals) is still deployed in some countries, though the preference for new installations seems to be the use of vehicle actuated systems now that the technologies can be readily implemented. Questions have been raised over the safety of flashing amber control, it appears that the continued use of these alternative forms of control is still considered acceptable because they have historical precedents, thus drivers are aware of their meaning. The installation of such operation within the UK, where the consistent application of traffic signals 24 hours per day is more common, might lead to confusion.

## 2 Development of Assessment Techniques

The desktop study focussed on two separate assessment processes. Firstly, a set of LD *CRITERIA* was developed that could be used to identify sites that could be suitable for an alternative control strategy during LD periods. The criteria include the type of installation, current control strategy and flow profile.

Once potentially suitable installation types were identified, site specific conditions were examined to establish which LD options might be appropriate for a given installation type. A number of assessment *PARAMETERS* was developed, covering junction geometry, visibility, demands and safety issues, to provide consistency to this process.

This assessment process has been designed to ensure that all relevant information is reviewed before any traffic signal installation is deemed suitable for alternative LD operation. Traffic signal installations are provided for a variety of reasons, and the knowledge of the history of a specific installation is important in assessing the suitability of potential LD strategies.

## 3 Option assessment

A total of 25 options was developed. These were subjected to a NATA (a multi-criteria approach to the assessment of UK highway schemes) style of assessment against the previously identified criteria and parameters to identify their suitability for further consideration for LD operation. The assessment included factors relating to economy, environment, safety, legislation and design.

The viable options were then classified according to their potential for implementation – short, medium or long term – depending upon factors such as required changes to legislation, technology or driver comprehension.

## 4 Further option development

The medium and long term options were examined further to identify suitable alternatives that would warrant further investigation. The following options were identified:

- *Flashing amber to minor arms, switch off signals on major arms* – This concept reverts a junction to priority mode of operation during LD periods. Priority operation could only be achieved if the appropriate signs and markings were displayed as would be expected at a normal priority junction; initial investigations looked at the viability of using Variable Message signs to display a ‘Give Way’ sign on the approach from the minor road. However, this has been reconsidered following stakeholder consultation in Stage 5, due to the issue of maintenance costs and visual aspect of the additional street furniture.

- *Utilise SCOOT detection loops for MOVA (IN detectors)* – This concept highlighted that the costs associated with providing multiple forms of detection at a junction could be reduced by sharing detection, for example MOVA LD operation within a SCOOT network.

The implications of these options would require further investigation, potentially using on-street trials. It should be noted that flashing amber signals in the UK currently have a specific meaning at Pelican crossings; an important change in the significance of the flashing amber signal would require the existing use to be phased out (through the use of Puffin crossings) and an extensive road user re-education programme to publicise the new application.

## 5 Stakeholder Consultation

The study identified a number of options that could be deployed to reduce unnecessary delays to traffic during LD periods. The opinion of those with a vested interest in the operation of signal controlled installations and highway safety is important given they are responsible for the installation and maintenance of such facilities; they could highlight concerns and possible additional signal control developments.

Key stakeholders for the introduction of alternative traffic control strategies include scheme designers, policy decision makers and road users. A consultation document was produced to summarise the research undertaken and options developed; stakeholders were then invited to comment and rate potential options for managing traffic in LD periods.

Developments to UTC/SCOOT systems were well received by those authorities that used them; such changes would provide benefits to road users without affecting safety. Some authorities also registered an interest in the use of low minimum green times during LD periods, whilst recognising the potential impact on safety.

The two long term options of most interest to the stakeholders are the use of SCOOT detection loops for MOVA IN detection, and the use of flashing ambers on the minor road with signals turned off on the major road. Using SCOOT loops for MOVA operation will not be applicable at every installation, like any control method site specific criteria will need to be considered. However the concept of using detection for multiple control types could save local authorities money on installation/maintenance over using different detection, whilst improving the operation of the highway network in LD periods.

The use of flashing amber signals on the minor road and turning off signals on the major road was considered more cost effective, assuming it can be made to work safely, than informing road users of priority using Variable Message ‘Give Way’ signs to mirror priority intersections during LD periods. The concept of signing the minor road to inform priority was considered a suitable way forward, but the critical issue is the additional street furniture required and the additional maintenance costs.

## Conclusions

This study found potential options that achieve the first objective – *“prevent unnecessary delays to traffic, hence minimising vehicle delays and emissions’*. The design of traffic signal controlled junctions generally concentrates on periods of heavy demand, maximising capacities and providing facilities for all users of the junction. There is a tendency to assume that the same control strategy will suffice for all other periods, although this frequently imposes unnecessary delay on users, increasing emissions and journey times as well as driver frustration. By careful study of individual installations or wider networks, it should be possible to minimise these non-peak delays whilst maintaining safe operation.

Of the 25 potential options, 15 were considered viable in the short to medium term (i.e. either minor or no changes needed to legislation, engineering or driver perception). These involve changes to the operation of installations, which would probably not be noticeable to users. A further 4 options were considered long-term possibilities, involving either significant changes to legislation, technological advancements and development or extensive driver re-education, or a combination of all three. The remaining 6 options are not recommended for further consideration, either due to safety concerns or because of limited benefit compared with the cost of provision.

Some options could have a minor effect on electricity consumption of the on-street equipment, thus addressing the second objective – *'reduce the energy consumption of signal installations'*. However, the replacement of incandescent lamps with LEDs would have a far more significant effect on power consumption than any of the LD options, with no negative effects on operational effectiveness or safety.

**Recommendations**

A number of recommendations have been made to improve the operation of traffic signal installations on LD periods. These recommendations include:

1) Development of technologies to increase the use of LED signals/ELV equipment in the UK (for example retrofitting old installations);
2) Improve the efficiency of existing installations through continued maintenance and utilising newer technologies;
3) Drive improvements to alternative forms of detection including wireless technologies;
4) Introduce developments of SCOOT/UTC to improve performance in LD periods;
5) Trial and monitor Low Minimum Green Times during LD periods; and
6) Further investigate switching off signals in LD periods.

The DfT could support the introduction of alternative methods of LD control, however the development and implementation of LD strategies must lie with the local authorities, providing the motivation for manufacturers to develop their traffic signal products to be more reliable and effective. If an authority or group of local authorities wish to explore the use of alternative methods of operation or detection, the DfT could consider providing support and advice where possible if it can be shown that a method of operation can benefit the control of traffic,.

The choice of which LD operation would be most appropriate for a specific site will be dependent upon individual characteristics of that site, and based on numerous criteria that must be assessed by the engineer. However there are opportunities for embracing developing technologies and making minor changes to installation parameters that could reduce installation and maintenance costs and improve the efficiency of LD methods of operation that retain signal control and its intrinsic safety compared with priority operation. These include improvements to equipment, for example detection and use of low voltage equipment, and trialling whether low minimum green times should be considered permissible during LD periods. Software developments to improve the efficiency of operation of traffic signals in LD periods should be actively encouraged, for example developments to UTC/SCOOT operation to make it more flexible during LD periods whilst retaining the ability to provide coordination when necessary.

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# 1 Introduction

## 1.1 Overview

1.1.1 It is not uncommon for criticisms to be made of highway authorities that the operation of traffic signals during periods of Low Demand (LD), for example overnight, causes unnecessary delays. Comparison is frequently made with practices overseas, where various techniques are applied to 'demote' signalised junctions to priority mode of operation, for example the flashing amber on main road/flashing red on minor road employed in some States of the USA. AECOM was commissioned by the Department for Transport to carry out a desktop study to investigate, assess and recommend potential alternative techniques that could be applied at signal-controlled junctions during periods of LD.

## 1.2 Objectives

1.2.1 The objectives of this desktop study are to investigate options for signal controlled installations that will help

- reduce unnecessary delays to traffic, hence minimising overall vehicle delays and emissions;
- reduce the energy consumption of signal installations; and
- maintain or enhance levels of road user safety, especially for vulnerable road users.

1.2.2 It is considered essential to the success of this project to identify and review the varying and often conflicting issues that could be revealed by the research, whilst examining the operational and practical limitations of options.

1.2.3 The following areas have been considered when evaluating each option:

- **Safety critical** – there are many reasons why traffic signal control is implemented at junctions, but in most cases the main objective is the safe management of conflicting traffic demands. Safety issues include visibility constraints, the need to provide for non-motorised users and approach speeds. It is therefore important that this study develops a means to define the impact on safety of the options in different locations. A recently published report by TRL[1] provides useful guidance with respect to pedestrian safety;

- **Cost** – the cost impact of each option will depend on the requirement for additional equipment/street furniture, the development of software to implement control strategies and the cost of changing legislation (e.g. publicity);

- **Energy consumption and environmental impact –** the consideration of the relative energy consumption of different operational conditions must extend beyond the pure consumption of the traffic signals themselves. The energy expended by a vehicle slowing to a stop, idling and then regaining the original cruise speed must also be considered including the resultant tail pipe emissions. It is prudent therefore to consider the overall carbon footprint of any control method;

- **Criteria for operation** – it is important to consider a number of different factors in defining the mechanisms to assess whether a specific installation could adopt LD conditioning. Elements such as traffic composition and flow, speed limits, presence of Vulnerable Road Users (VRU), inter-visibility, geometric road layout have to be taken into consideration, and comparative effects evaluated. It is also important that any suggested measures should be relevant for the immediate environment of the signal installation. What might be

[1] Transport Research Laboratory (2009) *The Effect of Traffic Signal Strategies on the Safety of Pedestrians,* Report PPR414

suitable for an isolated simple signal-controlled rural junction may not be appropriate for a complex linked urban network;

- **Legal framework** - current legislation and codes of practice, primarily the ZPPPCRGD[2], the TSRGD[3] and TA 84[4] respectively, are intended to maintain safe standards for traffic signalling. However, some of the potential options would not be permitted within the parameters laid down in these documents. It has therefore been necessary to assess each measure as it is formulated, to determine if it could be implemented within existing legislation or whether a change in legislation would be required.
- **Road user perception** – the main technical thrust of this study could be considered as the definition of a control method. In reality the technology is already available to switch off, flash certain lamps or detect approaching conflicting movement. Therefore the main area of concern is how road users will understand and react to new control strategies; and
- **Vulnerable road users –** in safety critical terms this varied group of users will have different specific needs and these needs will require detailed consideration.

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[2] TSO (1997) S.I. *2400 Zebra, Pelican and Puffin Pedestrian Crossings Regulations and General Directions (1997)*
[3] TSO (2002) *S.I. 3113 Traffic Signs Regulations and General Directions (2002)*
[4] DMRB Volume 8 Section 1 (2006) *TA 84/06, The Code of Practice for Traffic Control and Information Systems*

# 2 Methodology

The methodology can be considered in 5 key stages:

1. Review of current UK and overseas practices
2. Development of assessment techniques
3. Assessment of options
4. Further development of options
5. Stakeholder consultation

## 2.1 Review of Current Practice (Chapters 3-6)

2.1.1 A preliminary investigation of current practice in the UK and worldwide was carried out. As described previously, the UK legislation currently limits what can be done in Low Demand (LD) periods. Part-time signals are permitted, but generally only used at roundabouts or similar geometric layouts where reverting to priority mode of operation does not compromise the legibility (hence safety) of the junction.

2.1.2 An on-line questionnaire was set up to determine what other options have been explored to date within the UK, and also to ascertain current issues and future aspirations. Invitations to participate were issued through the Traffic Systems Group (TSG, previously the Traffic Control User Group) and also by direct approach. Twelve local authorities in the UK, including Transport for London and Greater Manchester UTC, responded.

2.1.3 Mainland Europe, the US, Canada and Australia already utilise certain LD control mechanisms. A similar on-line questionnaire was therefore created to identify overseas practices, and subsequent contact with respondents used to locate associated research.

## 2.2 Development of Assessment Technique (Chapters 7-10)

2.2.1 An assessment framework was developed to establish the suitability of employing LD strategies to existing or new traffic signal installations. The information collected in the review of current practice was further analysed to produce a contextualised list of current control strategies, and identify the various constraints likely to be encountered in various environments. This enabled the development of a process that can be applied to determine the suitability of specific options according to specific site characteristics:

***Low Demand Criteria***

2.2.2 Objective CRITERIA were developed that can be used to identify sites that could be suitable for an alternative control strategy during LD periods. This allows a designer to categorise a particular junction, series of junctions or network consistently, and create continuity between the appraisal process and the potential roll out of an LD strategy.

2.2.3 The parameters considered included electricity consumption, emissions, delay, impact on safety, junction geometry and layout and amendment to legislation.

***Site Assessment Parameters***

2.2.4 The second key element of this task was to define PARAMETERS that would identify which, if any, LD strategy could be suitable for any given installation. These include the geometric characteristics of the installation, visibility and stopping sight distances, traffic speeds and demands and collision history.

***Definition of 'Low Demand'***

2.2.5 The set of conditions used to define 'LD' depends largely upon flow characteristics, but will vary according to the type of installation as identified in the site assessment, and also differ according to the LD option being considered. The LD parameters could be used as triggers to switch from standard to LD strategies and back again.

## 2.3 Assessment of Options (Chapters 11-15)

2.3.1 Using the information gained in the review of current practice a 'long list' of options was developed. This included all potential options that had been identified from previous discussion with authorities in the UK and overseas, irrespective of their viability within the confines of UK legislation or good practice.

2.3.2 Utilising the criteria framework, these options were then assessed using a NATA-style appraisal system (New Approach to Appraisal - framework used to assess transport schemes in the UK, utilising a multi-criteria assessment) to allow subjective multi criteria decisions to be made on their suitability. The summary table included alongside each option description in Chapter 12 indicates the outcome of this assessment.

2.3.3 The assessment elements were collated from various sources. For example, CO2 emissions and delays were estimated by applying each option to a hypothetical network, modelled in the micro-simulation program VISSIM, to provide comparable emissions data (Appendix B).

2.3.4 The resulting assessments allowed each option to be classified as follows:

- Short-term – options considered viable within the UK for immediate consideration
- Medium-term – options that would require minor changes to current regulations, or technological advances to be made in order for them to work effectively; and
- Long-term – options that would require significant changes to legislation, technology or driver education before they could be considered for use within the UK.

## 2.4 Options for Further Development (Chapter 16)

2.4.1 The short- and medium-term options identified in Chapter 13 could either be implemented within the current legislative or technical framework or with minor changes or developments. The long term options would only be achievable through further development of technologies or by significant changes in legislation; those that were felt could benefit from further appraisal, and perhaps be developed into on-street trials, have been identified.

## 2.5 Stakeholder Consultation (Chapter 17)

2.5.1 Stakeholders include scheme designers, policy decision makers and road users. This report has been produced to enable these groups and individuals to provide feedback to the research. Though a number of options will be examined and discussed, further work would be needed before any street trials are carried out. This includes wider consultation in the form of market research with the general public. This research should utilise a series of focus groups to determine the level of understanding for the changed requirements. It would also assess the reaction of drivers to amended traffic signal operation and the use of amended signs or new signs/signals. The results of this additional research could be used to test the viability of the options selected.

# Review of Current Practice

# 3 Review of Current Practice – UK

## 3.1 Overview

3.1.1 UK legislation currently limits options for reducing delay during LD periods. Part time signals are permitted, but are generally only used at roundabouts or similar geometric layouts where reverting to priority mode of operation does not compromise the legibility (hence safety) of the junction. Existing options for other junction types consist of changes to the methods of operation, for example different timing sets or changing from fixed time plans to vehicle actuated control.

3.1.2 This Chapter provides information on current UK policy for traffic signal controlled junctions. In addition this Chapter summarises the findings of a survey of local highway authority practices with regard to preferred methods of controlling traffic in LD periods.

## 3.2 Legislation, Policy and Guidance

***Vienna Convention***

3.2.1.1 The size, colour, type and meaning of traffic signs and signals in the UK generally conform to the principles of the Vienna Convention on Road Signs and Signals [5]. The Vienna Convention is an international treaty to standardise signing (including road signs, traffic signals and road markings) within UN member states.

3.2.2 Those countries that have ratified the treaty, including many European countries, agree to adopt in full the principles of the document. However there is a level of interpretation permitted which has led to the current differences in signing that exist between member states. **Table 1** overleaf summarises the permitted use of traffic signal lights as defined in the Vienna Convention. It can be seen that particular meanings are attributed to both flashing and non-flashing operation. (It should be noted that although the UK signed the convention, this was never ratified. Consequently, it should be considered as a reasonable indication of good practice, rather than a strict legislative framework).

3.2.3 There is general conformity within all member states (including the UK) in the application of non-flashing signals to provide as safe a control method for vehicles and pedestrians as possible. A minor difference is that some countries do not use the red/amber (or 'starting amber') combination prior to full green. Red flashing aspects are used within various countries, being used only at special locations such as level crossings, airports and ferry terminals. They are not used within a standard three aspect signal head.

3.2.4 However, there is a difference between UK use of the flashing amber signal and that deployed elsewhere. In many countries a flashing amber aspect is used to indicate 'proceed with caution', and it is common that signal-controlled junctions will revert to flashing amber operation during periods of LD, i.e. the junction becomes self regulating with pedestrians given legal precedence over traffic. Flashing amber signals have a different meaning within the UK. In 1969 the Pelican Crossing was introduced, which utilises a flashing amber aspect prior to the full green aspect for vehicles signifying that vehicles must give way to pedestrians already on the crossing.

***UK Traffic Signals Operation***

3.2.5 The standards determining the physical and operational characteristics of traffic signals within the UK are contained within the Traffic Signs Regulations and General Directions 2002 (TSRGD)[6], covering the signing and signalling requirements for all types of junctions,

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[5] United Nations (1968) *Vienna Convention on Road Signs and Signals*

[6] TSO (2002) *S.I. 3113, Traffic Signs Regulations and General Directions (2002)*

pedestrian crossings and highway features. TSRGD predates the Vienna Convention (first published in 1957), but since adopted its requirements. It details the following criteria for the use of traffic signals:

- Traffic signal head dimensions and mounting requirements;
- Permitted lighting sequences within Great Britain;
- Permitted symbols for use with traffic signals;
- Requirements in relation to British and European specifications for traffic signals;
- Requirements for road markings used in combination with traffic signals at installations; and
- The significance of different traffic signal aspects available.

**Table 1** – Permitted use of traffic signal lights (according to Vienna Convention 1968)

| Mode of Operation | Type of Signal | Colour | Permitted Location | Instruction |
|---|---|---|---|---|
| Non-flashing | Full Aspect | Green | Junction | Proceed (if safe to do so) |
| | | Amber | Junctions, level crossings, swing bridges, ferry terminals etc. | Stop if safe to do so (without stopping past stop line) |
| | | Red | Junction | Stop |
| | | Red + Amber | Junction | Signal is about to change, but shall not be passed until red has disappeared |
| | Left facing arrow | Green | Junction | Left turning traffic only may proceed |
| | Right facing arrow | Green | Junction | Right turning traffic only may proceed |
| | Upward facing arrow | Green | Junction | Ahead moving traffic only may proceed |
| | Downward facing arrow | Green | Above individual lane | Traffic permitted in lane below signal |
| | Cross | Red | Above individual lane | Traffic not permitted in lane below signal |
| | Diagonally pointing arrow | Amber/White | Above individual lane | Lane due to close, change lane in direction shown |
| Flashing | Full aspect | Red | Level crossings, swing bridges, airports, fire stations and ferry terminals | Stop |
| | | Amber | Junction | A single amber flashing light or two amber lights flashing alternately shall mean that drivers may proceed but shall do so with particular care. |
| | | White | Level crossings | Proceed |

3.2.6 The TSRGD does not specify methods of operation for traffic signals, but prescribes the permitted UK use of the red, amber and green aspects (regulation 33[7]). "The sequence of illumination of the lights shown by the signals shall be as follows-

*a) Red,*

*b) Red and Amber together,*

*c) Green,*

*d) Amber"*

3.2.7 The regulations do not allow any alternatives to the traffic signal sequence. The complementary The Zebra, Pelican and Puffin Pedestrian Crossings Regulations and General Directions (1997)[8] requires the use of flashing amber to ensure vehicles allow pedestrians to clear a crossing before proceeding. The regulation is included below, and clearly defines the current meaning of flashing amber signals to drivers.

3.2.8 "The vehicular light signal at a "Pelican" crossing shall convey the following information, requirements and prohibitions-

*e) the flashing amber light shall convey the information that vehicular traffic may proceed across the crossing but that every pedestrian if he is on the carriageway or a central reservation within the limits of that crossing (but not if he is on a central reservation which lies between two crossings which form a system of staggered crossings) before any part of a vehicle has entered those limits, has the right of precedence within those limits over that vehicle, and the requirement that the driver of a vehicle shall accord such precedence to any such pedestrian."*

***Current Control Strategies***

3.2.9 Given that UK legislation currently precludes use of any signal display other than steady green, amber, red or red/amber, changes to signal operation during LD periods tend to be based on timing changes and changes to the control strategy. Changes made depend on whether a junction forms part of a coordinated UTC system or is isolated, and on the control strategy that applies during normal periods. The definitions of the various control strategies are fully described in Part 2 of TAL 1/06[9] , but briefly they are:

3.2.10 **Fixed Time** – signal timings and stages remain unaltered, leading to inefficient operation and unacceptable delays to drivers. Nowadays, simple fixed-time operation is very rarely encountered at junctions due to its inflexibility and consequent inefficiency. It could be used as a fall-back control system in the event of detector failure, however its use is not encouraged by the DfT.

3.2.11 **Vehicle Actuation (VA)** – stage timings and stages called are dependent on demands being placed with the junction controller. Depending upon the demand profile, vehicle stages run for a defined minimum period, or could be extended to a defined maximum period before serving another registered demand, thereby reducing delays to vehicles. Vehicle demands are registered by detectors located on each approach, and for pedestrians by push-button units.

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[7] TSO (2002) *S.I. 3113, Traffic Signs Regulations and General Directions (2002)*

[8] TSO (1997) *S.I. 2400 The Zebra, Pelican and Puffin Pedestrian Crossings Regulations and General Directions(1997)*

[9] DfT (2006) *Traffic Advisory Leaflet 1/06 General Principles of Traffic Control by Light Signals*

By adjusting the green times for demanded stages, alternative timing plans can be used to change the maximum periods of green allowed to each movement, called MAXSETS, where the maximum allowable cycle time is adjusted according to the time of day, and hence demand. When demand is low the junction usually reverts to a stage giving the major road a green signal, changing only upon a demand from the minor roads. Alternatively, the signals could revert to an all red stage ('quiescent all-red') when no vehicles are detected on any approach. This is marginally more efficient in LD periods, as the time required to initiate a demanded stage will not have to include an element of time to shut down a conflicting stage.

3.2.12 **MOVA (Microprocessor Optimised Vehicle Actuation)** – MOVA was developed in the mid-eighties to overcome variations of demand over time that would adversely affect the efficiency of VA operation. MOVA differs from VA in that it is a 'delay minimalisation' form of control. Compact MOVA (CMOVA) is more appropriate at low-speed sites, and requires less extensive vehicle detection than MOVA.

3.2.13 **Linked systems** – Systems of two or more signal installations could operate more effectively when linked. Each controller generally has to run on identical or sub-multiple cycle times. By linking a series of installations, combinations of stage timings, cycle times and offsets can be selected to cater for known variations in traffic flows by time of day and day of the week. The different plans are fixed, apart from the use of demand dependent stages, and this method therefore assumes that variations in flow are small. Systems are normally synchronised by cableless linking units or by cabled links.

3.2.14 **Urban Traffic Control (UTC)** – Under UTC, signalised junctions are controlled from a central computer. Basic UTC utilises fixed timing plans to control the cycle times, start and length of green period and the offsets between adjacent installations, which might vary by time of day and day of the week. The disadvantage is that traffic conditions can change day to day within the network, thus fixed timing plans can become outdated quickly and are insensitive to traffic flow. Consequently, Adaptive UTC was developed, with techniques such as SCOOT (UK) and SCATS (Ireland) which adapt to traffic fluctuations in real time. The central computer constantly checks traffic flows within an entire network and makes frequent but small amendments to signal timings to optimise the network by reducing net vehicle delay throughout the network and hence improve the flow of traffic.

***Low Demand Operation***

3.2.15 In networks controlled by UTC, either using fixed timing plans or adaptive control, several options are available for controlling traffic during LD periods. Where it is necessary to retain synchronisation within the network then UTC control can be retained. Fixed time plans can be changed to reduce the cycle time (although this is constrained by the requirement that every stage has to appear), or SCOOT will automatically adjust the allocation of green time, cycle time and offsets automatically to adapt to the lower traffic demands. It is also possible to decouple some or all of the installations on the network and change the method of operation from UTC to vehicle actuated, thus only serving demanded stages rather than cycling through a chosen sequence of stages.

3.2.16 Common to all junctions is that the operation of the traffic signals does not change with regard to varying the display of the traffic signal aspects; rather changes are made to the methods of operation to reduce potential delays as much as possible. The exception to this is part-time signalling of roundabouts. The Design Manual for Roads and Bridges (DMRB) describes the use of part time traffic signals on roundabouts during busy periods[10]. The following extract notes the permitted application.

3.2.17 "Part-time control is the condition where signals are switched on at set times (generally peak periods) or under certain traffic conditions by queue detectors. When traffic flows are light the roundabout operates in a self-regulating manner under normal priority mode of operation."

3.2.18 The use of part time signals is site dependent, and not used significantly as a method of control. Recent research detailed in LTN 1/09[11] highlights the safety implications of utilising part time signals, noting that their use is declining and many part time installations have since been converted to full time operation.

## 3.3 Local Authority Practices

3.3.1 Though UK legislation limits the available options for signal displays, the previous paragraphs outline a number of strategies that local highway authorities can adopt to modify the operation of traffic signals during LD periods. Authorities will employ different strategies for managing traffic signal networks, therefore in order to ascertain which methods are most widely used an on-line questionnaire was developed. The questionnaire invited key local authorities to comment on current LD practices, together with potential aspirations for future changes to permitted methods of operation.

3.3.2 Local authorities of varying sizes, including Transport for London and Greater Manchester UTC were approached either directly or via the Traffic Systems Group (TSG) with an invitation to complete the questionnaire. The TSG is a sub-group of ADEPT's Engineering Committee and provides a forum for practitioners in the field of traffic control systems, in which many local authorities, contractors and professionals participate.

3.3.3 The questionnaire was divided into three sections:

- current practices for traffic signals in LD periods;
- aspirations; and
- additional comments.

3.3.4 The outputs of the responses are summarised in **Table 2** (The identities of the 12 responding authorities are not given for confidentiality reasons).

[10] DMRB Volume 6 Section 2 Part 3 (2004) *TD 50/04, The Geometric Layout of Signal Controlled Junctions and Signalised Roundabouts*

[11] DfT (2009) *LTN 1/09, Signal Controlled Roundabouts*

**Table 2** – Current Low Demand practices of UK highway authorities

| Junction control type | Question | Responses from Local Authorities | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of Signal Installations | | 6096 | 2102 | 558 | 530 | 485 | 375 | 350 | 210 | 191 | 150 | 149 | 88 |
| Urban Networks utilising SCOOT or similar | Current Low Demand Practice | Low Demand Plan or VA | Low Demand Plan or VA | Vehicle Actuation | Vehicle Actuation | Low Demand Plan or VA | Vehicle Actuation | Vehicle Actuation | Low Demand Plan or VA | Vehicle Actuation | Vehicle Actuation | Low Demand Plan or VA | Vehicle Actuation |
| Urban Networks utilising UTC | Current Low Demand Practice | Low Demand Plan or VA | Low Demand Plan or VA | Vehicle Actuation | Vehicle Actuation | Low Demand Plan or VA | Vehicle Actuation | Vehicle Actuation | Vehicle Actuation | Vehicle Actuation | Vehicle Actuation | Low Demand Plan or VA | *n/a* |
| Isolated signalised roundabouts | Current Low Demand Practice | Low Demand Plan/VA or turn off | Low Demand Plan or turn off | Low Demand Plan/VA or turn off | Low Demand Plan | *No definite method given* | Low Demand Plan | VA or turn off | *n/a* | Turn off | Low Demand Plan/VA | Low Demand Plan/VA | *No definite method given* |
| Isolated junctions with pedestrian crossing facilities | Different MAXSET used in low demand | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes |
| | Revert to all red during low demand | No | No | No | No | No | No | No | No | No | No | No | Yes |
| Isolated junctions without pedestrian crossing facilities | Different MAXSET used in low demand | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes |
| | Revert to all red during low demand | No | No | No | No | Yes | No | No | No | No | Yes | No | Yes |
| Mid block pedestrian crossings | Different MAXSET used in low demand | No | No | No | No | Yes | No | No | No | No | Yes | No | Yes |
| | Pre-timed MAXSET in low demand | No | Yes | No | No | Yes | No | Yes | No | No | No | No | Yes |

3.3.5 For networks utilising UTC, whether fixed time or using SCOOT, all responses suggested that networks are adjusted to cater for reduced demand outside of peak periods. The scored responses indicate Vehicle Actuation to be the favoured method of operation in UTC systems when demand is low.

3.3.6 The decision on which alternative operation method to use appeared to be site dependent. For example, authorities which have a high proportion of locations with closely associated junctions that remain relatively busy favour retaining control under SCOOT or UTC. When traffic flows are low they then revert to Vehicle Actuated (VA) control. Other authorities with lower numbers of traffic signal installations revert from SCOOT or fixed time UTC to VA based on time of day rather than flow-related criteria.

3.3.7 Strategies for signal controlled roundabouts differed between authorities, though this was partly due to whether a particular authority had signal controlled roundabouts in their network and the nature of that network. The favoured option was to retain fixed time on a LD specific timing plan; keeping the roundabout traffic signals synchronised was considered important. Four authorities indicated that VA was used as a method of operation; the use of VA is based on individual site conditions where flow conditions allow this method of operation to be used. Similarly the use of part time signals is site dependent, and their use in new installations is diminishing. Where part time signals are in operation, comments relating to their use affirmed that particular arms tended to be signal controlled as peak hour control only rather than a measure for fully signalised roundabouts. The signals would be activated by UTC timetable, predetermined flow conditions being met or queue detectors.

3.3.8 Isolated junctions usually operate under adaptive control systems such as VA or MOVA. All local authority responses stated that different VA MAXSETs (timetables prescribing the maximum green times given to each phase) are used for LD periods to reduce delay. The use of a quiescent all red stage at isolated junctions varies depending on whether pedestrian crossing facilities are available. With pedestrian facilities included at junctions only one of the consulted local authorities used quiescent all red operation; at locations without pedestrians three authorities indicated that a quiescent all red stage was used. This could be attributed to a perceived safety issue with operating junctions with quiescent all-red when pedestrian crossing facilities are present, potentially as pedestrians could perceive a resting red signal as meaning it is safe to cross rather than using the push button to register a demand for the pedestrian stage.

3.3.9 The consulted local authorities varied in their strategies for mid-block (stand alone) pedestrian crossings. The majority made no change to the timings for stand-alone pedestrian crossings; such crossings are demand dependent anyway and when a demand is placed the pedestrian crossing gives a red signal at a particular point in a cycle. Nevertheless four authorities use different MAXSETs in LD periods.

## 3.4 Importance of traffic signal detection

3.4.1 In order to provide efficient control over traffic in both peak conditions and during LD periods, suitable detection is required. The detection equipment must be correctly set up and well maintained in order to effectively register and service demands for vehicles.

3.4.2 Incorrectly set up or mis-aligned detection can reduce the effectiveness of the operation of a junction, for example failing to recognise a demand will increase delays on that approach, and incorrect calibration for vehicle sizes might negate the advantage of installing bus priority measures.

3.4.3 Damaged detection can radically affect the operation of a whole junction. On approaches where detection has failed the result is usually significant queuing. This can propagate back through a network and affect the operation of upstream junctions. The additional impact is that a junction with damaged detection might allocate inappropriate green time, which can result in unbalanced flows and the potential to affect adjacent junctions by over-saturating particular movements. It will also cause unnecessary delays on other approaches at the junction.

# 4 UK Aspirations

## 4.1 Introduction

4.1.1 Though the UK is currently limited in its permitted practices for reducing delays in LD periods, there are potential options that could be introduced if sufficient benefits could be demonstrated. These include introducing measures as currently used overseas or perhaps other approaches developed specifically for the UK.

4.1.2 This chapter details the results from the survey questions regarding possible future strategies. It should be stressed that some of the suggested strategies could have profound implications for pedestrians and other vulnerable road users, which are considered in greater detail in Chapter 12.

## 4.2 Local Authority Aspirations

4.2.1 Local highway authorities were invited to comment on potential options for managing traffic in LD periods, based on current overseas practices, and on aspirations for changes to currently permitted methods of operation. The results are summarised in **Table 3***,* and discussed in the following paragraphs.

Respondents were asked to give a score of between 1 and 5 to each option, where:-

5 = Always consider (standard practice);
4 = Would consider;
3 = May consider;
2 = Would not consider; and
1 = Would definitely not consider.

4.2.2 A general point that applies to all options that involve switching signal off was that this might result in a significant increase in erroneous fault reporting by members of the public, falsely believing that the installation had malfunctioned.

***Flashing amber given to all traffic – vehicles must proceed with caution***

4.2.3 Feedback on the option to provide flashing amber to all approaches to a junction received varied ratings from consultees. Though some scored to indicate they would give the option consideration, they shared the same concerns as those who did not consider the option viable.

4.2.4 A key concern for this option is the treatment of vulnerable road users, including pedestrians. With flashing amber aspects displayed to all vehicular approaches, emulating the 4-way stop used in the US, it was unclear if pedestrians would have priority over vehicles or whether the junction would revert to providing uncontrolled crossing points as in other countries. It was suggested that a pedestrian demand via a push button unit could turn the vehicular traffic signals to red to allow pedestrians priority, reverting back to flashing amber after the pedestrian phase. The current use of flashing amber signals at Pelican crossings signifies pedestrian priority; the application of flashing amber for a second purpose could not safely co-exist with a different meaning that approaching drivers might encounter conflicting vehicular traffic, The use of flashing amber for Pelican crossings would need to be phased out before an alternative use could be considered, in addition to the amendments required to the regulations, directions and specifications for signal control.

**Table 3** – UK highway authorities' opinions on potential Low Demand control options

| Option | Transport for London | Greater Manchester UTC | Lancashire County Council | The City of Edinburgh Council | Sheffield City Council | Oxfordshire County Council | Cardiff Council | South-ampton City Council | Cumbrian Highways | Anonymous Response | Blackburn with Darwen Borough council | Average Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of Signal Installations | 6096 | 2102 | 558 | 530 | 485 | 375 | 350 | 210 | 191 | 150 | 88 | |
| Flashing amber given to all traffic | 3 | 3 | 2 | 1 | 4 | 1 | 4 | 2 | 3 | 4 | 2 | **3** |
| Flashing amber on major arm / Flashing red (or secret STOP sign) on minor road | 3 | 3 | 2 | 1 | 4 | 1 | 4 | 1 | 3 | 2 | 3 | **2** |
| Switch off signals on major arm / Flashing amber on minor road | 3 | 2 | 3 | 1 | 3 | 1 | 4 | 2 | 4 | 2 | 3 | **3** |
| Switch off signals, junction reverts to priority mode of operation | 3 | 2 | 4 | 1 | 3 | 2 | 4 | 4 | 5 | 2 | 2 | **3** |
| Puffin crossing reverts to 'zebra' control i.e. flashing amber | 3 | 1 | 5 | 1 | 3 | 2 | 3 | 3 | 3 | 4 | 1 | **3** |
| What flow level do you feel it would be acceptable to revert to alternative control (% of peak hour flow)? | - | 10% | - | 20% | 30% | 50% | 50% | 40% | 20% | 20% | 50% | **30%** |

4.2.5 Another concern highlighted was the enforcement of the flashing amber. Given police enforcement of all traffic signal offences is impracticable, there would be the potential for drivers to begin to ignore traffic signals as there is no defined priority. In the event of an incident litigation could rest with highway authorities if it is unclear where priority lies.

4.2.6 Driver education was also highlighted, an issue which concerns all options. Where alternative LD control has historically been provided in other countries, drivers are aware of the rules and regulations. Applying a new form of control in the UK would require local authorities or central government to fund campaigns to raise driver awareness of any proposed changes and ensure sufficient education.

***Flashing amber on major arm/Flashing red on minor arm***

4.2.7 Though currently the flashing red signal (or amber signal) could not be used in the UK for this purpose, the option was suggested to the local authorities to obtain comments on its viability. This option was rated in a similar way to the use of flashing amber signals on all approaches, pedestrian safety being the primary concern. In particular the audible and tactile facilities that impaired users rely on would need to be disabled. It could also be argued that the use of flashing red signals for wig-wag crossings would be undermined.

4.2.8 Another comment implied the use of flashing red and amber would be more confusing than just using flashing amber, with more regulation for drivers to be aware of.

***Switch off signals on major arm/Flashing amber on minor arm***

4.2.9 As with the other options, a varied response suggested the concept would be viable but a number of issues would need to be considered.

4.2.10 It was considered that switching the main road off during LD periods could cause a critical safety problem; in the event of traffic signals developing a fault during normal operation, drivers might not apply the necessary caution as the precedent will have been set that inactive signals signify priority.

4.2.11 However it was highlighted that this option could be more achievable in terms of driver education. With the major route uncontrolled, junctions would effectively operate as priority intersections with a clearer priority.

***Switch off signals, junction reverts to priority mode of operation***

4.2.12 This option received the highest score of all options. Though safety concerns remain that the junction running in LD mode could be misinterpreted as a malfunction of the traffic signals, it should be stressed that this method of operation is used successfully in Germany. An additional issue is that junction layouts might have to be altered to accommodate uncontrolled use, hence increasing the cost of implementation of this form of LD control. Elements such as visibility would need to be established to an acceptable level to be safe under both priority and traffic signal control. This is examined in greater detail in Chapter 10.

4.2.13 Local authorities might have examples of signalised junctions that operate successfully when the traffic signals are turned off from observations during traffic signal malfunction. Though under this condition most drivers naturally proceed with caution, local authority observations could provide some data as to junction types and locations where such benefits have been observed.

4.2.14 One highway authority reports that such a junction already exists within their jurisdiction. The signals only operate at the beginning and end of the school day, to allow buses to enter and egress a site; outside of school periods the signals are deactivated, with the side road/access marked as the minor arm of a priority intersection. This is similar to part time signals at roundabouts, where priority is unambiguous during periods when the signals are not operating.

***Puffin crossing reverts to priority mode of operation i.e. flashing amber***

4.2.15 This option applies to mid block pedestrian crossings only, switching their operation and priority to that of a zebra crossing. Though the ratings are mixed, the scores suggest that some consideration would be given if issues could be resolved. A key issue is the provision of facilities for visually impaired pedestrians; the lack of signal control during LD periods would disadvantage them, as the pushbutton would be present but not operative.

4.2.16 The flashing amber signal is currently associated with Pelican crossings as prescribed in The Zebra, Pelican and Puffin Pedestrian Crossings Regulations and General Directions (1997) (ZPPPCRGD). If the flashing amber was to be designated for use during LD periods at junctions and pedestrian crossings, amendments would be required to the regulations requiring that normal pedestrian crossing operation must cease to utilise flashing amber (i.e. Pelican crossings). There is currently a mixture of Pelican and Puffin crossings in the UK. Should Pelican crossings be wholly replaced by Puffin crossings then consideration could be given to reclassifying flashing amber signals (with the necessary regulation changes).

***What flow level is it acceptable to revert to alternative control (% of peak hour traffic)***

4.2.17 Local authorities were asked to comment on what would be considered an acceptable limit for consideration as an LD period. The majority of respondents suggested it would be when flows reached between 20% and 50% of the flows witnessed during peak hours at that particular junction. 24 hour flow data has been examined for a sample city centre (Leeds), the analysis detailed in **Appendix A** suggests a much lower value of around 5% would be appropriate. It was also generally felt that switching to LD strategy should be restricted to specific times of day to prevent unexpected changes at random times when flows could drop sporadically.

4.2.18 A solution could be integrated into current operation of junctions, where the LD strategy is activated only during pre-specified periods AND when flow levels have dropped below a specified level for a predetermined period.

## 4.3 Department for Transport position

4.3.1 UK Government has discussed the issue of changing traffic management guidance on a number of occasions, including the introduction of flashing amber signals where appropriate. The following response highlights the Department for Transport’s stance on traffic signal control in the UK:

4.3.2 “The Department has no plans to consider adopting flashing yellow traffic signals during off-peak hours. Removing the protection afforded by a red signal leads to concerns for the safety of pedestrians, especially blind or partially sighted pedestrians. The preferred method is for more traffic responsive operation of traffic signals which should lead to reductions in unnecessary delays.”

4.3.3 Many of the options considered in Chapter 12 involve modification of the response of traffic signals to reduce delays and unnecessary stop/starts. Nevertheless, some options have also been developed that consider implementing priority mode of operation during LD periods.

## 4.4 Summary

4.4.1 The local authorities surveyed provided a diverse reaction to the example options in the questionnaire. Despite this, the exercise highlighted a number of issues which would require mitigation before alternative methods of operation are considered.

4.4.2 The key issue is the safety of pedestrians and other vulnerable road users, in that traffic signal control provides pedestrians with an opportunity to cross safely, with priority over vehicles for a period of time Methods to revert junctions to priority mode of operation, albeit with signals to warn highway users, would reduce or remove an element of that pedestrian priority.

4.4.3 In addition, driver comprehension and education was noted as a concern. Alternative LD operation has historically been used in other countries therefore drivers are aware of the rules and regulations. Introducing a new form of control to motorists would require funded campaigns to raise driver awareness of any proposed changes and ensure sufficient education.

4.4.4 The Department for Transport view is that traffic signals should be made more responsive to traffic demands to reduce unnecessary delays, rather than advocating the use of flashing amber, or similar, priority mode of operation during LD periods.

# 5 Review of Current Practice – Overseas

## 5.1 Introduction

5.1.1 Alternative mechanisms for LD period control are employed within mainland Europe, the USA, Canada and Australia. Practices within these countries could be applied within the UK or adapted to provide a different mechanism for control, thus overseas systems and techniques have been researched to ascertain which if any might be appropriate.

5.1.2 Two methods have been used to collect data on global techniques. Contacts within worldwide AECOM offices have been used to obtain guidance on appropriate standards and advice on current practices. In addition, invitations to participate in an online survey were issued through international special interest groups to obtain information on current practices, aspirations and issues around the world.

5.1.3 This Chapter details the findings regarding overseas policies for the use of traffic signals in LD periods.

## 5.2 Europe

5.2.1 Chapter 3 describes the permitted use of traffic signals by countries who are signatories to the Vienna Convention (VC), a treaty standardising signing (including traffic signal use) within UN member states. Many European countries have different traffic control methods for traffic signals and signs and employing LD systems, whilst adhering to the convention designed to standardise traffic sign use internationally.

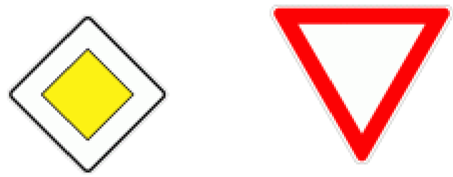
5.2.2 It should be appreciated that there are attitudinal differences in the status of pedestrians in various countries, which can be shown to affect the signalling of pedestrians and traffic turning movements. For example, in certain locations the pedestrian has priority across side roads with the consequence that turning vehicles must yield to conflicting pedestrians. In the UK, however, no such behaviour would appear to prevalent despite the UK Highway Code stipulating that drivers should "give way to pedestrians who are already crossing the road into which you are turning" (which is why the 'left turn on red' rule has never been introduced). Therefore it might be considered less acceptable to remove pedestrian signalling during LD periods.

***Germany***

5.2.3 During normal operation, Germany utilises the three aspect signal arrangement as used in the UK. During LD periods three alternative forms of control are used:

- Flashing amber – Traffic signals are turned from normal operation to a flashing amber at night, requiring vehicles to proceed through junctions with caution;
- Signals switched off – Some junctions are turned off late at night, requiring vehicles to navigate a junction using right of way priority with other vehicles. Germany is the only country where significant use of this option has been identified.
- Use of Vehicle Actuation – The main road is given a green light as the default stage, if a demand is registered on the side road it is given the appropriate amount of green time before reverting to the main road.

**Figure 1 –** European Priority Signing



'Priority' sign 'Yield' sign

5.2.4 The circumstances of the need for specific LD control define the method used. The favoured method is to switch the traffic signals off during the early hours of the morning and at weekends where demand is historically known to be low. Reverting the junction to flashing amber control is an alternative form of control to reduce delays through the introduction and warning of priority mode of operation at signal controlled junctions.

5.2.5 Flashing ambers can be used for all approaches as signs are provided at junctions to indicate priority. These signs are mounted below the traffic signal heads and show the right of way when the traffic signals are not functioning or are under flashing control. **Figure 1** illustrates the sign plates used in Europe.

5.2.6 The use of the Priority Road sign is widespread in mainland Europe, but is not prescribed for use in the UK.

5.2.7 Though flashing amber aspects and switching signal installations off are options currently deployed in Germany, modern technologies such as vehicle actuation are becoming more commonplace and replacing the early nineties preference for turning traffic signals off. In cities especially, the use of low power LEDs in vehicle actuated systems means the energy saving advantage of switching signals off or to flashing amber is reduced.

***Italy***

5.2.8 Unlike Germany, Italian traffic signals are not turned off during LD periods. Italy employs the flashing amber aspect where off peak traffic is low, utilising vehicle actuation to retain control at key junctions. The changes on operation, like other countries, tend to be time based rather than when traffic falls below a certain level.

***Netherlands***

5.2.9 The Road Traffic Signs and Regulation in the Netherlands[12] specifies the operation and use of traffic signs and signals. The Netherlands use the same three aspect traffic signal arrangement and sequence as the UK, though in some locations a red/amber two aspect signal is used with the amber light signifying that vehicles should proceed with caution.

5.2.10 A study has been carried out by a consultancy in the Netherlands, with knowledge of the systems used. It confirmed that most traffic signals are under vehicle actuated operation during peak times, changing timing plans where appropriate during LD periods. UTC systems are used, with a preference given to UTOPIA/SPOT systems, an adaptive UTC method of operation.

5.2.11 It is noted that LD options are generally not employed at isolated junctions. Though vehicle actuation is still used to optimise traffic flows during normal operation, there is no change to timing plans in LD periods. The main road receives a green signal under the default stage, with side roads registering demands to change the stage.

[12] Ministry of Transport, Netherlands (2006) *Road Traffic Signs and Regulation in the Netherlands*

***Belgium***

5.2.12 Similar to the Netherlands, vehicle actuation is commonplace for traffic signal networks within Belgium, as it is for isolated junctions. The survey submission from Belgium suggests that urban networks under SCOOT and isolated junctions use LD timing plans under VA revert.

***Finland***

5.2.13 Finland adopts traffic control systems commonly used within mainland Europe, combining intelligent traffic signal operation such as VA, part time signals and flashing amber signals. The flashing amber signal is featured in Road Signs and Other Devices of Traffic Control in Finland[13] published by the Finnish Road Administration, which clearly distinguishing between solid amber signals (stop) and flashing amber signals (proceed with caution).

5.2.14 It is evident that Finland is proactive in assessing the safety of traffic signal installations by the research that is undertaken by the Road Administration. Research undertaken in 1996[14] concerned the safety of traffic signal controlled junctions, specifically on high speed roads. Of particular note the research identified that at installations subject to part time control, the recorded collision rate when the signals were not in operation was on average 3½ times higher than when the signals were operating. The author observed that current guidance recommends continuous operation of traffic signals. Chapter 6 discusses other safety reviews carried out on overseas traffic signal operation.

***Ireland***

5.2.15 Signals in Ireland are regulated by the Road Traffic (Signs) Regulations[15]. The regulations are similar in structure to the UK Traffic Signs Regulations and General Directions (2002), and do not allow for the use of flashing signals (other than at Pelican crossings as defined in The ZPPPCRGD (1997) and special junctions such as level crossings. Traffic signal operation during LD periods is managed by changes to the stage timings.

5.2.16 However, in the last few years individual Councils have erected flashing amber arrow supplementary aspects to signify a 'turn left on red' control, where left turning vehicles yield to main road traffic. There are no regulations to support their use, and a current review of Chapter 9 of the Irish Traffic Signs Manual has identified that the message imparted to drivers by such a signal can be misleading, especially where pedestrian facilities exist.

5.2.17 In Dublin, the traffic signal network is operated under SCATS based Urban Traffic Control with no fixed time control used. Whereas SCOOT UTC systems generally continue to optimise a network unless junctions are isolated under pre-timed plans, SCATS is able to dynamically unlink junctions from the network and revert to vehicle actuated operation when certain volume conditions are met. As such, the system is operated for 24 hours per day with LD managed by the central computer. It was indicated that the volume of traffic considered as LD would be approximately 20% of peak flows.

5.2.18 Elsewhere, VA is used to operate junctions when traffic demand is low.

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[13] Finnish Road Administration (2004) *Road signs and other devices of traffic control in Finland*

[14] Finnish Road Administration (1996) *Traffic Safety at Signal Controlled Junctions on High Speed Roads in Finland*

[15] Department of the Environment, Ireland (1997) *Road Traffic (Signs) Regulations*

## 5.3 USA

### *Federal Policy*

5.3.1 At a federal level, the standards defining what measures can be implemented to control traffic using traffic signals are set out by the US Department for Transport, detailed in the Manual for Uniform Traffic Control Devices (2003 edition) (MUTCD)[16] and the US Traffic Signal Timing Manual (2008)[17].

### *Vehicles*

5.3.2 Under normal operation, the traffic signal sequence changes from a red signal to a green signal, then back to red via an amber signal. The use of flashing aspects is permitted as an off-peak control measure at typical signal installations or as a permanent installation at low trafficked intersections.

5.3.3 The US Traffic Signal Timing Manual (2008) encourages a variety of strategies for controlling traffic in low volume conditions. These include:

- *Ensure efficient signal timing operations (avoid unnecessary stops and delays);*
- *Consider flashing operation (yellow-red or red/red) if conditions allow;*
- *Use appropriate resting state for the signal with no traffic demand (i.e. rest in red, rest in green and "walk" on major roadway);*
- *Allow skipping of unnecessary movements (i.e. uncalled left-turn phases) but assure it does not create "yellow trap";*
- *Use half, third, or quarter cycle lengths relative to other coordinated signalized intersections; and*
- *Allowing pedestrian actuations to temporarily lengthen a cycle length, removing an intersection out of coordination, if pedestrian and vehicular volumes are low.* [16]

5.3.4 Part 4 of the MUTCD relates to Highway Traffic Signals; the following is an extract relating to the guidance for use of flashing signal indications.

5.3.5 "When a traffic control signal is operated in the flashing mode, a flashing yellow signal indication should be used for the major street and a flashing red signal indication should be used for the other approaches unless flashing red signal indications are used on all approaches." [17]

5.3.6 The use of flashing red highlights the biggest difference between the operation of traffic signals between the UK, Europe and the USA. The use of flashing red is prohibited by those countries signed up to the Vienna Convention other than for use at level crossings and other specific locations (as detailed in Chapters 3 and 4). However in the USA flashing indication is only permitted with the inclusion of a flashing red signal, flashing amber on all approaches is not permitted. When flashing all-red is employed, the junction operates under the USA's 'four way stop' priority rule, which has no UK equivalent.

5.3.7 The MUTCD also provides guidance on the transition between flashing mode and normal operation. It indicates that when changing from the yellow/red flashing mode to normal staged operation, the provision of a full red signal should be considered before displaying a green signal to any approach. This red signal interval is recommended to be 6 seconds.

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[16] United States Department of Transportation (2008) *US Traffic Signal Timing Manual*

[17] United States Department of Transportation (2003) *Manual for Uniform Traffic Control Devices*

5.3.8 Numerous safety studies have been carried out to assess the impact of using flashing signals operation in LD periods. These studies are detailed in Chapter 6.

***Pedestrians***

5.3.9 It is noted that guidance states pushbutton locator tones, that is the audible signal emitted whilst accessible pedestrian crossings are activated, should be deactivated during flashing operation of the traffic control signal. In addition the pedestrian signal heads are not permitted to be displayed when the traffic control signal installation is being operated in flashing mode. This means that pedestrian crossings are not considered operational under such control, in particular impaired user facilities including audible and tactile facilities must be disabled.

***State Specific Policy***

5.3.10 Though the federal regulations determine the permitted use of traffic signals within the USA, the application and operation of traffic signal controlled junctions within individual states could differ.

5.3.11 Traffic signal experts within American AECOM offices provided information on utilised methods of operation for signal installations within a number of States. It is apparent that during normal operation traffic signal networks are operated in a similar manner to other countries worldwide, utilising UTC (e.g. SCATS, or fixed time) in networks with VA used to control networked junctions during LD periods or as a permanent installation at isolated junctions.

5.3.12 During LD periods, three strategies have been highlighted as being used in states including New York, Wisconsin and Michigan.

5.3.13 Fixed time signals – timing plans are changed to reduce the cycle time and thus the green time available to each movement.

5.3.14 Vehicle actuated signals – Depending on whether the detection is available, junctions revert to semi or full actuated operation with LD MAXSETS, providing a green signal to the main route and responding to registered demand on side roads.

5.3.15 Flashing operation – This is usually used at isolated junctions during LD periods or permanently at lightly trafficked junctions.

5.3.16 AECOM Engineers in the State of Wisconsin advise that no state specific policies or guidelines are provided for LD conditions. It is preferred to retain signals under normal operation with appropriate changes made to timing plans, with flashing operation considered to be less safe.

5.3.17 The safety of flashing operation when compared to other junction control types has been questioned on numerous occasions. In San Francisco, 375 traffic signal installations were changed from normal operation to flashing operation between 12AM and 6AM. Accidents tripled, virtually all caused by right angle collisions.[18] Drivers surveyed after the change claimed the operation was confusing, expecting that all movements would be given a red light and have to stop rather than the red/amber split. Studies into accidents at flashing operation junctions are detailed in Chapter 6.

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[18] Institution of Transportation Engineers (1999) *Traffic Safety Toolbox*

## 5.4 Canada

### *Federal Policy*

5.4.1 Canadian traffic signal standards and guidance is contained within the Canadian Manual of Uniform Traffic Control Devices[19] (CMUTCD). In addition to the normal use of traffic signals with red, amber and green aspects, the manual indicates the significance of the flashing "ball" indications. Similar to the USA, traffic facing a flashing amber "ball" must proceed with caution (giving way to vehicles and pedestrians already within the junction); traffic facing a flashing red "ball" must stop prior to the stop line before continuing with caution.

5.4.2 The CMUTCD states stand-alone flashing beacons could be used at junctions where full traffic control signals are not required, but where warning signs are not sufficient due to visibility issues. Either flashing amber ball or flashing red ball aspects could be shown when used as a stand-alone installation. When used as a LD mechanism at junctions within a three aspect signal head, the flashing amber on main road/ flashing red on side road is utilised. This is typically used in urban areas of smaller towns rather than city networks running UTC.

### *Provincial Policy*

5.4.3 There are numerous provincial guidance documents which re-iterate the use of flashing signals within Canada, in addition providing guidance for their permitted operation.

5.4.4 The Ontario Traffic Manual [20] provides the following guidance:

The planned flashing operation of signalized intersections may be advantageous to traffic flow under some specific and limited conditions. Flashing operation may be of assistance in reducing vehicle delay and stops in pretimed networks at locations with poor signal spacing. Planned flash is only applicable under conditions of very light minor street traffic such as during the overnight period, or in locations that have extended periods of low volume such as accesses to an industrial area. Caution should be used in the application of planned flashing signal operation. It should only be used if:

- *Sidestreet traffic is very light (less than 200 vph combined for both directions);*
- *The traffic signals operate fixed time (i.e., no side street vehicular or pedestrian actuation).*
- *The planned flash mode is amber flash for the main street, red flash for the side street.*
- *There is no emergency vehicle pre-emption capability.*
- *Pedestrian volumes crossing the main street during planned flashing period are very light.*
- *The major roadway is not channelized and has no more than four lanes.*

5.4.5 If planned signal flash is implemented, regular safety reviews should be conducted to compare the occurrence of collisions during the flash hours at intersections with planned flash with similar locations without planned flash. "

5.4.6 Of particular interest is the requirement that the traffic signals must operate under fixed time (during normal operation) for flashing operation to be considered. As suggested by the use of flashing signals in other countries, for example Germany, the introduction of Vehicle Actuation and other intelligent control systems has reduced the benefit to delays of using junctions in flashing operation, provided the detection is well set up and maintained. The majority of junctions in the UK are controlled using vehicle actuation, unless in an urban network where UTC is more beneficial.

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[19] Transportation Association of Canada (1998) *Canadian Manual of Uniform Traffic Control Devices*

[20] Ontario Ministry of Transport (2007) *Ontario Traffic Manual Book 12 – Traffic Signals*

## 5.5 Australia

5.5.1 Traffic signal operation in Australia is similar to the UK and some countries in Europe in that signals must always be operated with the same aspect sequence, using various control mechanisms to reduce delays to vehicles.

5.5.2 The Australian Manual of Uniform Traffic Control Devices [21] provides the following list as acceptable forms of traffic signal operation:

- **Fixed time operation** – fixed time signals are inflexible in their operation and can generate substantial traffic delays which may result in increasing some types of accidents;
- **Traffic actuated operation** – traffic actuated signals should be employed at all intersections not incorporated in a 'master' controlled coordinated system;
- **Co-ordinated signals** – signals on arterial routes should, desirably, be co-ordinated to obviate congestion and maintain flow; and
- **Flashing operation** – flashing yellow signal operation may be used to indicate an equipment failure. Red or green signals shall never be flashed.

5.5.3 Australia utilises Urban Traffic Control systems (albeit SCAT in preference to SCOOT) in networks and vehicle actuation at isolated junctions to manage traffic effectively. No flashing signal operation or other forms of control are permitted.

## 5.6 Summary

5.6.1 This chapter details the practices of a number of countries with respect to the operation of traffic signals in LD periods. It is apparent that all countries under review utilise intelligent methods of operation, using UTC or VA to optimise signal timings for prevailing traffic conditions.

5.6.2 The alternative methods of control in Europe consist of flashing amber operation and in Germany only, turning the signals off. In the United States, the flashing amber/red operation is used where appropriate to reduce delays in LD periods.

5.6.3 With traffic signal technology advancing (e.g. MOVA over VA and SCOOT revisions), the need for flashing signals is reducing; vehicle actuated traffic signals are able to cater for the LD and adjust the signal timings as required to minimise delay. With regard to power consumption flashing signals would save electricity using bulbs, however LED technology has reduced power consumption considerably.

5.6.4 Flashing signals are still permitted and indeed utilised, though a preference for new installations appears to be traffic actuated systems; questions have been raised over the safety of such control as discussed in the following chapter, however the continued use of these alternative forms of control are still considered viable as they have been used historically, thus drivers are aware of their meaning. The installation of such operation to a country which has a consistent application of traffic signals 24 hours per day might lead to confusion.

[21] Queensland Government (2003) *Australian Manual of Uniform Traffic Control Devices*

# 6 Overseas Policy Safety Review

## 6.1 Overview

6.1.1 UK traffic signal operations are provided to manage vehicle conflicts at junctions, regulate traffic flows and provide positively controlled pedestrian facilities. Traffic signals can provide the same level of priority for all road users. The safety of all road users is paramount when providing signal control, hence many other countries favour maintaining full signal control 24 hours per day, as in the UK.

6.1.2 The use of modern traffic control systems such as adaptive UTC or vehicle actuation allows junctions to be reactive in their operation, automatically providing the appropriate green time to manage the progression of traffic and hence minimise delays during various traffic flow conditions. This provides effective control both during busy periods and when traffic demands are lower, but requires installation and maintenance of appropriate vehicle detection equipment.

6.1.3 A number of countries do not always maintain full traffic signal control throughout the day, instead reverting to flashing amber or flashing red/amber operation, or in one case switching off late at night or early in the morning. This combats driver frustration over unnecessary delays whilst waiting at signal controlled junctions with no opposing traffic. There are a number of concerns over this approach, highlighted by previous research into the performance of flashing operation. Responses from UK local highway authorities suggest concerns over their potential for use within the UK.

6.1.4 The key issues are:-

- Safety for drivers and pedestrians;
- Road user perception of flashing signal operation; and
- Availability of appropriate guidance for ‘safe’ use of flashing signals.

6.1.5 The concerns raised by the UK local authorities are detailed in Chapter 4. This chapter summarises previous overseas research in to the safety of alternative forms of traffic signal control during LD periods.

## 6.2 Findings

6.2.1 The prominent research into the topic of flashing LD operation of traffic signals is from the USA. A number of studies have been conducted to assess whether flashing signal operation has a significant effect on accidents at junctions.

6.2.2 The majority of papers compare where junctions have been changed from using flashing signals (either 4-way or with an identified priority to the major road) late at night and early morning to normal signal operation, as summarised below, with one research paper comparing accident rates for a change to using flashing operation from normal operation.

***Change from flashing signal operation to normal signal operation***

6.2.3 Polanis [22] published an article in the Institute of Transportation Engineers (ITE) Journal using 19 case studies to identify whether a relationship exists between flashing traffic signal operation (4-way stop) and numbers of right-angle accidents. All 19 locations previously utilised flashing amber signals in LD periods, however normal traffic signal operation was reinstated when accident studies highlighted a particular issue with collisions.

[22] Polanis (2002) *Right angle crashes and late night/early morning flashing operation*

6.2.4 The article compares the accident record for the junctions before the change to normal operation and for a similar period after the change. A summary of the combined accident numbers for all 19 locations is shown in **Table 4** below.

**Table 4 –** Summary of Low Demand period accident data from 19 case studies

| Scenario | Total no. of months recorded | No. of Right-angle accidents | Total no. of accidents | % accidents right-angle/total |
|---|---|---|---|---|
| **Before (flashing)** | 888 | 156 | 612 | **25.5%** |
| **After (normal)** | 906 | 35 | 413 | **8.5%** |
| | | **-78%** | **-33%** | |

6.2.5 The above table indicates that 25.5% of the collisions that occurred at junctions using flashing operation were due to right-angle collisions, potentially where minor road vehicles failed to give way to mainline traffic. When the junctions reverted to normal signal operation during LD periods the total number of accidents fell by 33%, with right-angle collisions reduced by 78%. The comparatively low reduction in accidents compared to the impact on right-turning incidents suggests there was a change in accident type when reverting to normal traffic signal operation.

6.2.6 The article also considers each location in turn. The results are similar to the summary table above; the data indicate that ceasing the use of flashing signal operation at the 19 sites reduced the number of accidents; the author noted that at locations with a high main road to minor road traffic ratio i.e. with a heavier mainline movement, there was no guarantee that right angle collisions would be reduced.

6.2.7 The author concluded that there are some locations where the use of flashing signal operation does not impact on the number of right-angle collisions, and it remains a “strategy to reduce delay that need not be abandoned”. Its use requires careful consideration and monitoring is key; “a strategy that monitors, on a regular basis, crash activity associated with signals programmed for late night/early morning operation and removes the method of operation from use if patterns emerge approaches the criteria for an ideal safety improvement”.

6.2.8 It is considered that this conclusion is based on the USA already utilising flashing signal operation, thus monitoring existing installations is a viable course of action. In countries where flashing operation is not currently used, there might be some objection to providing a method of operation perceived to be less safe than full signal control,

6.2.9 Barbaresso [23] similarly compared before/after studies of junctions transferred from 4-way flashing amber control to normal traffic control. 6 sites, specifically 4 arm junctions, were chosen at random based on them having changed their method of LD control. Accident data for three years before and three years after the change in control was analysed for trends in accident types and frequency.

6.2.10 10 other sites were selected as control data, to augment the analysis of accident trends against traffic flows, ratios of mainline to minor road traffic and the presence of alcohol related incidents.

[23] Barbaresso (1987) *Relative Accident Impacts of Traffic Control Strategies During Low-volume Night-time Periods*

6.2.11 **Table 5** below summarises the accident rates per million vehicles identified as right angle collisions, during flashing operation.

**Table 5** – Right angle accident rate per million vehicles

| Site | Right-angle Collisions Accident Rate per Million Vehicles | |
|---|---|---|
| | **Before (Flashing signals)** | **After (normal operation)** |
| 1 | 6.31 | 1.26 |
| 2 | 35.06 | 0.00 |
| 3 | 16.31 | 0.00 |
| 4 | 3.90 | 0.56 |
| 5 | 6.83 | 0.00 |
| 6 | 13.11 | 0.00 |
| **Total** | **81.52** | **1.82** |
| **Mean** | **13.59** | **0.30** |

6.2.12 The results indicate that right angle accident rates were reduced through the removal of flashing signal operation from existing traffic signal installations. They do not however discuss the total change in accidents; as with the Polanis study, the number of total accidents might not have reduced by the same degree; the number of shunt type accidents could have increased with the introduction of signal control. The author also made the following conclusions based on detailed analysis of the accident data:

- It was noted that alcohol impaired drivers were more likely to be involved in a collision at a junction in flashing signal operation rather than under full signal control;
- The frequency of accidents due to right-angle collisions was highest in the early hours of the morning, between 12AM and 3AM. The author noted a similar pattern emerged at normal traffic signal controlled junctions, coinciding with bars closing;
- Junctions with lower ratios of mainline to minor road traffic during LD periods experienced a higher accident rate than those junctions with a dominant main line flow;
- It was concluded that traffic volumes did not directly affect the frequency of right-angle collisions when flashing signals were in operation, rather the ratio of traffic on the approaches as described above; and
- Normal signal controlled junctions recorded a higher number of rear-end shunts than junctions under flashing signal operation during LD periods, though this statistic was based on total accident. As a number of accidents per million vehicles, little difference was recorded between normal and flashing traffic signal operation.

***Change from normal signal operation to flashing signal operation***

6.2.13 The Federal Highway Administration (FHWA) commissioned a series of studies into the operation of flashing traffic signal operation. One of these studies, carried out in 1980 by Benioff, et al [24] concentrated on the safety impact of San Francisco changing a number of traffic signal installations to utilise flashing signals late at night.

[24] Benioff, Carson, Dock (1980) *A study of clearance intervals, flashing operation and left turn phasing at traffic signals: volume 3 flashing operation*

6.2.14 San Francisco converted 413 signal controlled junctions to provide flashing signals during LD periods. A number of different flashing signals were used, as summarised below:

- 375 junctions changed from normal operation to amber/red flashing signals;
- 36 junctions were changed from normal operation to red/red flashing signals; and
- 2 intersections were changed from amber/red to red/red flashing operation.
- 107 of the junctions within San Francisco remained under normal traffic signal control. Accidents were recorded throughout the process of the signal control conversion, providing before and after accident rates for 24 hour periods by type of installation.

6.2.15 The conclusions suggested a significant increase in the number of right-angle collisions where junctions formerly operating under full traffic signal control had been changed to amber/red flashing operation. There was no significant change in the number of accidents for the 107 junctions that remained under full traffic signal control.

6.2.16 A similar National Study was carried out in 1993 under a separate study by Kacir et al [25], resulting in a series of guidelines being published in 1995.

6.2.17 This study was also undertaken as a commission from the FHWA. In addition to literature reviews and surveys of current practice, accident trends relating to flashing signal operations were investigated.

6.2.18 A number of sites were chosen for the four year period accident investigation, all four arm junctions currently under traffic signal control. The 200 sites were categorised as:-

- Junctions remaining under flashing signal operation;
- Junctions remaining under 24 hour normal traffic signal control;
- Junctions changed from normal operation to flashing signals; and
- Junctions changed from flashing signals to normal operation.

6.2.19 The accident analysis in **Table 6** summarises the average number of accidents recorded at each junction type.

**Table 6 –** Low Demand traffic signal use accident frequencies

| Time Period | Number of accident per junction control change | | | |
|---|---|---|---|---|
| | Normal to Flashing | Flashing to Normal | Normal Unchanged | Flashing Unchanged |
| Before | 13 | 1 | 12 | 2 |
| After | 32 | 0 | 13 | 12 |
| **Total** | 45 | 1 | 25 | 14 |

6.2.20 It can be seen that the change from normal operation to flashing operation yielded an increase in accidents, as suggested in other research papers. However retaining flashing operation also yielded an increase in accidents, though no specific reason for this was provided.

[25] Kacir et al (1993) *Evaluation of flashing traffic signal operation*

***Guidance***

6.2.21 Following a number of accident studies, some summarised above, a second study[26] was commissioned to provide guidance for the provision of flashing signal operation. This gave the following guidelines:

- **Actuated Traffic Signals –** If a traffic signal is capable of operating in the actuated mode, then flashing operation generally should not be used as a control strategy during low-volume conditions.
- **Pre-timed Traffic Signals** – In general, amber/red flashing operation can be considered at a junction if the following conditions are present:
- Major street two way volume is less than 500 vehicles per hour;
- Minor street volume is less than 100vph;
- Major to minor street volume ratio is greater than 3:1; and
- There has been no more than one accident at the junction during the preceding two years of normal signal operation.

6.2.22 Red/red flashing operation could be used if there are six or more lanes on the major street and the junction meets the following guidelines:

- Major street two way volume is less than 500 vehicles per hour;
- Minor street volume is less than 100vph;
- Major to minor street volume ratio is less than 3:1;
- There has been no more than one accident at the junction during the preceding two years of normal signal operation; and
- It is an isolated junction (more than ½ mile from adjacent junctions).

***Summary***

6.2.23 Each paper reviewed highlighted the increase in accidents as a result of changing the method of operation to provide flashing operation in place of normal traffic signal control, or inversely accident savings were recorded where signals had reverted to full signal control from flashing operation.

6.2.24 However many of the results focus on the change in accidents attributed to right-angle collisions rather than looking at all accidents. A shift might occur in the type of accident between priority and signal controlled junctions, for example increases in the number of shunt type accidents. Other factors could also contribute to increases in accidents which do not relate to the change in method of operation; Barbaresso highlighted a number of these, including incidents involving alcohol impaired drivers.

6.2.25 US guidance does not specify that junctions should not revert to priority mode of operation during LD periods; rather, it suggests that designers must carefully consider the use of flashing signals. If vehicle actuated systems are available then it is advised that flashing signals should not be considered. However traffic signals under ‘fixed time’ operation (which could include UTC control) could cause significant and unnecessary delay to vehicles during LD periods; in these circumstances flashing amber operation is suggested as a suitable form of control provided the accident rate is low and traffic demand is sufficiently low.

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[26] Kacir et al (1995) *Guidelines for the Use of Flashing Operation at Signalised Intersections*

# Development of Assessment Techniques

# 7 Option Assessment

## 7.1 Overview

7.1.1 It is clear that current UK policy limits opportunities for adapting the operation of traffic signals during LD periods. Any change to current UK legislation to permit alternative traffic signals operation will have to conform to the 1968 Vienna convention, thereby permitting the use of flashing amber for traffic control but not flashing red.

7.1.2 Vehicle Actuation is widely used within the UK to control traffic, at all times not just during LD periods. Other countries use this technique but still use flashing signals or turn signal control off at some installations. Countries bound by the 1968 Vienna convention vary in their approach; some, like the UK, maintain 24 hour signalling, whilst others utilise flashing amber signals on all approaches at appropriate junctions. Countries not signed up to the Convention, for example Canada and the USA, use flashing red with amber, or just flashing amber.

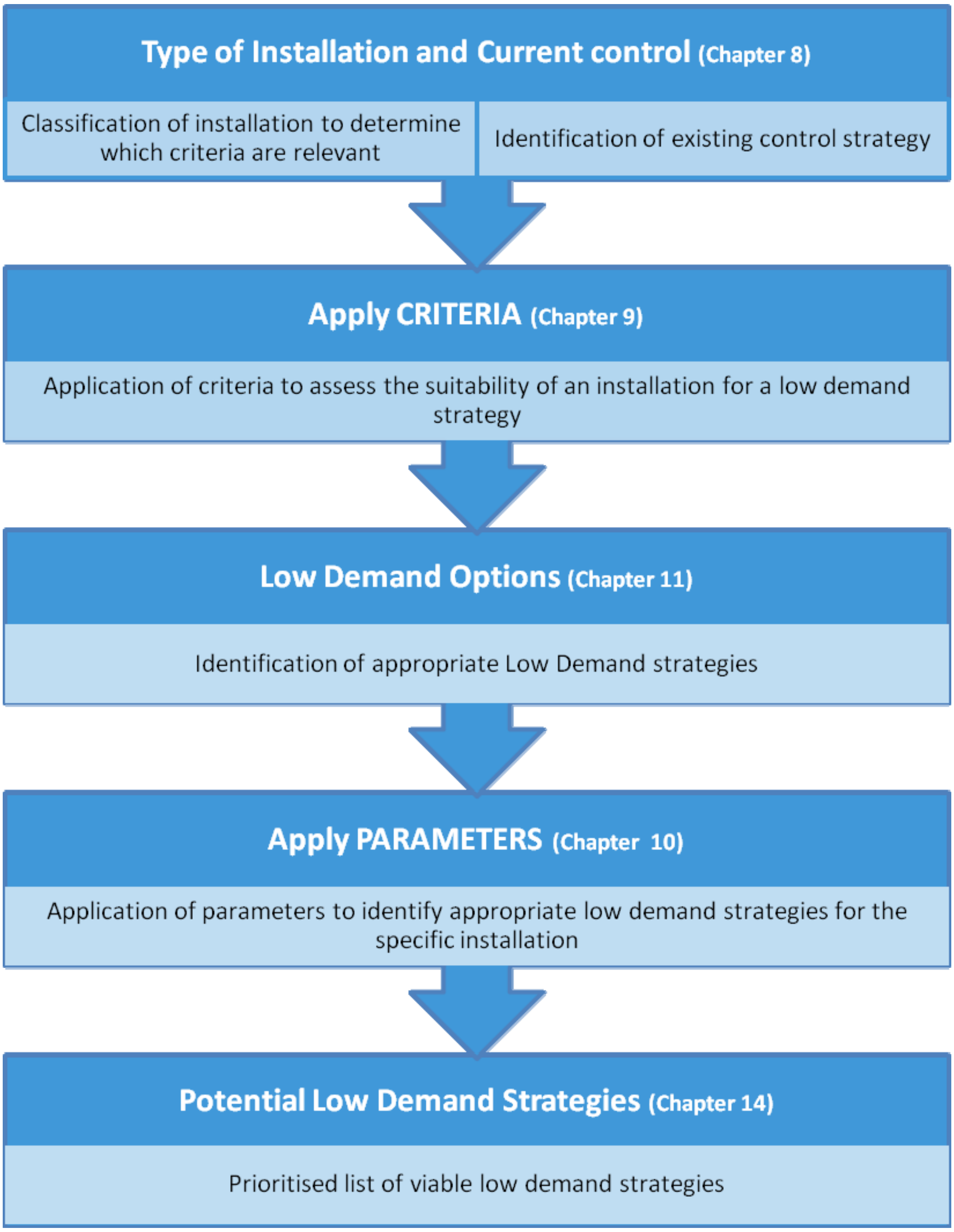
7.1.3 The techniques applied by other countries were seen to represent a potential benefit when used in the right locations. However, there are issues relating to safety, control methods and public acceptance which would need to be addressed before some of these could be adopted in the UK. There are some measures that could be implemented under existing legislation, such as quiescent all red at VA junction, which is currently adopted by only a minority of local authorities. Such operation increases the responsiveness of traffic signals to demands by reducing the time needed to start up a particular stage; rather, stages can be called almost immediately (following the red/amber starting intergreen) from the resting state.

## 7.2 Objectives

7.2.1 This stage defines a framework which assesses the suitability of applying a LD strategy to existing or new traffic signal installations. The framework is described by the process shown in **Figure 2**.

7.2.2 This process defines CRITERIA for appraising existing traffic signal installations to identify their suitability for implementation of a LD strategy, and identifies which PARAMETERS could to be applied to test appropriate strategies for each site. This framework is then used to develop specific options for traffic control during LD periods, and research elsewhere used to assess each option and determine its suitability for application in the UK.

**Figure 2 –** Process for assessing an installation



# 8 Factors Influencing Traffic Signal Control Strategies

## 8.1 Overview

8.1.1 Though there are many options available for operating traffic signals during normal operation and during LD conditions, trends were identified for the methods currently employed by local authorities.

8.1.2 In addition, a list of constraints applicable to the operation of traffic signals has been identified and collated into a list of parameters that should be checked during a site assessment to influence the control method used in LD periods.

## 8.2 Current Control Strategies

- SCOOT and fixed time UTC: generally local authorities retain UTC control or revert to VA control in LD demand periods, dependent on junction location and LD demand use;
- Isolated junctions typically operate under Vehicle Actuation, the current preferred LD demand strategy being to change the MAXSETs;
- Signal controlled roundabout strategies differ between authorities; the most favoured option is to implement a specific LD demand timing plan.

8.2.1 The review of current practices in the UK and overseas enabled a list of traffic signal operation methods to be developed. authorities employ varying strategies for managing traffic signals during LD periods; responses from local authority consultees indicated individual preferences for modifying traffic signal control during periods of LD, shown in **Table 2** (Chapter 3).

8.2.2 A common comment is that the strategy adopted has to be site-dependent, and a 'black box' solution cannot be applied blindly at every installation. Four broad categories of installation type can be considered:

8.2.3 **SCOOT and fixed time UTC systems** are commonplace in urban networks; in general networks retain UTC control or revert to VA control in LD periods, based on historic flow data and their location in relation to other installations. In addition, policy decisions would determine what operational strategies are used.

8.2.4 **Isolated installations** typically operate under Vehicle Actuation, therefore the preferred strategy is to change the MAXSETs to shorten the potential cycle time and reduce delays. At some installations VA is not used, instead relying on CLF (cableless linking facility – allows installation timings to be synchronised with other installations via internal clocks) or fixed time signals to control traffic with a fixed cycle time and stage sequence.

8.2.5 **Signal controlled roundabout strategies** differed between authorities:

- The leading choice for standard practice was changing the roundabout to operate on an LD specific timing plan; maintaining traffic signal coordination throughout the roundabout was considered essential.
- Four authorities indicated that VA was used as a method of operation; the use of VA is based on individual site conditions where flow conditions allow this method of operation to be used and traffic levels are sufficiently low that coordination is not required.

- Similarly the use of part time signals is site dependent, and not used significantly as a method of control. A recent Local Transport Note[27] brings into question the safety of part-time signals, and their use is declining. Where part time signals are in operation, comments relating to their use affirmed that they were generally only considered at roundabouts where partial signalisation existed; fully-signalled roundabouts were not considered appropriate for part-time signals. Where they are used, part time signals are activated by UTC timetable or upon predetermined flow conditions being met.

8.2.6 **Mid block crossings** represent all stand-alone signal controlled crossings, including Pelican, Puffin, Equestrian and Toucan crossings. They are usually demand dependent, with VA providing vehicular traffic with green time extensions where necessary, although when located within a UTC/SCOOT network their operation will be synchronised with adjacent junctions in the network. Local authority practices differed in the use of different MAXSETS or the application of pre-timed MAXSETS during LD periods.

8.2.7 The traffic signal control strategies for which site constraints are to be identified can therefore be summarised as:

- Networks utilising adaptive UTC
- Networks utilising fixed time UTC
- Installation operating Vehicle Actuation
- Signalised roundabouts
- Junctions operating fixed time, or with CLF
- Mid-block pedestrian crossings.

## 8.3 Constraints to traffic signal operation

Constraints likely to be encountered with the introduction of traffic signal controlled junctions include:

- Junction Location;
- Junction Type;
- Junction Design;
- Traffic Conditions;
- Non-motorised user requirements.

8.3.1 There are a number of physical and dynamic issues which need to be considered before implementing traffic signal control at any location, and the method of signal operation is site dependent based on the objectives for the installation control. These parameters, discussed more fully in Chapter 10 of this report, have been considered for their potential impact on the introduction of alternative LD strategies and are summarised in **Table 7** opposite:-

[27] DfT (2009) *LTN 1/09, Signal Controlled Roundabouts*

**Table 7 –** Constraints affecting traffic signal control strategies

| Category | Constraint | Low Demand Implications |
|---|---|---|
| **Installation Location** | Large Urban/Urban/ Non-urban | Flow profiles will differ with regard to peak periods experienced. The introduction of an LD strategy will need to be consistent irrespective of the area. |
| | Proximity of adjacent installations | Closely associated junctions generally require coordination to be maintained at all times. This is achieved either by CLF, UTC control, linked VA or linked MOVA. Where coordination is not required, VA/MOVA is the normal mode of operation |
| **Installation Nature/Type** | Roundabouts | Roundabouts require coordination between arms to operate effectively. |
| | 3 arm junctions | These junctions generally operate under easily understood staging arrangements; therefore there is the potential to introduce alternative LD strategies. |
| | 4 arm junctions | |
| | Complex junctions (e.g. gyratories) | Junctions with complex layouts and requirements for control might not be suitable for certain LD strategies. |
| | Pedestrian and/or cycle facilities at junctions | Such facilities are integral within signal controlled installations and their incorporation should form an integral part of the design process., |
| | Mid-block pedestrian crossings | Mid block crossings already operate to a high level of efficiency, Benefits of LD operation could be lower than other installations. |
| | Grade separated junctions | The difference in nature of grade separated junctions will impact on potential LD strategies. For example, it would not be desirable to introduce a method of operation that would stack vehicles on the slip roads of a motorway rather than on the circulatory carriageway. |
| **Installation Design** | Detection Equipment | The detection required for the various control strategies differs. It might be necessary to introduce additional detection equipment to facilitate alternative LD control. |
| | Stopping sight distances | SSD is considered when determining the primary form of signal control at a junction. It will also determine whether LD strategies reverting to priority mode of operation will be feasible. |
| | Junction intervisibility | DMRB specifies visibility requirements for signal controlled junctions (mandatory only on motorways/trunk roads), which are less onerous than for priority junctions. |
| | Speed | The speed of traffic will have a significant influence on the possible LD strategies that could be considered for an installation |
| | Street lighting | A poorly lit installation will affect visibility and the potential to introduce alternative forms of control. |
| | Hurry Call/Select vehicle priority | The requirement for maintaining priority measures, for example for buses or emergency service vehicles, will need to be considered during LD periods. |
| | Angles of intersection | Whilst less critical at signalised junctions, some LD options could be more difficult to implement at skewed junctions. |

| Category | Constraint | Low Demand Implications |
|---|---|---|
| **Traffic** | Mainline flow | Overseas guidance suggests establishing datum mainline flow values above which LD operation should not be considered. |
| | Side road flow | The side road flow is equally as important as the main road flow in terms of acceptable levels for LD strategies. |
| | Main/side road ratio | Some overseas guidance considers ratios of main/side road flows when determining the suitability for LD operation. |
| | Collision record | Within the UK, collision records at signal-controlled junctions are generally low compared with priority junctions. Installations with higher than average collision rates might not be suitable for the introduction of LD strategies. |
| **Non Motorised Users** | Pedestrian volumes | Where 24-hour pedestrian demand exists, the need to provide full-time controlled crossing facilities would restrict the choice of LD strategies. |
| | Visually-impaired users | Standardised facilities for visually impaired pedestrians (e.g. audible and tactile facilities) are recommended in the UK. In particular, differing types of tactile paving are used to indicate controlled and uncontrolled crossing points. Any change to control methods could result in confusion. |
| | Equestrians | Consideration for equestrians would need to be given at some locations. |
| | Cycle routes | Toucan crossings can be treated in a similar manner to pedestrian facilities. Locations with on-street signalled cycle lanes could be treated in a similar way by provision of select vehicle facilities.. |

# 9 Low Demand Criteria

## 9.1 Definition

CRITERIA – Used to assess whether a specific installation is suitable for the introduction of a LD strategy.

9.1.1 These criteria could potentially act as triggers to switch automatically between standard operation and the LD strategy selected.

9.1.2 Though the criteria will be largely based upon flow characteristics, the choice of a specific LD strategy will depend on factors such as the type of installation. The suitability will be defined through the following steps:

- Identification of the type of installation
- The current method of traffic signal control
- Flow characteristics

## 9.2 Type of Installation

- Installations should retain their legibility to road users, including potential conflicts and priority, irrespective of the method of operation used during LD periods.

9.2.1 One strategy would be to revert to priority operation during LD periods, as with part-time signalised roundabouts. The significance of this is that, during periods when the signals are not operating, the junction retains its legibility to all road users such that the conventional roundabout priority mode of operation is observed. The same cannot be said of most other types of installation (except, perhaps, 3-arm junctions with an obvious 'main road/side road configuration and no pedestrian facilities). Hence the adoption of this specific strategy would have to be restricted to a very limited range of junction types, whereas other strategies could be applicable to a wider range of installations.

## 9.3 Method of current control

- The current method of control could affect whether alternative LD strategies should be considered.
- If VA is in operation at a junction, there might be little benefit in changing the operation method.

9.3.1 TR2500, the specification covering the essential requirements for traffic signal controller equipment, lists a specific set of control strategies in Appendices A to F. The current method of control could affect whether LD strategies should be considered, as summarised below:

A. *Vehicle Actuated* – If a traffic signal installation has the capability to operate under VA or MOVA, overseas guidance suggests that there is little benefit in changing the operation method in LD periods to a method utilising priority mode of operation; it is preferable to introduce an LD timing plan with a shorter maximum cycle time. Additionally, quiescent all-red could be introduced to decrease the time taken to serve a demand, thus minimising delays for junctions operating under VA.

B. *CLF* – A traffic signal installation operating under CLF is likely to require coordination with adjacent junctions, particularly during peak periods. The decision on whether an alternative LD strategy is appropriate will be site specific, depending on the level of coordination required during periods of LD.

C. *Part time* – Part time signals already represent an LD strategy applied to roundabouts and other locations where controlled facilities are only required for parts of the day. The application of part time signals is site dependent.

D. *Hurry Call* – Hurry calls are used where it is desirable to minimise the delay experienced by a particular vehicle type, for example to allow emergency service vehicles to call a dedicated stage sequence and prevent other conflicting movements from being called whilst the vehicle navigates a junction or network. Such hurry calls usually operate 24 hours a day; therefore LD strategies must retain the ability to suppress conflicting movements in the event of an emergency.

E. *Vehicle Priority* – Priority measures are used to allow certain vehicle types to register a demand and receive priority over conflicting movements. Examples of this are bus priority and cycle priority. The ability to implement alternative LD strategies will depend on whether the priority measures must be maintained 24 hours a day and whether they control segregated links, in which case they must be incorporated into the selected strategy.

F. *UTC (adaptive/fixed time)* – UTC networks are designed to maintain coordination within networks of traffic signal installations. The current LD strategies adopted by UK authorities differ primarily based on site conditions. Some junctions continue under UTC control to retain coordination irrespective of changes in demand patterns, whereas other installations might revert to VA where appropriate detection exists and the local authority deems no coordination is required with other installations. Two UK authorities confirmed their use of VA as an LD alternative to retaining UTC control, though only at a percentage of installations.

## 9.4 Flow Criteria

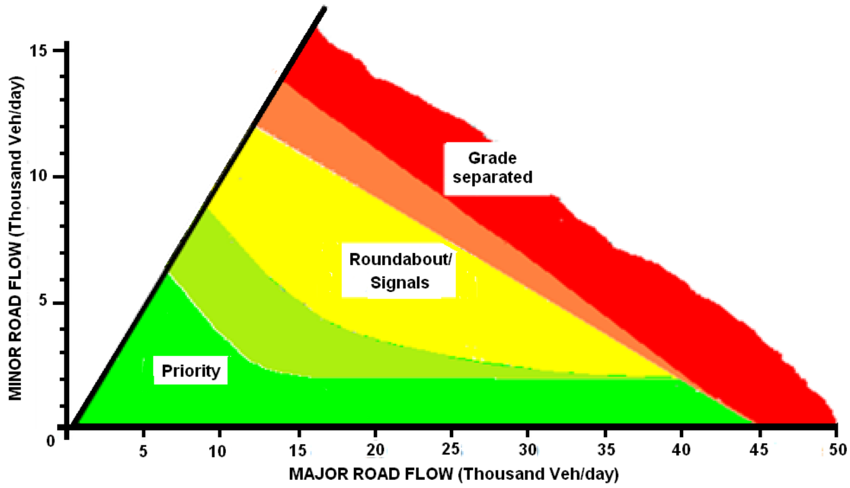
- Base flows for major/minor roads and pedestrians should define when a LD strategy becomes operational.
- Timetabling would standardise permitted changes to predictable times of day, such as late nights and early mornings.
- Site trials would be required to determine numerical data for flow criteria.

9.4.1 Traffic flows in general, and specifically the relationship between flows on the major and minor road at a junction, determine the selection of control during normal demand conditions. **Figure 3** from Transport in the Urban Environment[28] provides an indication of the recommended method of operation of a junction based upon the ratio between daily traffic flows on the major and minor arms.

9.4.2 The conditions under which priority mode of operation (green), roundabouts/signals (yellow) and grade separated junctions (red) should be used are clearly indicated. However the 'overlap' areas indicate flow conditions where consideration would be given to either strategy. This method of selection, based both on flow volumes and ratios, could be adapted to identify the suitable categories of LD strategy for an installation. The above methodology would require adaptation to perhaps consider hourly flows rather than daily demands.

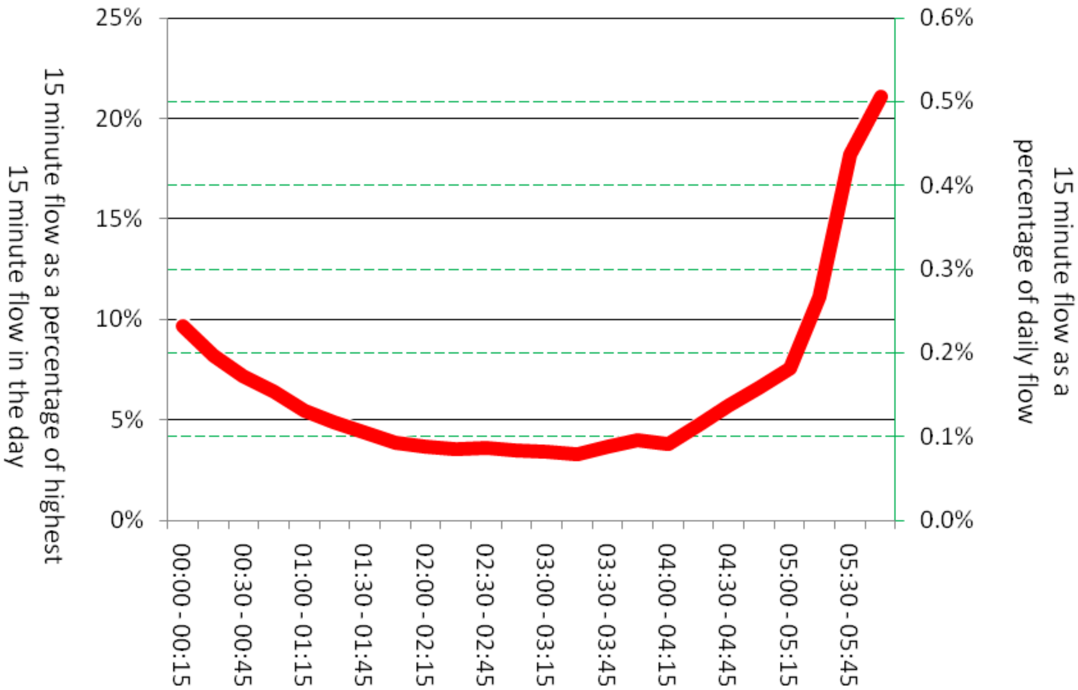
[28] Institute of Highways and Transportation (1997) *Transport in the Urban Environment*

**Figure 3 –** Junction control method based on major/minor road flows




9.4.3 In order to adapt the above concept for LD use, analysis of 24 hour periods over 7 days would be required to ascertain whether an installation would be suitable for an LD strategy. Sample data from a cordon survey has been examined to identify potential trigger values as a percentage of peak and 24-hour flows (**Appendix A**), and the summary graph in **Figure 4** suggests that perhaps a flow of 5% of peak hour flow, or 0.1% of 24-hour flow, might be appropriate. Site trials would be required to determine numeric thresholds below which LD strategies could be considered.

**Figure 4** – Overnight traffic flows as a percentage of peak and 24-hour flows



9.4.4 In addition to traffic volumes, pedestrian and cyclist demand will need to be taken into account when establishing suitable time periods to implement LD strategies. Pedestrian volumes generally fall during late night and early morning periods as with traffic. However, at some locations Non Motorised User (NMU) demands might remain or peak at atypical times, for example close to schools and colleges, or due to the night time economy. Where this occurs it would be inappropriate to introduce an LD strategy which would impact on the signalled control of pedestrian movements.

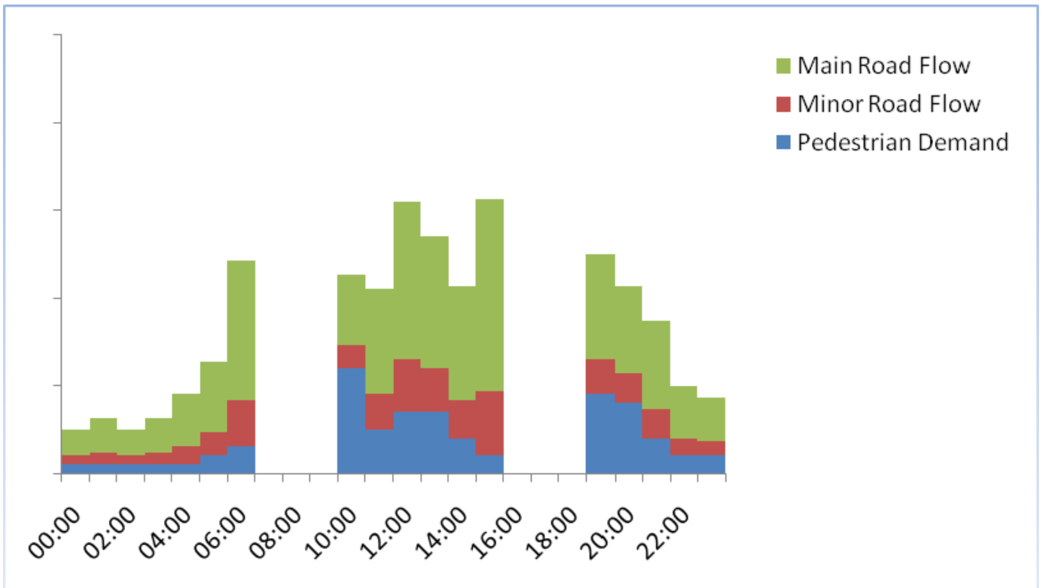
9.4.5 Overseas research provides guidance on utilising LD strategies reverting to priority mode of operation based on traffic flows. It suggests that major road flows should be less than 500 vehicles per hour[29], but also that the minor road flows should be low enough to provide a major/minor road traffic volume ratio of 3:1 or greater.

9.4.6 Taking in to account the three demand criteria, and assuming the minor road flow would be a ratio of the major road flow, a logic formula could be derived with which to determine when low strategies would be suitable. For example, a LD strategy could be deployed if:

Main Road Flow < X vehicles per hour (vph)
**AND**
Minor Road Flow < X/3 vph (assuming a ratio of 3:1)
**AND**
Pedestrian flow < Y pedestrian per hour (pph)

9.4.7 **Figure 5** illustrates a hypothetical flow profile for major road, minor road and pedestrian demand over a 24 hour period.

**Figure 5 –** Hypothetical major road/minor road/pedestrian demand profile




9.4.8 Switching to LD strategy could be suppressed during peak periods and perhaps other site-specific periods, to prevent switching during inappropriate times of day. This is illustrated in **Figure 5** above, with the LD strategy parameters isolated between 0700-1000 and 1600-1900.

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[29] Kacir et al (1995) *Guidelines for the Use of Flashing Operation at Signalised Intersections*

9.4.9 One UK County Council identified a concern that permitting installations to change operation mode based on traffic flow during the day would result in apparently “random” changes in control. It was suggested that it would be better to use standard times of day rather than flow criteria, so that drivers know when to expect alternative forms of control, such as those reverting to priority mode of operation. Timetabling could be introduced to restrict initiation of the LD strategy to predictable times of day, such as late nights and early morning.

# 10 Site Assessment Parameters

## 10.1 Definition

- PARAMETERS – Used to determine which (if any) strategies would be suitable for an installation satisfying the criteria defined in **Chapter 9**.

10.1.1 Signal control is applied in various circumstances, with sites classified in a variety of ways such as urban (town and city environment) / non-urban (suburban or rural environments), linked/isolated and simple/complex. The application of any LD strategy will depend on numerous site dependent factors. This Chapter discusses assessment parameters that could be used to determine which, if any, LD strategy might be suitable for any given installation, to allow consistent categorisation of a particular junction or series of junctions.

## 10.2 Assessment Parameters

***Installation Location***

Urban/Non-urban

- Urban networks generally experience prominent peaks throughout the day, less pronounced in rural areas.
- Absolute traffic volumes per hour or per cycle would provide a consistent approach to determining LD periods, although there could also be a need to relate the parameter to peak period demands.

10.2.1 Urban and non-urban roads represent different operating environments in terms of highway use and traffic control. Two key differences are the behaviour of traffic in terms of flow profiles throughout the day and vehicle speeds.

10.2.2 In urban environments, speeds limits are generally lower (30-40mph) and vehicle speeds could be lower due to higher volumes of traffic and property frontage activity. At the other end of the spectrum, non-urban roads might allow higher speed limits which are more readily attainable due to a reduced level of traffic. The speed limit might affect the application of LD strategies, as discussed under Junction Design below.

10.2.3 In addition, urban environments generally experience peak periods in the morning and evening (and during an interpeak period in many towns and cities) as motorists commute to and from Central Business Districts. Outside of these peak periods traffic levels can drop quite dramatically. These peaks could be less pronounced in non-urban locations which do not include business districts; the levels might remain fairly steady and comparatively low throughout the day albeit with perhaps small peaks from school run traffic. The profile of traffic demands could make it preferable to adopt absolute traffic volumes as the switching criterion to ensure consistency, rather than considering a percentage of peak hour demands.

Proximity of adjacent installations

- Close networks of junctions could need to maintain coordination; therefore certain LD strategies would not be suitable. Conversely, linking could actually be *less* desirable during LD periods as it could introduce unnecessary delays to minor roads.
- Isolated junctions have a wider scope for implementing alternative LD strategies as no coordination is required.
- Guidance suggests 1km as an appropriate distance above which installations could be considered isolated. Adjacent installations less than 1km apart could be more suitable under co-ordination.
- The impact of adjacent installations is site dependent rather than prescribed by a set distance.

10.2.4 The location of an installation will be critical for determining whether a LD strategy can be utilised. Installations not in close proximity to others and operating independently could potentially switch to LD status based on conditions at that installation in isolation.

10.2.5 However if there is a close network of junctions, they could be under UTC control (adaptive or fixed time) in which case it might be preferable to change timing plans to cater for periods of LD to maintain coordination and control vehicle progression through the network. This view was prevalent in the responses from UK local authorities, where several confirmed their use of LD timing plans to reduce the delay to vehicles. One authority specifically commented that site specific decisions were made, accounting for traffic flows, the proximity of the other sites, the speed limits etc. to determine whether to run fixed times at all times of the day or revert to VA.

10.2.6 The opinions on alternative operation methods confirmed that LD strategies should depend primarily on site conditions. Many busy junctions remain under coordinated control within city centres irrespective of localised LD conditions. It is only at installations with appropriate detection and where no coordination is required with other installations that VA is used.

10.2.7 The operation of junctions within a local authority's jurisdiction, including distances under which junctions are considered part of a network, is usually determined by internal policies. However TAL 7/99[30] recommends that "when junctions are some distance apart (more than about 1km) isolated junction control [may be more appropriate". It is generally accepted that an installation is independent when the platooning effect of adjacent installations dissipates between them; hence there is no interaction between them. Obviously, this is very much dependent upon numerous site specific conditions, including speed, distance and intervening elements that could cause break up of platoons.

10.2.8 Overseas guidance for using alternative LD methods rarely mentions information on distances between installations. USA guidelines recommend that red/red flashing operation should only be considered at isolated installations, more than 0.5 miles (800 metres) from adjacent installations. However it should be noted that the red/red flashing operation signifies a four way stop, which does not have an equivalent in the UK. The alternative flashing red/yellow does not specify a minimum distance between installations.

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[30] DfT (1999) *Traffic Advisory Leaflet 7/99, The "SCOOT" Urban Traffic Control System*

10.2.9 It is considered that the impact of adjacent installations is site dependent rather than prescribed by a set distance, given the individual nature of junctions operating as isolated junctions or under UTC. Therefore installations which are affected by the arrival patterns of upstream junctions or affect downstream junctions might require different consideration to those isolated junctions which can operate without influencing the behaviour of other junctions.

***Installation Design***

Stopping sight distances

- Provided the traffic signal installations meet specified desirable minimum visibility (which may differ by local authority), any LD strategy should be feasible.
- If the minimum visibility requirement is not met, strategies reverting to any form of priority mode of operation might not be applicable.

**Table 8** –Stopping sight distance requirements from Manual for Streets 2 (MfS2) for urban areas and all purpose trunk roads

| Design Speed | Vehicle Type | Reaction Time | Deceleration Rate | Comments |
|---|---|---|---|---|
| 60kph and below | Light vehicles | 1.5s | 0.45g | |
| | HGVs | 1.5s | 0.375g | See 10.1.9(MfS2) |
| | Buses | 1.5s | 0.375g | See 10.1.10(MfS2) |
| Above 60kph | All vehicles | 2s | 0.375g (Absolute Min SSD) | As TD 9/93 |
| | All vehicles | 2s | 0.25g (Desirable Min SSD) | As TD 9/93 |

10.2.10 Manual for Streets 2[31] gives latest guidance on stopping site distance (SSD) for urban roads where the design speeds are below 60kph. For speeds above 60kph, reference should also be made to design guidance given in the Design Manual for Roads and Bridges (TD 9/93)[32]. The SSD is defined in the Manual for Streets 2 as the distance drivers need to be able to see ahead and they can stop within from a given speed. SSD is calculated from the speed of the vehicle, the time required for a driver to identify a hazard before applying breaks and deceleration rate of the vehicle.

The basic formula used for calculating SSD (in metres) is $SSD= vt+v^2 /2(d+0.1a)$

Where: v=speed (m/s)

t= driver perception-reaction time (seconds)

d= deceleration 9m/s$^2$)

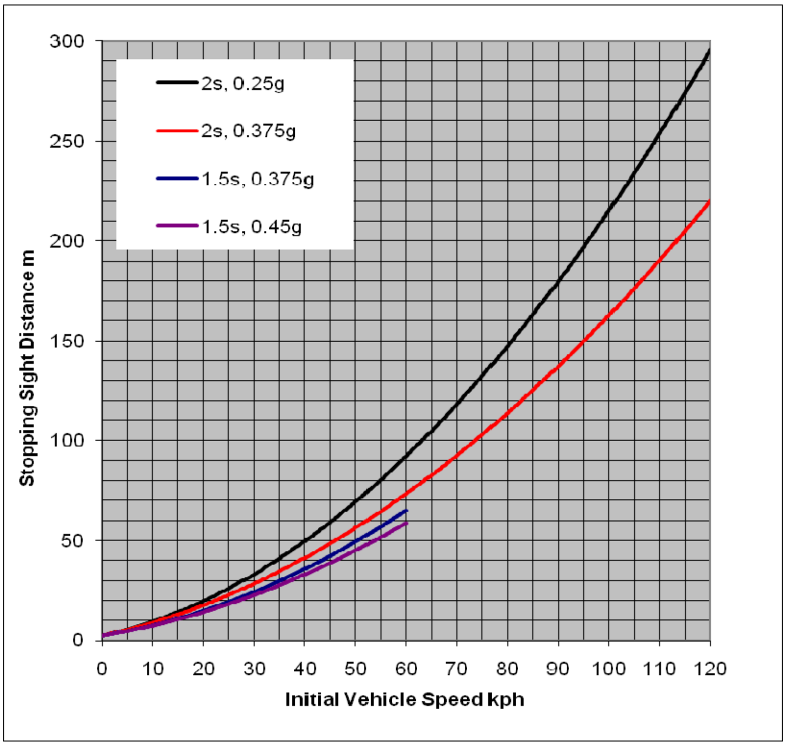
a= longitudinal gradient (%)

(+for upgrades and – for downgrades)

[31] CIHT 2010 *Manual for Street 2: Wider Application of the Principles*

[32] DMRB Volume 6 Section 1 (1993) *TD9/93, Highway Link Design*

**Figure 6** – Graph showing recommended SSD values, allowing for bonnet length.



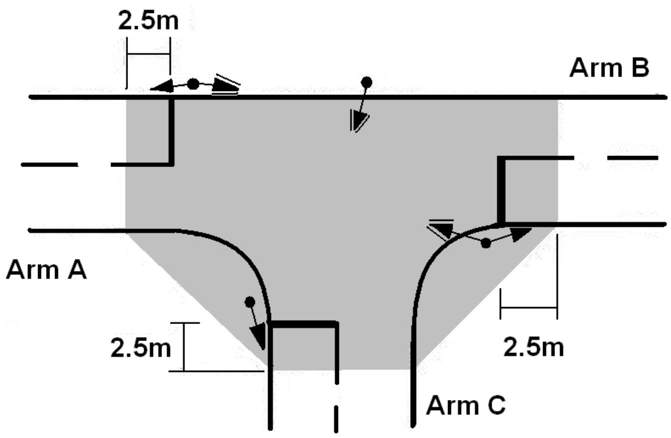

10.2.11 It should be noted that local authorities will likely have their own guidance which might be based on the Manual for Streets or the DMRB but with amendments based on local policies. Any signal controlled installation should aim to have adequate minimum visibility on all approaches to operate under any considered LD strategy.

Junction Intervisibility

- Traffic signal controlled junctions require that intervisibility is present between junction arms.
- The visibility requirements for priority junctions must be achievable if LD strategies changing to priority mode of operation are to be considered.

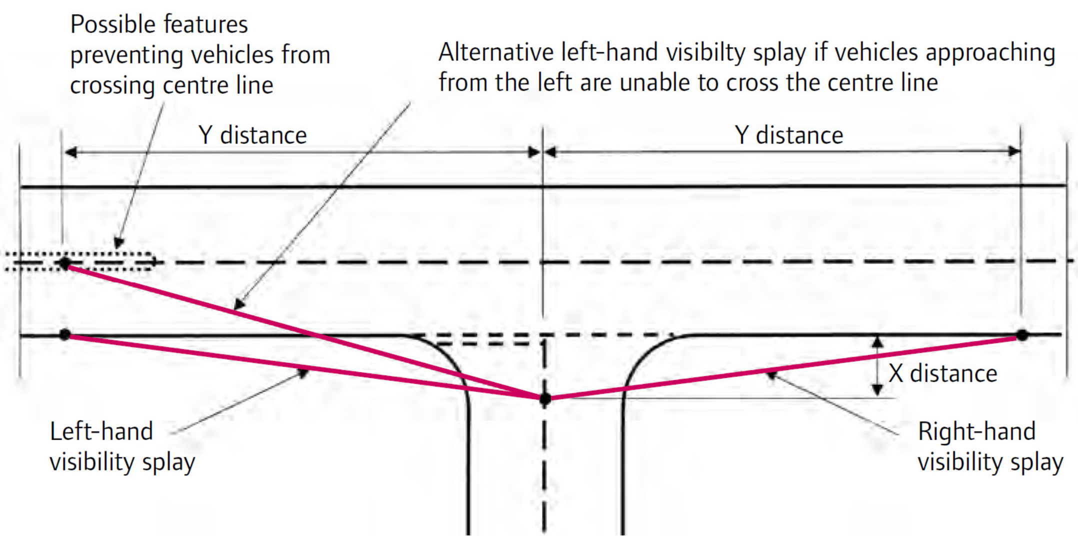
10.2.12 The visibility assessment for a signal controlled junction requires that opposing arms are visible from a distance of 2.5m back from each stop line, creating an intervisibility zone in which there must be no major visual obstruction (not including lighting columns, traffic signal poles etc). The intervisibility zone is given in TD 50/04, and is reproduced in **Figure 7** below.

**Figure 7** – Junction intervisibility zone for a signal controlled junction




10.2.13 The visibility requirements for signal controlled junctions are expressed differently than for priority junctions. Because signal control removes the conflicts, there is no need to differentiate between major and minor arms. In contrast, a priority junction requires vehicles on the minor road to have sufficient visibility to see approaching vehicles from either direction on the major road, the distance varying dependent on the major road speed limit. This visibility distance is known as the ‘y’ distance, and is illustrated in **Figure 8**. The required visibility splay should be achievable from a distance x on the minor road, measured from the kerbline of the major road Manual for Streets suggests 2.4m as appropriate for urban areas, with reduction to 2m in very exceptional low-trafficked areas. As with stopping sight distances, it should be noted that local authorities will likely have their own guidance which might be based on Manual for Streets or the DMRB but with amendments based on local policies.

**Figure 8** – Visibility requirements for a priority junction (extract from Manual for Streets 2)



10.2.14 Any LD strategies reverting junctions to priority mode of operation will only be viable if the appropriate visibility is present in accordance with Manual for Streets dependent on the location of the junction. If visibility requirements cannot be met, the LD strategies applicable to the junction might be limited.

***Traffic Speeds***

- 85%ile speed data should be collected for approaches to an installation to allow other site criteria to be assessed.

10.2.15 The speed of traffic approaching an installation will be an important factor in assessing the suitability of various LD options. The geometric elements detailed in this Chapter, for example visibility, generally rely on the design speed for the installation approaches. . At new or existing junctions, the 85th %ile speed measurement (in wet weather) is usually applied, although the DMRB for trunk roads assumes all junctions are new, therefore the design speed for the road must be used

10.2.16 Speed data for all approaches to an installation should be obtained to allow assessment to be carried out relating to the suitability of LD strategies based on other criteria in this Chapter.

***Angles of Intersection***

- Acute angles, that is angles less than 70$^{o}$ (or greater than 110$^{o}$), could result in ambiguous priority with LD strategies utilising priority mode of operation.

10.2.17 The design requirements for traffic signal controlled junctions[33] state a preference for major and minor carriageways to intersect at 90$^{o}$. Intersection angles between 70$^{o}$ and 110$^{o}$ are accepted where there are significant physical constraints, though issues can be encountered with vehicles performing tight turning manoeuvres and with locating secondary traffic signals.

10.2.18 Where acute angles are present at a junction, the suitability of certain LD strategies should be considered. If an LD strategy includes reverting a junction to priority mode of operation, acute angles could make the priority movements ambiguous, or cause undesirable high speed turning movements.

***Street Lighting***

- Unlit traffic signal installations will require careful examination to ensure the safety of all roads users; LD strategies relying on priority mode of operation might not be suitable if sufficient illumination (hence visibility) cannot be maintained during hours of darkness.

10.2.19 In unlit or poorly lit environments, it would be necessary to examine the visibility of road users to determine whether potential LD strategies could jeopardise safety.

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*Manual for Streets 2*

[33] DMRB Volume 6 Section 2 Part 3 (2004) *TD 50/04, The Geometric Layout of Signal Controlled Junctions and Signalised Roundabouts*

### *Select Vehicle Priority Measures*

- If select vehicle priority measures are required 24 hours a day, they must be integrated into any LD strategy.
- This could limit the ability to implement LD control utilising priority mode of operation.

10.2.20 Many installations have measures in place to provide priority for specific road user classes over general traffic. Three key examples of this are bus priority measures and emergency service vehicle hurry calls for vehicles, and cycle priority signals for non-motorised users.

10.2.21 Bus priority measures, for example bus pre-signals, might only require operation during busy periods and thus the application of LD strategies would be feasible. However some bus priority measures, such as bus gates on segregated links, would operate 24 hours a day and therefore would need to be integrated into the desired LD strategy.

10.2.22 Hurry calls are commonplace at installations adjacent to fire stations and hospitals where emergency service vehicles can request a specific stage to be called to provide them with a green signal. This form of priority measure is normally required 24 hours a day; therefore many alternative LD options might not be suitable.

10.2.23 Some overseas standards make reference to permitted use of signals when emergency service hurry call facilities are present. Specifically, Canadian federal policy makes no mention of such measures but provincial policy does; the Ontario Traffic Manual permits the use of flashing signals where “light” traffic is present, but recommends caution in their use. Such flashing signals “should only be used if there is no emergency vehicle pre-emption capability”[34].

10.2.24 The applicable LD strategies will therefore be affected by the presence of hurry calls. An assessment must be made of the viability of certain LD strategies if hurry calls or priority signals are present.

### *Detection equipment*

- The available detection at a traffic signal installation will affect which LD strategies will be suitable, unless additional equipment is to be installed.

10.2.25 The efficient operation of traffic signal controlled junctions depends heavily on accurate and reliable detection. It is essential that suitable detection systems are used for particular applications, which are correctly set up and maintained. It must also be recognised that different signal control systems require different detector locations, for example an installation under SCOOT control might not automatically have the necessary detection in place to revert to VA in LD periods.

10.2.26 Vehicular detection is a key factor when considering alternative signal strategies in LD periods. The installation of additional loop detectors can be expensive, disruptive and represent an additional maintenance liability, although Microwave Vehicle Detectors (MVD’s) are commonplace as an alternative. A number of manufacturers have developed wireless detection, using either above ground or carriageway embedded sensors, which communicate to the controllers via access points. Though manufacturers have confirmed their adherence to current detection specifications, these systems have yet to achieve widespread use. This technology is discussed in Chapter 16.

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[34] Ontario Ministry of Transport (2007) *Ontario Traffic Manual Book 12 – Traffic Signals*

10.2.27 The presence of pedestrian detection at an installation represents a crucial factor in the introduction of alternative LD strategies. The use of intelligent pedestrian detection with Puffin crossings or at junctions with nearside pedestrian demand units means that many installations are capable of operating more efficiently in LD periods, interrupting traffic movements only when a pedestrian demand is made. Installations without pedestrian detection would not be suitable for certain LD strategies.

10.2.28 Site assessments should therefore include observations on detection equipment available at an installation and its apparent condition with regard to effectiveness and maintenance.

***Junction Dynamics***

Traffic Demands

- Traffic volumes and the ratio between major and minor road flows will determine which LD strategies are most suitable.
- Site trials will be required to determine specific thresholds for considering LD strategies.

10.2.29 As defined in Chapter 9 flow criteria would generally be used to define LD periods. Traffic volumes have therefore been included as a criterion to determine whether an installation is suitable LD operation before a full site assessment is carried out.

10.2.30 Traffic volumes must also be considered as parameters for selecting specific LD strategies once an installation has been considered suitable for alternative LD operation. Demands on the major and minor arms of a junction and the ratio between them will determine the type of LD strategy that would be suitable, for example the flow requirements for a strategy reverting to priority mode of operation might be significantly lower than a strategy making more effective use of full traffic signal control. Traffic counts and modelling as a minimum would be required to quantify these values.

10.2.31 In addition to traffic volumes, flow profiles will provide important information regarding the operation of an installation. Though peak hour traffic flows would identify the highest volumes experienced at a traffic signal installation, the fluctuations in traffic volumes between these peaks will determine when a change in the operation of traffic signals can be considered, based on the flow criteria..

10.2.32 It is considered that 24 hour traffic flow information should be obtained for installations under review.

Collision Record

- Overseas guidance recommends that where a collision has been recorded in the preceding two years, a LD strategy reverting to priority should not be considered.
- The justification for providing a traffic signal installation should be considered to ensure any safety issues addressed by the signals are not reintroduced by an LD strategy.

10.2.33 The collision record for an installation is critical for establishing whether a proposed method of control or operation type is suitable, and should be reviewed whenever any change to an installation's method of operation is being considered. Though conflicts between vehicles are minimised at traffic signal controlled installations, patterns in collision records could indicate issues with visibility, for example at particular times of the day. Vehicle speeds could also suggest that a change in the method of operation would not be appropriate.

10.2.34 Guidance in other countries suggests that certain control strategies should not be considered where there has been a personal injury accident recorded in the preceding two years of operation. This recommendation is aimed at locations where the intention is to revert the installation from signal control to priority mode of operation. In addition to this guidance, it is considered that the original justification for providing traffic signal control at a specific location should be taken into account. If a scheme has been provided to address a particular safety issue then any LD strategy considered must not reintroduce that issue.

10.2.35 Within the UK, collision records at signal-controlled junctions are generally low compared with priority junctions. Installations with higher than average collision rates might not be suitable for the introduction of LD strategies.

Non-motorised users (NMU)

- Engineering judgement must determine whether there is a sustained need for pedestrian and cycle facilities, rather than basing a strategy on NMU volumes

10.2.36 The needs of pedestrians and cyclists must be taken into account when considering suitable LD strategies. Engineering judgement must determine whether a location is suitable based on the surrounding environment. Locations adjacent to schools might remove or reduce the extent to which an LD strategy can be implemented between peak periods. Similarly installations adjacent to locations catering for the night time economy, where peaks of pedestrian demand will occur late at night, might also not be suitable.

10.2.37 The need for maintaining cycle facilities must be also considered. Safety of cyclists could be adversely affected by the introduction of alternative LD control strategies. For example, LD strategies reverting to priority operation would remove the benefit of cycle priority measures including Advanced Stop Lines (ASL's). Signal control might have been introduced to address a particular safety issue with vehicular/NMU movements, thus its removal could re-introduce a safety issue.

# Assessment of Options

# 11 Assessment of Options

## 11.1 Introduction

11.1.1 This Chapter describes the factors against which the 'long list' of options were assessed to identify their suitability for further consideration for LD operation. The factors are based on a NATA style approach, with additional items added relating to specific traffic signal design issues. NATA (New Approach to Appraisal) is the framework used to assess transport schemes in the UK, utilising a multi-criteria assessment including:

- Environment (air quality, landscape etc)
- Safety (collisions, security)
- Economy (Transport user benefits, reliability)
- Accessibility (Severance, Access to the transport system)
- Integration (Transport interchange)

11.1.2 A number of the factors above provide a key for the assessment tables in Chapter 12; the impact of every option on each of the factors has been summarised alongside the detailed descriptions of each option.

## 11.2 Process

11.2.1 Each option was assessed against the criteria and parameters developed in Chapters 9 and 10. This was an iterative process, feeding back to confirm, or in some cases modify, the criteria and parameters. Later Chapters and Appendices contain detailed description of the elements of this process:

- **Chapter 12** summarises the 25 options considered, together with a description and NATA appraisal table for each option;
- **Chapter 15** summarises the viable options
- **Appendix B** describes the use of VISSIM micro-simulation to model comparative journey time and emission data for each option;
- **Appendix C** examines the implications of various LD strategies on electricity consumption, and compares the benefits with other energy reduction measures

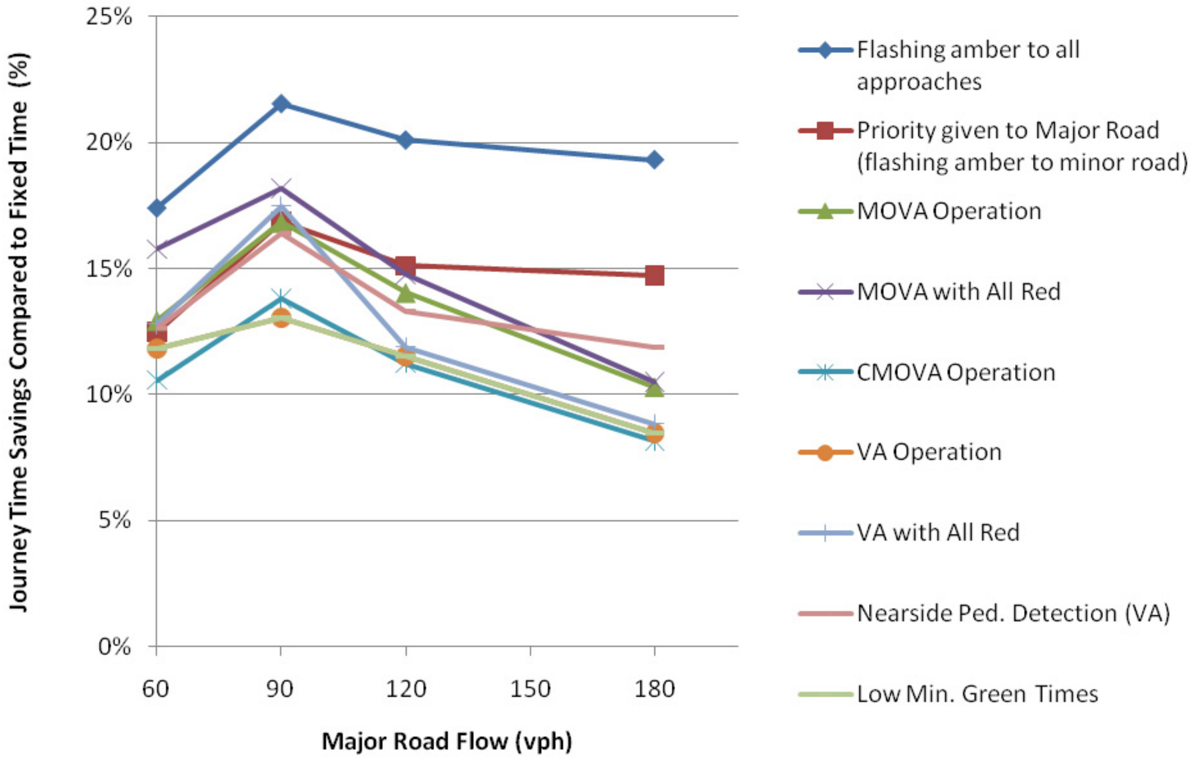
## 11.3 Economy

### *Impact on Journey times*

11.3.1 Many drivers criticise the operation of traffic signals during LD periods when the few vehicles using a network are stopped unnecessarily.

11.3.2 As discussed earlier, the increased use of Vehicle Actuation at traffic signal installations can reduce delays experienced during LD periods. Alternative methods of control during LD periods provide differing benefits in reducing junction delay. A number of options have been modelled using VISSIM micro-simulation on a hypothetical network to illustrate this. **Figure 8** below, reproduced from **Appendix B**, shows indicative journey time savings for various options compared to fixed-time operation.

**Figure 9** - Network Journey Time savings expressed as a percentage change from Fixed Time operation (2:1 Major/Minor ratio)




### *Vehicle operating costs*

11.3.3 The change in vehicle operating costs (VOC) is directly linked to the change in journey times and delay. VOC are classified as costs that change dependent on vehicle usage and are therefore based on vehicle miles travelled. VOC include items such as fuel, tyres, oil, maintenance, repairs and mileage dependent depreciation.

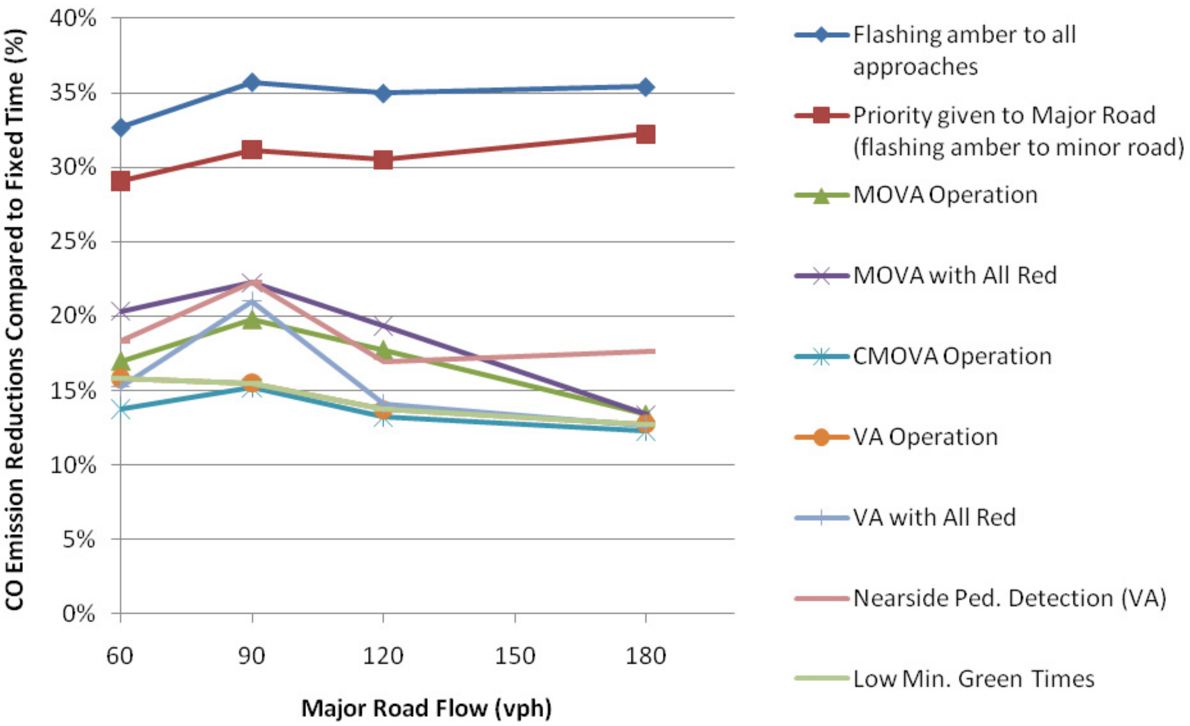
## 11.4 Environment

### *$CO_2$ Emissions*

11.4.1 A key target of this study is the additional $CO_2$ emissions caused by vehicles stopping and starting unnecessarily. If normal traffic signal operation during LD periods was replaced by an alternative strategy reducing unnecessary stop/starting, delays would be reduced and $CO_2$ emissions would reduce.

11.4.2 The extent to which this occurs will depend on the traffic volumes at a particular junction and how much braking and acceleration is required by vehicles to comply with signal control. The same hypothetical VISSIM network that was used for examining journey times produced emission data. **Figure 10**, reproduced from **Appendix B** illustrates comparative $CO_2$ emissions for various options compared to fixed-time operation.

**Figure 10** – Network $CO_2$ emission reductions compared with Fixed Time operation (2:1 Major/Minor ratio)




***Electricity Consumption***

11.4.3 There is some potential to save on the operating costs of a traffic signal installation by utilising LD control strategies to revert junctions to priority operation, such as turning signals off or using flashing signals. Chapter 13 examines the reduction in energy consumption that could be achieved by implementing an extreme LD strategy (switching every 3rd signal head off for 5 hour per day), and estimates that this could achieve country wide savings of perhaps 12.8GWh per year. However the replacement of incandescent lamps with LEDs would have a far more significant effect on power consumption.

11.4.4 Several authorities are currently in the process of replacing all their incandescent heads to LED, and if this was carried out country wide the savings would be of much greater magnitude, perhaps 135GWh per year. The potential savings from introducing LD control mechanisms would also be reduced when applied to LED installations.

11.4.5 For the NATA style assessment of LD options in Chapter 12, a comparative electricity saving is provided based on applying an option to a hypothetical signal controlled T-junction with controlled pedestrian crossing facilities. For the purposes of estimating the savings for each option, it has been assumed that all signal aspects are running in dimmed mode, as virtually all installations are fitted with photocells (though some local authorities might choose not to dim signals). The calculations also assume that LD operation is permitted for a 5 hour period, for example overnight.

## 11.5 Safety

### *Change in collision rates*

11.5.1 Studies carried out overseas indicated that collision rates increased when introducing priority mode of operation as an alternative LD control to traffic signal control. The findings of these studies are detailed in Chapter 6. A study by Kacir et al [35] identified the change in collisions as a result of changing the LD method of operation between normal signal control and flashing signal control. **Table 9** below summarises the findings.

**Table 9 –** Low Demand traffic signal use collision frequencies

| Time Period | Number of collisions per junction control change | | | |
|---|---|---|---|---|
| | Normal to Flashing | Flashing to Normal | Normal Unchanged | Flashing Unchanged |
| Before | 13 | 1 | 12 | 2 |
| After | 32 | 0 | 13 | 12 |
| **Total** | 45 | 1 | 25 | 14 |

11.5.2 It can be seen that the change from normal operation to flashing operation yielded a significant increase in collisions, as suggested in other research papers. In addition, it was noted that retaining flashing operation yielded an increase in collisions, though no specific reason for this was provided. Consideration needs to be given to the likely increase in collisions as a result of introducing a particular method of operation within the UK, based on historic data from overseas studies.

11.5.3 Qualitative comments have been provided by UK local authorities in response to the questionnaire on the potential impact of the options on collision rates.

11.5.4 The 2009 TRL report on the effects of traffic signal strategies on pedestrian safety[36] concludes that night-time strategies such as “decoupling from UTC, running night-time plans having much shorter cycle time, and ‘rest on red’” could provide an increase in the levels of pedestrian safety. All of the options mentioned, along with many others, have been examined in this study.

### *Legibility to drivers*

11.5.5 Traffic signal control provides a method of control where vehicles movements are co-ordinated and conflicts are managed. Signals are designed to be legible to drivers to provide the safest means to navigate a junction. Any option for LD must retain this legibility, either by retaining the clarity of signal control, or ensuring that drivers can comprehend the relative priority of traffic streams at an installation.

11.5.6 Any changes to operation that do not represent current UK practice would also require public education to ensure drivers are aware of the necessary rules and regulations. Introducing a new form of control to motorists would require funded campaigns to raise driver awareness of any proposed changes.

[35] Kacir et al (1993) *Evaluation of flashing traffic signal operation*

[36] Transport Research Authority (2009) *“The Effect of Traffic Signal Strategies on the Safety of Pedestrians” Report PPR414*

## 11.6 Legislation

11.6.1 UK regulations regarding the use of traffic signals generally conform to the 1968 Vienna Convention on Road Signs and Signals, and are detailed in TSRGD and ZPPPCRGD. The Vienna Convention specifies particular uses for both the flashing and non-flashing operation of traffic signal aspects, which the member states must conform to. The UK has signed the Vienna Convention, although this has never been ratified. Nevertheless, its contents can be considered a reasonable indication of good practice, and a strong case would be needed to advise going against its guidance.

11.6.2 Some member states utilise flashing signals during LD periods which requires drivers to proceed with caution. The UK does not adopt this method control, thus if such operation was to be introduced then changes to UK legislation would be required.

## 11.7 Design

***Need for additional equipment***

11.7.1 Existing traffic signal installations will have the appropriate detection for the methods of operation currently employed at that particular location, for example System D loops and Above Ground Detection (AGD) at VA junctions or upstream SCOOT loops within UTC networks.

11.7.2 Additional detection could be required on junction approaches, or modification needed to existing controllers to enable alternative strategies to operate. Where it is anticipated that additional equipment would be required, this has been highlighted within each option.

***Changes in geometry/layout***

11.7.3 If full signal control is to be retained at an existing installation, no changes to the junction geometry should be required provided it conforms to current standards. Geometric changes might be needed if alternative forms of operation are introduced, such as reverting to priority mode of operation. If such a method is desired, the appropriate visibility criteria both on approach to the installation and at the installation itself must be satisfied, which could involve physical alterations and hence reduce the benefit/cost ratio.

11.7.4 The potential changes required to implement a proposed method of operation have been highlighted in the summary tables.

***Departmental specifications and guidelines***

11.7.5 In addition to the impact on UK legislation for signal control, there are design guides and specifications dictating how traffic signals must operate and what timings should be provided as a minimum to reduce conflict between movements. Some alternative methods of operation might require changes to current minimum timings or guidance produced for newly developed technologies. Predicted changes will be highlighted under the option assessment.

# 12 Low Demand Control Options

## 12.1 Introduction

12.1.1 Any options identified for use in LD periods should be so designed as to provide all users with a clear junction arrangement irrespective of the method operation used. This Chapter details the range of options considered for use in LD conditions. Each option has been summarised on a separate 'options sheet' and validated against the factors from Chapters 9 and 10.

## 12.2 Categories of Low Demand strategy

12.2.1 The LD options have been categorised into two key forms. The first is changing the method of operation of the installation whilst retaining full signal control of user movements; the second is to revert to some form of priority mode of operation when vehicle volumes are sufficiently low, thus reducing unnecessary delay.

12.2.2 The category to which each option is allocated is highlighted using colour coding within their summary tables.

- **Options retaining full signal control**; and
- **Options reverting to priority mode of operation**.

12.2.3 A key at the bottom of each option sheet indicates whether emissions and journey times for that option have been validated using the hypothetical VISSIM simulation (V), and the short-list status of that option (S = Short-term, M = Medium-term, L = Long-term or X = not recommended for further development), for example:

| V | X |
|---|---|

## 12.3 Strategies retaining full signal control during Low Demand periods

(highlighted in **BLUE**)

12.3.1 Current methods of traffic signal control allow LD volumes to be accommodated in various ways, including changing fixed time signal installations to operate on lower cycle times or using different MAXSETS on VA systems to reduce potential delay. These methods have been identified in **Chapter 3**.

12.3.2 Strategies retaining full signal control will include measures to optimise existing methods of signal operation to minimise the delay to users. Some existing methods of operation have been included as they will represent suitable options for LD operation at some installations. The options considered are detailed on the following pages.

## 12.4 Strategies introducing priority mode of operation during Low Demand periods

(highlighted in **MAGENTA**)

12.4.1 The alternative to providing full signal control is to introduce an element of or full priority mode of operation to manage vehicle movements. Within the UK this method of operation is currently only seen at part time signal installations at roundabouts. Roundabouts are able to operate under this part time arrangement as the switching off of the signals does not compromise the legibility of the junction.

**Option 1: UTC/SCOOT low cycle time (LCT)**

This option would impose a maximum allowable network cycle time during LD periods from a predetermined timetable. This lower cycle time would be the shortest period during which every installation in the network could achieve a cycle running each stage at or close to its minimum green time. The advantage of this in UTC systems is that waiting times for vehicles would be reduced, as stages would cycle more quickly. Co-ordination can still be maintained between installations to optimise the operation of the network.

It should be appreciated that lowering cycle times will reduce or remove the ability for SCOOT to adjust the split of green times to demanded phases. As a result, it would be difficult to maintain the normal off-peak coordination for fixed-time systems.

This option is essentially a revision to the network timetables and parameters, there would be no physical or infrastructure changes required to the highway network or installations. Full signal control would be retained thus the option would have no impact on junction safety.

| | | OPTION 1 |
|---|---|---|
| ECONOMY | Impact on Delay | Lower cycle times in UTC systems will reduce waiting times for vehicles through quicker stage changes, provided the co-ordination between installations can be maintained. |
| | VOC | Minimising delay through shorter cycle times should reduce VOC |
| ENVIRONMENT | $CO_2$ emissions | $CO_2$ emissions should reduce with shorter cycle times, with the waiting time for vehicles at a red signal reduced. |
| | Electricity consumption | No change to existing electricity consumption |
| SAFETY | Change in accidents | Retention of full signal control will not change number of conflicts, thus collision rate should remain unchanged |
| | Legibility to drivers | Changes will be made to the method of operation however junction will still operate under full signal control hence legibility will not change |
| LEGISLATION | Changes required | None |
| DESIGN | Changes in geometry/layout | None required |
| | Additional equipment | Existing detection and equipment will permit operation under low cycle times. |
| | Departmental specifications & guidelines | Changes made to allow shorter cycle times would be required within the TR2500 specification. |

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**Option 2: UTC/SCOOT extra low cycle time (ELCT)**

This option seeks to further reduce waiting times for vehicles in urban networks under UTC/SCOOT by removing the need to allow time for demand dependent stages to operate within a cycle when no demand is present, a situation that will likely occur during periods of LD. As a result, required stages can be made to cycle quickly to reduce delay; if a demand is registered then the UTC system would increase the network cycle time temporarily to service that demand before returning to the ELCT.

As with the LCT no changes to the infrastructure would be required to benefit from the reduction in delay, vehicle operating costs and $CO_2$ emissions. The changes would be within the system software; the challenge for the successful implementation of this option is the modification that would have to be made to the UTC system software to permit the ELCT operation when stages are not required.

As with the other options retaining full signal control, the legibility of the junction and control over conflicts would remain unchanged; thus collision rates should be unchanged.

| OPTION 2 | | |
|---|---|---|
| ECONOMY | Impact on Delay | Overall cycle time reduced by not allowing time for DD stages. If DD stage called, cycle time can be increased temporarily before returning to ELCT. |
| | VOC | Linked to the reduction in delays to vehicles, some movements could see benefits to VOC as cycle times are reduced when stages are not called. |
| ENVIRONMENT | $CO_2$ emissions | Emissions reduction would be linked to savings in delay. Saving would be junction dependent. |
| | Electricity consumption | Little change to electricity consumption should be seen, all signal heads will retain a single lit aspect at any time. |
| SAFETY | Change in accidents | The collision rate will not be influenced by changes in cycle times. |
| | Legibility to drivers | The legibility of the junction would remain. |
| LEGISLATION | Changes required | No change would be required for removal of stages from operation |
| DESIGN | Changes in geometry/layout | None required |
| | Additional equipment | No additional equipment should be required |
| | Departmental specifications & guidelines | Option would require substantial modification to the existing SCOOT/UTC software. |

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**Option 3: Adaptive UTC/SCOOT system**

This option combines the benefits of option 1 and 2 to provide a network which seeks to operate under the lowest cycle time achievable during LD periods. If particular stages are not called a network should be able to respond dynamically to lower the required cycle time.

Adaptive UTC systems, for example SCOOT, would respond to strategic flow detectors within an urban network; upon an LD period being detected, the cycle time at which the system operates would be reduced to the shortest period that would allow every installation in the network to satisfy its minimum green requirements.. In addition, if particular stages at installations are not demanded, the UTC system would allow the network cycle time to change accordingly to minimise delay. Under fixed time UTC systems different plans could automatically be selected based on the strategic flow detection and network conditions.

> Such operation could reduce the delays, vehicle operating costs and $CO_2$ emissions within a network whilst retaining full signal control. To provide such a system, new software and algorithms will be required to allow the management of installations in this way. There may also be the need for additional detection.

| | | OPTION 3 |
|---|---|---|
| ECONOMY | Impact on Delay | Delay can be significantly reduced by automatically changing to the optimum cycle time to manage vehicular delay. |
| | VOC | Reductions in delay would have the effect of reducing VOC. |
| ENVIRONMENT | $CO_2$ emissions | An efficiently optimised network will have a significant effect on $CO_2$ emissions, as network delay would be reduced. |
| | Electricity consumption | The retention of full signal would not reduce electricity consumption. |
| SAFETY | Change in accidents | No change in collisions should be observed, the UTC operation optimises full signal control. |
| | Legibility to drivers | Legibility will be retained. |
| LEGISLATION | Changes required | No legislation changes will be required, current method of operation. |
| DESIGN | Changes in geometry/layout | No layout changes should be required to existing traffic signal installations. |
| | Additional equipment | Additional detection could be required for strategic detection. New software/algorithms will be required to optimise individual junctions. |
| | Departmental specifications & guidelines | Specifications for revised use of UTC systems would be required, together with new software to cater for micro-management of junctions. |

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**Option 4: Utilise SCOOT detection loops for Low Demand VA capabilities**

This option would be used in urban networks, where SCOOT adaptive UTC co-ordinates series of junctions to minimise delay and maximise capacity. When demand is low it might not be necessary to provide this co-ordination and this option explores the possibility of utilising the existing SCOOT detection to provide VA capabilities at downstream junctions, thus reducing delay.

The key issue with using SCOOT detection in this way is that SCOOT loops are placed at the upstream end of links whereas Vehicle Actuation relies on detection on the immediate approach to an installation, normally 40m from the Stop line, to more accurately register the presence of traffic and call the appropriate stage. The distance between an installation and an upstream SCOOT loop would affect the accuracy of the travel time prediction such that benefits would reduce as link lengths increased. The presence of impediments (for example stationary vehicles or lane merges) or network sinks (side roads, parking) would reduce the accuracy or lead to unnecessary stage changes.

In a SCOOT system each junction utilises a basic traffic plan and minimal local detection to ensure each stage appears. The SCOOT loops are used to determine the green times and offsets. A controller operating with these traffic plans might not be equipped with all the detection necessary to operate in the VA mode.

**It is proposed to discount this option from the list of viable options** due to the accuracy problems that will be encountered when using upstream detection for VA operation.

| | | OPTION 4 |
|---|---|---|
| ECONOMY | Impact on Delay | The travel time for vehicles between the upstream loop and the installation could not be accurately predicted; therefore each stage would require a permanent demand. This would negate much of the advantage to delay that VA provides. In addition, the loss of co-ordination would need to be considered. |
| | VOC | VOC could benefit however the issue of inaccurate travel times would reduce the scale of potential benefits |
| ENVIRONMENT | $CO_2$ emissions | The principal of the option would reduce the $CO_2$ emissions through improved journey times however the issue of inefficient operation with the SCOOT loops too far upstream would remove much of the benefit. |
| | Electricity consumption | No change to existing electricity consumption |
| SAFETY | Change in accidents | Retention of full signal control will not change number of conflicts between approaches. |
| | Legibility to drivers | Changes will be made to the method of operation however junction will still operate under full signal control hence legibility will not change |
| LEGISLATION | Changes required | None required |
| DESIGN | Changes in geometry/layout | None required |
| | Additional equipment | The majority of SCOOT detection is connected to upstream controllers, with no direct connection to the installation it influences. Additional detection equipment could be required for VA operation |
| | Departmental specifications & guidelines | Existing SCOOT loop siting specifications are very prescriptive. Current controller specifications would probably not meet the requirements with regard to extensions and demands. |

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**Option 5: Install VA as a fallback from UTC/SCOOT**
When demand is low it might not be necessary to provide the co-ordination of UTC systems, and Vehicle Actuation could be more appropriate for serving demands. This option requires that VA is installed within an urban network environment at installations where coordination is not required.

VA represents a method of control that is responsive to prevailing vehicle demands. It can be installed to provide detection on all approaches to an installation or by installing detection on the side roads only and reverting to the main road as the default stage. The installation will run the appropriate stages to satisfy demands.

No additional development costs will be required to provide new software for this operation.

This method of operation is in current use within the UK; additional costs for existing installations will be incurred by providing the necessary loop detectors and/or AGD and interfacing it with existing controllers. The potential to develop new technologies to improve the reliability efficiency of VA operation should be considered.

| OPTION 5 | | |
|---|---|---|
| ECONOMY | Impact on Delay | Significant reductions in vehicular delay can be realised by using VA in place of fixed time traffic signal operation. |
| | VOC | VOC will reduce based on impact on delay and journey times. |
| ENVIRONMENT | $CO_2$ emissions | Significant savings should be seen over fixed time systems. |
| | Electricity consumption | Electricity consumption of the signal heads should be similar to normal operation; however additional detection would consume more electricity. |
| SAFETY | Change in accidents | Installations will remain under full signal control; therefore the collision rate should not be affected. |
| | Legibility to drivers | Junction will still operate under full signal control therefore legibility will not change. |
| LEGISLATION | Changes required | None required |
| DESIGN | Changes in geometry/layout | None required |
| | Additional equipment | Detection will be required to install VA at an existing traffic signal junction. |
| | Departmental specifications & guidelines | Development of AGD and other technologies would increase reliability. |

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**Option 6: Utilise SCOOT detection loops for MOVA (IN detectors)**

This option is intended to provide the ability to operate under MOVA control during LD periods in urban networks utilising SCOOT UTC to co-ordinates series of junctions. Rather than installing both the X-loop and IN detectors required for MOVA operation it is suggested that only the X-loop is installed, and the SCOOT loops upstream of the junction be used as IN detectors when MOVA is in operation.

The key advantages of this option over a full MOVA installation are the savings in the installation costs. The cost savings would be maximised if data from the upstream SCOOT loop could be relayed to the downstream controller and used for LD MOVA operation, else ducting would still be required along the length of a link.

In addition, MOVA has the potential to reduce vehicular delay, or provide priority for pedestrian movements if required, during LD periods.

> It is not *currently* possible to use SCOOT loops for MOVA operation; the loops provided for both SCOOT and MOVA have specific dimensions that the softwares are able to efficiently optimise installations. Technology and software developments would be required to overcome the configuration and data requirement differences.
> In addition consideration must be given to the optimum location of detection for each method of operation to ensure efficiency is not compromised by sharing detection locations. In effect the option may only be suitable in networks with shorter links between installations.

| | | OPTION 6 |
|---|---|---|
| ECONOMY | Impact on Delay | MOVA could significantly reduce delay at junction during LD periods, and particularly serve pedestrian demand more efficiently. |
| | VOC | Vehicle operating costs should reduce with a decrease in delay. |
| ENVIRONMENT | $CO_2$ emissions | Changes in $CO_2$ emissions will be reflected upon reductions in vehicular delay. The level of saving could be reduced if MOVA is programmed to be more responsive to pedestrians. |
| | Electricity consumption | If additional equipment or detection is in operation then electricity consumption would rise marginally. |
| SAFETY | Change in accidents | Retention of full signal control will not change number of conflicts, thus collision rate should remain unchanged. |
| | Legibility to drivers | The method of operation will change however the provision of full traffic signal control ensures there is no change to legibility. |
| LEGISLATION | Changes required | None required |
| DESIGN | Changes in geometry/layout | None required |
| | Additional equipment | Installation of MOVA unit to existing controllers and X-loop detection. |
| | Departmental specifications & guidelines | The technology/software to permit the shared use of detection for differing SCOOT and MOVA requirements. |

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**Option 7: Install MOVA as a fallback from UTC/SCOOT**
MOVA represents an effective fallback from UTC/SCOOT networks, providing an adaptive traffic control system when co-ordination is not required. If a level of co-ordination is required, for example at roundabouts, linked MOVA can be used.

MOVA responds to traffic demands by measuring saturation on each approach and producing its own signal timings and cycle times to balance both queues and vehicle delays. It can optimise an installation in both congested conditions and when demand is low.

MOVA trials indicate that MOVA can reduce vehicular delay by around 13% compared to VA operation[37]. This saving was established through assessment of 20 junctions upgraded to MOVA operation.

In addition to reducing delay MOVA can be more responsive to pedestrian demands, particularly when compared with VA operation. Under VA operation extensions are readily given to traffic movements when demands are registered, whereas MOVA can attribute a delay weighting factor to pedestrian demands.

> The use of MOVA as a LD control method is currently used within the UK. It requires an additional unit to be installed to existing controllers to provide MOVA operation, and the provision of loop detection and ducting, which can be up to 150m from the stop line.

| OPTION 7 | | |
|---|---|---|
| ECONOMY | Impact on Delay | Reductions in vehicular delay can be realised by using MOVA as a fallback for networked junctions. The scale of reduction will demand on the responsiveness to pedestrian demands. |
| | VOC | VOC will reduce based on impact on delay and journey times. |
| ENVIRONMENT | $CO_2$ emissions | $CO_2$ emission reductions should be seen as delays to vehicles are reduced. |
| | Electricity consumption | Electricity consumption due to the signal heads will be the same; however marginal change would occur due to changes in vehicle detection. |
| SAFETY | Change in accidents | Installations will remain under full signal control; therefore the collision rate should not be affected. |
| | Legibility to drivers | Junction will still operate under full signal control therefore legibility will not change. |
| LEGISLATION | Changes required | None required |
| DESIGN | Changes in geometry/layout | None required |
| | Additional equipment | Existing traffic signal installations will require MOVA unit and diamond loop detection for LD operation. |
| | Departmental specifications & guidelines | No change under normal MOVA installation, however development of current detection could reduce costs and improve reliability. |

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[37]Vincent R A & Peirce J R (1998) *TRRL Research Report RR170. MOVA: Traffic responsive, self-optimising signal control for isolated intersections*

**Option 8: Install Compact MOVA (CMOVA) as a fallback from UTC/SCOOT**

CMOVA represents an alternative method of traffic signal control for signal installations in low speed urban networks i.e. where the 85%-ile speed is less than 35mph. It removes the need for IN-detection to be provided, requiring only the X-detection to be installed at distances up to approximately 50m.

The reduction in detection over conventional MOVA reduces the installation costs, making it a viable option for installation within existing network environments. However CMOVA still provides an adaptive control system that is highly responsive to prevailing traffic conditions.

The use of CMOVA would benefit from further research and development of alternative forms of detection to reduce installation and maintenance costs, for example the use of above ground detection for the X-detector.

> The use of CMOVA at low speed urban locations represents a suitable, lower cost alternative to a full MOVA installation. Research and development of detection technologies will improve its efficiency and reliability.

| | | OPTION 8 |
|---|---|---|
| ECONOMY | Impact on Delay | CMOVA should reduce delay over networked operation where the 85%-ile speed is less than 35mph. |
| | VOC | VOC will improve with reductions in vehicle delay and journey times. |
| ENVIRONMENT | $CO_2$ emissions | $CO_2$ savings should be observed with reductions in delay and VOC. |
| | Electricity consumption | All traffic signal head will remain operational, thus no change in electricity consumption should be seen. Change in consumption due to detection should not change noticeably due to the minimal detection required for CMOVA. |
| SAFETY | Change in accidents | Installations will remain under full signal control; therefore the collision rate should not be affected. |
| | Legibility to drivers | Junction will still operate under full signal control therefore legibility will not change. |
| LEGISLATION | Changes required | None required |
| DESIGN | Changes in geometry/layout | None required |
| | Additional equipment | A MOVA unit and X-detector loops will be required. |
| | Departmental specifications & guidelines | No changes will be required. |

**Option 9: Install Vehicle Actuation at isolated junction**

Vehicle Actuation is a commonly used method of operation at both isolated junctions and in networks where co-ordination is not required, it is the default method of operation recommended by the DfT in such circumstances. It represents a viable LD option at locations where it is not currently installed, as it is responsive to vehicle demands, either on all approaches or by installing detection on the side roads and using the main road stage as a resting stage.

> The inclusion of VA as an LD option in this research should be used to encourage its use and development through greater use of alternative detection methods, thereby increasing its reliability. Within VA systems, the development of speed measuring technology not dependent upon loop detection could make junctions more efficient at optimising for delay.

| | | OPTION 9 |
|---|---|---|
| ECONOMY | Impact on Delay | VA installations can realise significant benefits over fixed time traffic control systems in terms of reducing vehicular delay |
| | VOC | VOC would reduce through benefits to delay, journey times etc. |
| ENVIRONMENT | $CO_2$ emissions | Significant savings should be seen over fixed time systems due to the optimising nature of the VA installation. |
| | Electricity consumption | The overall electricity consumption of the signal heads should remain the same under vehicle actuation, however additional detection will utilise additional electricity. |
| SAFETY | Change in accidents | Installations will remain under full signal control; therefore the collision rate should not be affected by the installation of VA. |
| | Legibility to drivers | Changes will be made to the method of operation however junction will still operate under full signal control hence legibility will not change |
| LEGISLATION | Changes required | None required |
| DESIGN | Changes in geometry/layout | None required |
| | Additional equipment | Additional detection might be required to install VA at an existing traffic signal junction. |
| | Departmental specifications & guidelines | Development of AGD and other technologies would increase reliability. |

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**Option 10: Install MOVA at isolated junctions**

As with VA junctions, MOVA (and CMOVA) is an established method of operation at isolated junctions, with the advantage of being able to detect changes to demand over time and adapt accordingly. As the distance between installations reduces, the need for MOVA diminishes.

As with SCOOT systems, MOVA relies heavily on loop detection for optimising junction operation, presenting potential maintenance issues should faults occur. It has been known for authorities to move away from loop detection at some installations because of maintenance issues.

MOVA by definition is used at isolated junctions, and is an effective method of adapting to changing traffic demands.

The installation and maintenance costs of providing MOVA could be reduced with the development of alternative detection techniques, hence its inclusion as an option for LD operation.

| | | OPTION 11 |
|---|---|---|
| ECONOMY | Impact on Delay | MOVA has the potential to significantly reduce delay at junction during LD periods, and particularly serve pedestrian demand more efficiently. |
| | VOC | With reduced delay, vehicle operating costs should reduce. |
| ENVIRONMENT | $CO_2$ emissions | Whether MOVA is programmed to be more responsive to pedestrians would affect the level of CO2 savings seen at an installation. |
| | Electricity consumption | The impact on electricity consumption will depend on the installation under consideration. If additional equipment or detection is required then consumption may rise. |
| SAFETY | Change in accidents | Retention of full signal control will not change number of conflicts, thus collision rate should remain unchanged. |
| | Legibility to drivers | Changes will be made to the method of operation however junction will still operate under full signal control hence legibility will not change |
| LEGISLATION | Changes required | None required |
| DESIGN | Changes in geometry/layout | None required |
| | Additional equipment | MOVA detection/equipment will be required at junction and on approaches. |
| | Departmental specifications & guidelines | None |

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**Option 11: VA quiescent all red operation – networked or isolated installations**

The specification for many existing traffic signal installations includes provision for operating under quiescent all red, reverting a junction to an all red stage when no vehicles are detected for a predefined time. Contact with a small cross-section of UK authorities suggests that its use is not widespread.

The key benefit of reverting to an all red state in LD periods is that the time required to change to green on any approach once a demand is registered is reduced from the lowest value, typically 5 seconds, to 2 seconds. This would reduce delay and hence the deceleration/acceleration associated with a full intergreen period. The potential benefit could be increased at some installations where the intergreens are greater; the value is calculated based on the relative distance between conflicting movements. Typical values range from 5 seconds to 12 seconds.

Walk-with-traffic pedestrian crossings would ordinarily automatically receive a green signal when conflicting movements are given a red signal. Under this option, these crossing facilities would be demand dependent to reduce the stage change time when there is no pedestrian demand.

> This method of operation is only applicable when an installation is fully vehicle actuated.

| OPTION 10 | | |
|---|---|---|
| ECONOMY | Impact on Delay | The time required to change to a stage would be reduced from the existing value, the lowest being 5 seconds, to 2 seconds if all approaches are resting in red |
| | VOC | A decrease in the time vehicles spend waiting at a stop line or slowing on approach to a installation would lead to benefits in VOC. |
| ENVIRONMENT | $CO_2$ emissions | A decrease in emissions should be seen by reducing delay of stage change time. |
| | Electricity consumption | No change to existing electricity consumption |
| SAFETY | Change in accidents | Retention of full signal control will not change number of conflicts between approaches. |
| | Legibility to drivers | Changes will be made to the method of operation however junction will still operate under full signal control hence legibility will not change |
| LEGISLATION | Changes required | No change would be required, quiescent all red currently used in UK, though not at all installations |
| DESIGN | Changes in geometry/layout | None required |
| | Additional equipment | Operation is only feasible if installation is fully vehicle actuated. AGD/loops required if operating on side road detection only. |
| | Departmental specifications & guidelines | None |

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**Option 12: MOVA quiescent all red operation – networked or isolated installations**

Quiescent all red operation can be activated for MOVA installations within the existing specification. Similar to using the quiescent all red stage that is provided within many VA specifications, this resting stage would reduce the response time for displaying a green signal to approaching traffic from around 5 seconds for typical conflicting stages to 2 seconds.

As with VA, the inclusion of this option is to raise its awareness as an LD strategy. MOVA (and Compact MOVA) would benefit from development of technologies to make junctions more efficient at optimising for delay whilst reducing installation and maintenance costs.

| | | OPTION 12 |
|---|---|---|
| ECONOMY | Impact on Delay | Quiescent all red operating within a MOVA installation should further reduce delay through more efficient stage changes based on vehicle detection. |
| | VOC | The benefits that MOVA could realise combined with a quiescent all red, a significant benefit could be realised. |
| ENVIRONMENT | $CO_2$ emissions | Whether MOVA is programmed to be more responsive to pedestrians would affect the level of CO2 savings seen at an installation. |
| | Electricity consumption | No change to existing electricity consumption |
| SAFETY | Change in accidents | Retention of full signal control will not change number of conflicts, thus collision rate should remain unchanged. |
| | Legibility to drivers | Changes will be made to the method of operation however junction will still operate under full signal control hence legibility will not change |
| LEGISLATION | Changes required | None required |
| DESIGN | Changes in geometry/layout | None required |
| | Additional equipment | MOVA detection/equipment will be required at junction and on approaches. |
| | Departmental specifications & guidelines | None |

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**Option 13: Use low minimum green values**

This option is intended to reduce lost time and the ability to cycle stages quickly to reduce vehicular delay. Currently phase minimums at traffic signal installations are usually set around 7 seconds for traffic streams and as low as 5 seconds for pedestrian crossings, and are extended up to their maximums depending on prevailing traffic conditions.

Though it is not intended to reduce pedestrian phase minimums below currently accepted timings, it is proposed in this option that traffic phase minimums be lowered during LD periods, potentially as low as 2-3 seconds. In instances where perhaps only a single vehicle registers a demand on an approach, the lowered phase minimum would provide only enough green for that vehicle to proceed before changing stage quickly to service another demand. This option would be particularly suited to installations controlled by MOVA as it assesses arrival rates and calculates the minimum green required.

There are instances where the change in phase minimums would not be suitable, for example on high speed roads where approaching vehicles have been observed to cross the stop line when the amber or red aspect is displayed, either because of the stopping distance required or to avoid additional delay. With pedestrian phase minimum green times unchanged, the use of this option at installations with walk-with-traffic facilities will be limited, as stages with pedestrian phases will retain the same stage time. A potential solution is to ensure that critical walk-with-traffic phases are demand dependent; when there is no pedestrian demand then the phase will not be called and lower minimum green values could be used.

Amendments to current guidance would be required to facilitate these changes, and should prescribe their use within LD periods only with exclusions for situations such as high speed roads. No changes to the physical infrastructure should be necessary.

> Installations where this option is suitable may be limited due to pedestrian crossings, however where applicable an installation should be more responsive to sporadic traffic arrivals during LD periods.

| OPTION 13 | | |
|---|---|---|
| ECONOMY | Impact on Delay | Reduction of traffic phase minimum green would allow stages to change more quickly to respond to conflicting demands, thus delay should be reduced. MOVA might realise more benefit than other methods of operation. |
| | VOC | Lowering the phase minimums to allow stages to cycle more quickly could reduce waiting times and thus fuel required decelerate/accelerate. |
| ENVIRONMENT | $CO_2$ emissions | Permitting stages to cycle more quickly should reduce vehicle delay and therefore reduce CO2 emissions. |
| | Electricity consumption | No change to existing electricity consumption |
| SAFETY | Change in accidents | Full signal control would still be retained, only perceivable impact is drivers running amber or red to clear during short stage. |
| | Legibility to drivers | Changes will be made to the method of operation however junction will still operate under full signal control hence legibility will not change |
| LEGISLATION | Changes required | No legislative changes required. |
| DESIGN | Changes in geometry/layout | None required |
| | Additional equipment | None required, controller software changes could be required |
| | Departmental specifications & guidelines | TR2500 specification and guidance will need to be changed to allow use of lower than current minimum green times. |

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**Option 14: Rationalise the number of signal heads in operation**

The majority of LD options centre on reducing vehicular delay, journey times, operating costs and improving $CO_2$ emissions which are at their highest during acceleration and deceleration. This option considers the impact of reducing the number of signal heads turned on in LD periods, for example overnight, on the electricity consumption of signal installations.

A traffic signal installation must have at least two identical sets of signals placed to face traffic approach from any direction, and at least one of those must be a primary signal head[38]. Where more than the prescribed number of heads are present, it might be possible to reduce the electricity consumption by rationalising the number of heads turned on in LD periods. Though the impact on one signal head would be small, reducing the number of signal heads on all approaches increases the potential benefit. As discussed in **Appendix B**, the benefit would reduce overall power consumption by about 7%.

The number of installations where this option would be appropriate will be limited. Most authorities have guidelines that encourage the reduction of street furniture, therefore the minimum number of signal heads are used to ensure safe control. The deactivation of signal heads would therefore be providing an under-signalled junction.

The majority of signal controlled junctions require red lamp monitoring in the interest of pedestrian safety; to remove traffic signal heads from operation could create difficulties with determining faulty signal heads during LD operation.

**It is proposed to discount this option from the list of viable options.** Current signal head provision ensures there is sufficient visibility of signals from each approach. In addition, the issue of red lamp monitoring would need to be overcome, however the number of installations this option will be applicable to will be minimal.

| OPTION 14 | | |
|---|---|---|
| ECONOMY | Impact on Delay | Option would not impact on junction delay. |
| | VOC | No change to vehicle operating costs would be realised if implemented on its own. |
| ENVIRONMENT | $CO_2$ emissions | No change to vehicle emissions if implemented on its own. |
| | Electricity consumption | 7% reduction in power consumption if one aspect turned off from each approach (3 approaches. |
| SAFETY | Change in accidents | Option could be misunderstood by pedestrians if signals are off. Reduced signal use could cause issue if remaining lamps fail. |
| | Legibility to drivers | With multi-lane approaches, many junctions would be under-signalled. |
| LEGISLATION | Changes required | There could be issues with the need to continually illuminate box signs and regulated movements. |
| DESIGN | Changes in geometry/layout | No change should be required, visibility of remaining signals is vital. |
| | Additional equipment | No additional equipment should be required |
| | Departmental specifications & guidelines | The majority of signal installations have red lamp monitoring. Switching off selected heads would require a change to the controller specification |

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[38] TSO (2002) *S.I. 3113, Traffic Signs Regulations and General Directions (2002)* Direction 55(11)

**Option 15: Switch off all signals, vehicle or pedestrian presence reinstates signal control**

This option is intended to reduce the electricity consumption thus the carbon footprint of an installation (junction or mid-block crossing) by turning it off when no vehicles or pedestrians are in the vicinity. Detection would be used to revert to full signal control when a user is detected.

Such operation could be provided via a number of forms with differing levels of control for road users. These include:

- Turn off all signals for traffic movements, retain pedestrian signal head operation on a red aspect. If a demand is registered at a push button unit (pbu) then the junction will return to full signal operation before displaying a green signal to pedestrians;
- Wide area pedestrian detection could be used to register a pedestrian demand; a green aspect would only be shown to pedestrians when a pbu is pressed, at which time the change can be made promptly;
- Wide area vehicle and pedestrian detection used. If vehicles are present within the wider area, use of a pbu reinstates full signal control. If no vehicles are detected, the pedestrian crossing can display a green signal immediately.
- If no pedestrian crossing facilities are available, wide area vehicle detection could be used to turn off traffic signals when there is no traffic demand, initiating a start up sequence when a vehicle enters a defined cordon around an isolated installation or network.

Significant development of detection technology would be required, in particular the use of reliable wide area detection to monitor the presence of road users. Existing upstream loops (for example SCOOT loops) should provide the appropriate distance over which to detect vehicles and reinstate signal control. Where existing loops are not available, a cost effective method for providing upstream detection would be required.

A further consideration is the distance over which users would be detected. This is critical for allowing sufficient time to initiate a startup sequence. TR2500[39] prescribes signals under part time operation (for this method of operation could be applied) shall not show any signal for at least 7 seconds after restoration of a power supply, followed by a 3 second amber period before a red signal. The remaining approaches remain unlit for the duration of the starting intergreen, to ensure that all traffic that has been shown an amber signal has cleared the junction. The starting intergreen is generally much longer than any normal intergreen for safety reasons. Appropriate guidance would be required for alternative, shorter start up sequences; for example immediately initiating the 3 second amber period upon detection.

A switch off sequence would need to be developed, potentially changing to an all red stage for a period when no vehicles are detected, before turning off.

> This option would require significant development to determine the appropriate detection type and location. In addition, safety critical switch on and switch off sequences would need to be developed.

| OPTION 15 | | |
|---|---|---|
| ECONOMY | Impact on Delay | Option is not focussed on reducing delay, key benefit is reducing electricity consumption when no demand present. |
| | VOC | No real change in VOC, concept to reduce electricity consumption, effect on environment etc. |
| ENVIRONMENT | $CO_2$ emissions | No significant change to vehicle emissions over normal LD operation, option reduces environmental impact of traffic signals equipment. |
| | Electricity consumption | A 4% saving in electricity consumption for every hour the signal are not in operation. |
| SAFETY | Change in accidents | Without suitable detection upstream, vehicles will be shown a signal on close approach to an installation, which could cause a high number of accidents. |
| | Legibility to drivers | If signals are reactivated in time for drivers to comprehend, legibility should not be affected. |
| LEGISLATION | Changes required | No changes required. |
| DESIGN | Changes in geometry/layout | None required |
| | Additional equipment | Suitable detection outside of immediate junction location would be required that the signals could be operative in sufficient time that drivers are not surprised. |
| | Departmental specifications & guidelines | TR2500 would require amending to allow this method of operation. |

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[39] Highways Agency (2005) *TR 2500 rev A Specification for Traffic Signal controller*

**Option 16: Provide Puffin crossing technology at junctions**
Controlled pedestrian facilities within junctions are typically either fixed appearance or demand dependent with no cancel facility (hence only called when a push button demand is registered). The disadvantage with demand dependent facilities is that no pedestrian detection is used to cancel demands if a pedestrian moves away from a crossing or prematurely crosses before the pedestrian stage is called, thus introducing unnecessary delay for vehicles.

At midblock pedestrian crossings, Puffin crossings minimise vehicle delay by pedestrian detection which enables pedestrian demands to be cancelled if a pedestrian moves away from a crossing. This option recommends deploying the same Puffin crossing technology at junction installations to remove unnecessary pedestrian stage calls. The DfT advocates the use of Puffin crossings to improve pedestrian safety (through the use of nearside indicators) in addition to the delay benefits for vehicles.

Additional cost will be associated with providing equipment and re-cabling; on a four arm junction an upgrade might cost in the region of 7.5-10K if the majority of the infrastructure (e.g. pole locations) remains the same.

Greater benefit might be achieved by combining this strategy with Option 10.

> The use of Puffin detection at junctions reduces the lost time associated with pedestrian phases being called after pedestrians have moved away from a crossing, provided the detection is installed properly. There will be a cost associated with installation of the kerbside equipment and providing the software to allow its use at junction installations.

| OPTION 16 | | |
|---|---|---|
| ECONOMY | Impact on Delay | The ability to cancel pedestrian crossing demand if user has cleared the crossing will reduce unnecessary delay for vehicles. Savings to delay will fluctuate based on number of cancelled pedestrian calls. |
| | VOC | VOC will reduce along with vehicle journey times when unnecessary pedestrian calls are cancelled. |
| ENVIRONMENT | $CO_2$ emissions | Removal of unnecessary pedestrian calls could reduce CO2 emissions through reductions in delay. |
| | Electricity consumption | No change in head consumption. However additional roadside detection will be required. |
| SAFETY | Change in accidents | Puffin crossings have been shown to improve safety in addition to the benefits to delay. |
| | Legibility to drivers | Installation will remain legible to drivers. |
| LEGISLATION | Changes required | None required |
| DESIGN | Changes in geometry/layout | None required |
| | Additional equipment | Pedestrian detection and nearside indicators will need to be installed at desired locations and connected to the controller. |
| | Departmental specifications & guidelines | Existing specifications cover the installation of Puffin crossing facilities |

V S

**Option 17: Use timetabled pre-timed maximum green at mid block pedestrian crossings**

At mid-block pedestrian crossings, there are two main methods of controlling the demand from both pedestrians and vehicles. Under normal VA control, once a pedestrian registers a demand using a push button unit, a maximum green timer will begin for the traffic stage currently running. Once that timer has reached its maximum or the traffic demand has subsided, the pedestrian stage will be called. An alternative option is the use of pre-timed maximum greens. Once a traffic stage has begun, the maximum green timer is started even if no pedestrian demand has been registered. As a result, if a pedestrian uses a push button unit after the timer has exceeded the maximum time, the pedestrian stage will be called immediately, thus reducing the delay caused to pedestrians.

> Utilising timetabled pre-timed maximum green times at mid-block crossings would require changes only to the specification for the method of operation, but during LD conditions, the crossing would become more responsive to pedestrian demands with little impact on vehicular flows.

| OPTION 17 | | |
|---|---|---|
| ECONOMY | Impact on Delay | Option reduces delay for pedestrians waiting at crossing when vehicular demand is low. |
| | VOC | Little impact on VOC. |
| ENVIRONMENT | $CO_2$ emissions | Impact on CO2 emissions is dependent on the pedestrian demand at an installation. |
| | Electricity consumption | No change to existing electricity consumption |
| SAFETY | Change in accidents | No change to accidents is envisaged, the options changes the point at which a pedestrian is called, the safety critical timings remain in place. |
| | Legibility to drivers | Installation will remain legible to drivers, option proposes only timing changes. |
| LEGISLATION | Changes required | None required |
| DESIGN | Changes in geometry/layout | None required |
| | Additional equipment | No additional equipment should be required |
| | Departmental specifications & guidelines | None |

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**Option 18: Retain current operation during LD periods**
In addition to considering alternative forms of operation during LD periods, it might be preferable to retain the current control method. This could occur where, for example, a particular accident trend is present at an installation or was used as justification for the introduction of the traffic signals.

> Retention of the current method of operation may be the most suitable option at some installations, if there are site specific conditions affecting the implementation of alternative LD operation.

| | | OPTION 18 |
|---|---|---|
| ECONOMY | Impact on Delay | No affect on current operation and typical delay. |
| | VOC | No change in operating costs would be seen without a change in the operation of an installation. |
| ENVIRONMENT | $CO_2$ emissions | Vehicle emissions will remain unchanged under current operation |
| | Electricity consumption | No change to existing electricity consumption |
| SAFETY | Change in accidents | No change to existing method of operation |
| | Legibility to drivers | Signal control will remain as legible to drivers as existing operation |
| LEGISLATION | Changes required | None required |
| DESIGN | Changes in geometry/layout | None required |
| | Additional equipment | None required |
| | Departmental specifications & guidelines | None |

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**Option 19: Display flashing amber signal to all arms (all approaches have equal priority)**

This option is used in many overseas countries. Flashing amber signals on all approaches to an installation signify that vehicles must proceed with caution. This method of operation reduces delay to vehicles as giving way to conflicting vehicles or gap seeking should incur less delay than the same junction under signal control. In many European countries, supplementary permanent signing is used alongside the signal heads to indicate the priority route when under flashing operation (**Figure 1**). As the UK does not currently use the priority sign, drivers would be unfamiliar with their meaning. In the USA, junctions operate under the 'four way stop' priority rule, which has no UK equivalent.

An additional benefit of flashing amber signals is the reduced electricity consumption of using a single intermittent flashing aspect on each signal head in place of a series of "always on" aspects. It should be noted that although the lit time would be reduced, there is the possibility that installations using tungsten halogen aspects rather than LED might be adversely affected in terms of lamp lifetime and reliability when in flashing mode.

**Chapter 6** describes a series of studies that concluded that accident rates as a result of side-on collisions do increase when junction control was changed to flashing amber operation, assuming no indication of a priority movement. It is noted that controlled pedestrian crossing facilities would be inactive under this method of operation.

**It is proposed to discount this option from the list of viable options**. This option does not grant priority to specific movements, which represents a safety risk supported by overseas research into this method of operation. In particular visually impaired pedestrians would be unable to rely on the audible and tactile facilities provided at controlled pedestrian facilities. Considering this form of signal control within the UK would rely on extensive driver education. The current use of flashing ambers is at Pelican crossings where vehicles allow pedestrians to clear a crossing before proceeding; drivers would not ordinarily expect a conflicting vehicular movement when proceeding through a flashing amber.
Significant legislative change would be required to change the meaning of flashing amber within the UK.

| OPTION 19 | | |
|---|---|---|
| ECONOMY | Impact on Delay | Potential delay due to waiting at signals is removed; delay giving way to conflicting vehicles should be less than the same junction under signal control. |
| | VOC | Vehicles not having to wait at signals would reduce delay providing flows are low enough that gap acceptance is possible. |
| ENVIRONMENT | $CO_2$ emissions | Emissions should be reduced as vehicles would not be required to stop under signal control, though slowing down will be required for drivers to assess the safety of crossing an installation. |
| | Electricity consumption | 10% saving. Concern over effect on tungsten halogen reliability. |
| SAFETY | Change in accidents | Reversion to a form of priority mode of operation would increase collisions, according to overseas safety studies. No controlled facilities would be available, hence reduced level of service for visually impaired pedestrians. |
| | Legibility to drivers | Could require additional signs on approach to the installation, potentially dynamic or including flashing to highlight operation method. |
| LEGISLATION | Changes required | Current use for flashing amber at Pelican crossings would need to be removed from use before its use for LD signals could be introduced. Changes to TSRGD and ZPPPCRGD. |
| DESIGN | Changes in geometry/layout | Sufficient visibility of approaches would be needed on safety grounds, which might require geometric/layout changes. |
| | Additional equipment | None required, programming changes possibly required |
| | Departmental specifications & guidelines | Signals manufacturers supply overseas customers; obtaining equipment for use of flashing ambers is feasible. |

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**Option 20: Display flashing amber signal to the major arms, display flashing red signal to minor arms**

Used in the USA and Canada, the give way operation of this option is similar to providing all approaches with flashing amber (Option 19). However, the use of flashing amber and flashing red on different approaches provides an indication of priority. Vehicles on the major arm would be given a flashing amber signal to proceed with caution, vehicles on the minor arms would be provided with a flashing red to stop and give way to vehicles on the major arms.

As with the other flashing signal options the key benefit is the impact on delays and the subsequent benefits to VOC and $CO_2$ emissions.

The use of flashing red within standard vehicular traffic signal heads is not currently permitted. They are only permitted within TSRGD in wig-wag signals used at level crossings, ferry ports, ambulance and fire stations and moveable swing bridges, where they indicate a vehicle must not proceed.

As with other options reverting to a form of priority mode of operation, flashing signals would require that controlled pedestrian crossing facilities are turned off. If pedestrian demand is likely to be present during LD periods, then it might not be suitable to employ this option.

**It is proposed to discount this option from the list of viable options**. The use of flashing red aspects to indicate vehicles can proceed with caution would create a high degree of confusion and misunderstanding, since in the UK flashing red lamps are **ONLY** used to signify 'Stop' at wig-wag signals.

| | | OPTION 20 |
|---|---|---|
| ECONOMY | Impact on Delay | Potential delay due to waiting at signals is removed; vehicles on the major arm will experience no delay, vehicles on the minor arm should experience less delay than signal control, though a junction running VA in LD should be efficient at optimising vehicle movements. |
| | VOC | The major arm would benefit from priority and thus VOC would be reduced. The benefit to the minor road would therefore be reduced over "flashing amber to all" option. |
| ENVIRONMENT | $CO_2$ emissions | Major arm emissions should be greatly reduced as no delay should be experienced, minor road vehicles will be required to give way however during LD periods emissions should be reduced when compared to full signal control |
| | Electricity consumption | 10% saving. Concern over effect on tungsten halogen reliability. |
| SAFETY | Change in accidents | As with "all flashing ambers", though with priority given to the major arm the junction will operate more like a priority intersection. |
| | Legibility to drivers | Legibility would be better than for all flashing ambers as priority is established, however driver education and acceptance is still vital to ensuring it can used within the UK. |
| LEGISLATION | Changes required | No driver should proceed on flashing red, currently used only in wig-wag signals. |
| DESIGN | Changes in geometry/layout | Sufficient visibility of approaches would be needed on safety grounds, which could require geometric/layout changes. |
| | Additional equipment | None required, programming changes |
| | Departmental specifications & guidelines | Signals manufacturers supply overseas customers; obtaining equipment for use of flashing red is feasible. |

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**Option 21: Display flashing amber signal to minor arms, switch off signals on major arms**

This option seeks to provide similar benefits to operating under flashing amber control. However by turning off the signals on the major arms and providing flashing amber signals only on the minor arms, an indication of priority could be given. It is intended that traffic on the major arms would be given priority, as no form of control will be provided. The flashing amber to the minor road would signify that vehicles must proceed with caution, giving way to vehicles on the major road.

Savings to electricity consumption would be significantly higher than retaining full signal control, with the major road turned off and the minor road using intermittent flashing. The issue of the reduction in reliability and lifetime of tungsten halogen lamps is a concern as with the full flashing amber option.

Pedestrian facilities under this method of operation would need to be turned off, as the vehicular traffic signals will not be operational.

> The use of flashing amber signals to indicate priority has been shown to increase accidents when used overseas. Considering this form of signal control within the UK would rely on extensive driver education, and the implementation would require additional measures to clarify the priority operation. The current use of flashing ambers is at Pelican crossings where vehicles allow pedestrians to clear a crossing before proceeding; drivers would not ordinarily expect a conflicting vehicular movement when proceeding through a flashing amber.

| | | OPTION 21 |
|---|---|---|
| ECONOMY | Impact on Delay | Delay due to waiting at signals is removed; vehicles on the major arm will receive priority, vehicles on the minor arm should see reduced delay than signal control. A junction running VA in LD should be efficient at optimising vehicle movements. |
| | VOC | Major arm would receive priority and thus VOC would be reduced. |
| ENVIRONMENT | $CO_2$ emissions | Major arm vehicle emissions should be reduced through provision of priority; minor road vehicles will be required to give way however during LD periods emissions should be reduced when compared to full signal control. |
| | Electricity consumption | 16% saving. Concern over effect on tungsten halogen reliability. |
| SAFETY | Change in accidents | As with flashing amber major arm/flashing red minor arm, priority is given to one direction so acts more as a priority intersection. |
| | Legibility to drivers | Legibility would be better than for all flashing ambers as priority is established, however driver education and acceptance is still vital to ensuring it can used within the UK. |
| LEGISLATION | Changes required | Current use for flashing amber at Pelican crossings would need to be removed from use before its use for LD signals could be introduced. Changes to TSRGD and ZPPPCRGD. |
| DESIGN | Changes in geometry/layout | Sufficient visibility of approaches would be needed on safety grounds, which might require geometric/layout changes. |
| | Additional equipment | None required, programming changes |
| | Departmental specifications & guidelines | Signals manufacturers supply overseas customers; obtaining equipment for use of flashing ambers is feasible. |

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**Option 22: Display Variable Message 'Give Way' signs to minor arms, switch off signals on major arms**

The concept of this option is the same as displaying flashing amber to the minor roads and switching off the traffic signals on the major roads.

It is proposed that instead of using flashing amber signals to indicate priority, Variable Message (or potentially permanently illuminated during LD periods) signs are used to show a 'Give Way' sign on approach from a minor road, as a driver would expect at a priority junction. This would overcome driver confusion over the use of flashing amber signals.

Visibility of the give way signs is paramount, particularly as the installations would likely be operating under priority mode of operation for a small portion of the day. Where possible signs should be located adjacent to each traffic signal head, as a minimum to indicate why the traffic signals are not in operation.

LD operation under priority mode of operation could be reinforced with the provision of give way markings on the minor arms. Without such markings drivers would be required to stop at the traffic signal stop line before giving way; in many instances drivers would have insufficient visibility of the major road. With give way markings provided in a similar fashion to left turn slip lanes at signal controlled junctions, the operation should be more apparent and safer.

The 'Give Way' signs would need to be connected to the controller in order that the switch to LD operation can activate them. Given the proximity of the signs to the traffic signals it should not be cost prohibitive, however monitoring in case of failure and maintaining the signs would be prohibitive without significant developments.

Pedestrian facilities under this method of operation would need to be turned off, as the vehicular traffic signals will not be operational.

> This option seeks to remove the confusion that may be realised by changing the method of operation of a signal controlled junction to priority operation. Unlike employing flashing aspects within the signal heads, this LD operation would ensure the appropriate give way signs and markings are provided as would be expected at a junction with priority mode of operation.
> The issue of pedestrian crossing facilities remains; the controlled pedestrian facilities would need to be turned off with the traffic signals which would limit suitable installation locations.

| OPTION 22 | | |
|---|---|---|
| ECONOMY | Impact on Delay | Delay whilst waiting at signals is removed; vehicles on the major arm will receive priority, vehicles on the minor arm should notice reduced delay over signal control. |
| | VOC | Major arm would receive priority and thus VOC would be reduced. |
| ENVIRONMENT | $CO_2$ emissions | Major arm vehicle emissions should be reduced through provision of priority; minor road vehicles will be required to give way however during LD periods however emissions should be reduced when compared to full signal control. |
| | Electricity consumption | A potential 20% saving based on the traffic signals being turned off in LD periods, however provision of VMS would reduce saving. |
| SAFETY | Change in accidents | As with displaying flashing amber major arm/flashing red minor arm, priority is given to one direction so acts more as a priority intersection. |
| | Legibility to drivers | Understanding of the operation should be improved as junction will contain the signs and markings from a priority intersection. |
| LEGISLATION | Changes required | No legislative changes required. |
| DESIGN | Changes in geometry/layout | Sufficient visibility of approaches would be needed, meeting the requirements for a priority junction. |
| | Additional equipment | The give way signs would be required for all minor arms; they must be connected to the controller to allow activation during LD periods |
| | Departmental specifications & guidelines | TR2500 specifications must be amended to permit the change. Legislation and guidance for road markings, signs etc. would also need to be amended. |

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**Option 23: Switch off all traffic signals**

This option would revert a signalised junction to priority mode of operation during LD periods by turning off all traffic signals. Vehicles would be required to give way, using gap acceptance to proceed through the junction. This method of operation is currently used at signalised roundabouts, where turning off the signals outside of peak periods does not compromise the legibility of the junctions.

As with the other options reverting to priority mode of operation, there are benefits to delay, the environment and electricity consumption, at the expense of control over conflicting vehicle movements.

Currently, part time signals are generally only provided where there is no pedestrian facility. At existing installations with integrated pedestrian facilities, this option would necessarily involve the loss of controlled crossing facilities.

It should be noted that the use of part-time signalling at roundabouts is declining, LTN 1/09[40] summarises a study on signalised roundabouts undertaken by the County Surveyors' Society in 1997; the study identified an increase in collisions at installations when their part-time signals were not operating. Partly due to the findings of this study the use of part time signals has declined, and many former part-time signals have been converted to full-time operation.

Such operation could be confusing to drivers, the installations could be interpreted as operating under LD conditions or the installation could be considered faulty.

Given that this option is currently in use within the UK at roundabouts, it must be included within the feasible list of options for LD control. However, i**t is not recommended that this option be deployed at junctions other than roundabouts** unless there is sufficient legibility of priority and visibility of approaching vehicles from the minor road.

| OPTION 23 | | |
|---|---|---|
| ECONOMY | Impact on Delay | In LD conditions, the delay should be minimised as vehicles will only experience delay when coming into conflict with other vehicles. |
| | VOC | Potential to reduce vehicle operating costs when demand is sufficiently low and thus conflicts are reduced. |
| ENVIRONMENT | $CO_2$ emissions | Potential to reduce average emissions for an installation as waiting times at junctions could be reduced. |
| | Electricity consumption | A 20% saving to daily consumption. |
| SAFETY | Change in accidents | With no signals in operation, collision rates will increase. The rate at which they increase would depend on whether an indication of priority is given between the major and minor arms. In addition, pedestrians would lose the controlled crossing facilities. |
| | Legibility to drivers | Traffic signals are currently turned off at part time signals at roundabouts, where the legibility of the junction is not compromised. At other junctions, the turning off of part time signals would result in no priority given to a specific movement. |
| LEGISLATION | Changes required | None |
| DESIGN | Changes in geometry/layout | Sufficient visibility of approaches would be needed on safety grounds, which could require geometric/layout changes. |
| | Additional equipment | None required, programming changes |
| | Departmental specifications & guidelines | Guidance for their use would be required to ensure consistency between authorities. |

[40] DfT (2009) *LTN 1/09 Signal Controlled Roundabouts*

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**Option 24: Switch off vehicular traffic signals at junctions, pedestrians reinstate signal control**

This option is a variant of Option 23. During LD operation and with no pedestrian demand, signals for traffic movements would be turned off and red aspects would be displayed to pedestrian movements, therefore the installation would operate as a priority intersection. If a pedestrian demand is registered, the traffic signal installation would need to be reactivated in full, stopping traffic before a green aspect can be shown to pedestrians to cross. This option differs from Option 15 in that if there is no pedestrian demand traffic movements would operate under priority conditions.

It is considered that the efficiency of this option could be enhanced further by providing wide area pedestrian detection to identify the proximity of NMUs and ensure the signals are reinstated automatically, prior to the push button demand being placed. This represents a time saving in responding to pedestrian demand.

The reactivation of signal control will be critical; the startup sequence will likely be similar to part time operation. TR2500[41] prescribes signals under part time operation shall not show any signal for at least 7 seconds after restoration of a power supply, followed by a 3 second amber period before a red signal. The remaining approaches remain unlit for the duration of the starting intergreen, to ensure that all traffic that has been shown an amber signal has cleared the junction. Given the traffic signals will be reinstated to service a pedestrian demand, the delay to pedestrians could be considerable; the pedestrian intergreen will follow the above startup sequence.

A switch off sequence would need to be developed, potentially changing to an all red stage for a period when no vehicles are detected, before turning off.

**It is proposed to discount this option from the list of viable options at junctions**. This option does not grant priority to specific movements, similar to Option 19. This represents a safety risk as identified in overseas research into the method of operation.
The option is intended to address the issue of retaining controlled pedestrian crossings at installations which may benefit from a change to priority mode of operation during LD periods. However users may be confused with the inconsistent use of traffic signal control between vehicular movements and pedestrians.

| OPTION 24 | | |
|---|---|---|
| ECONOMY | Impact on Delay | Switching off signals would remove red light delay to vehicles, though vehicle speed should still be slowed due to driver uncertainty in crossing the junction. |
| | VOC | With a pedestrian demand, VOC would be as per full signal control; however VOC should reduce when signals are turned off due to reductions in delay. |
| ENVIRONMENT | $CO_2$ emissions | Marginal benefits would be experienced, only when pedestrian demand was not present, else pedestrian control to revert vehicular movements to red would offset any benefit to emissions. |
| | Electricity consumption | A 20% potential saving, reduced for each pedestrian demand during LD operation. |
| SAFETY | Change in accidents | This option benefits from retaining controlled pedestrian crossing facilities. Vehicular collisions could still increase due to the loss of signal control. |
| | Legibility to drivers | Same vehicular legibility at turning off all traffic signals, though junctions suddenly turning on and off could cause confusion if not done in a clear way. |
| LEGISLATION | Changes required | , None. |
| DESIGN | Changes in geometry/layout | Sufficient visibility of approaches would be needed on safety grounds, which could require geometric/layout changes. |
| | Additional equipment | Detection for pedestrians approaching traffic signal installation |
| | Departmental specifications & guidelines | Pedestrian detection is not currently used on this scale. As with other options, it is guidance that would be required to clarify the use of such detection. An LD algorithm would need to be developed to switch effectively between methods of operation. |

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[41] Highways Agency (2005) *TR 2500 rev A Specification for Traffic signal controller*

**Option 25: Revert signalised mid-block crossings to priority operation**

When traffic and pedestrian demands are low at mid block pedestrian crossings, this option suggests that the crossing revert to priority operation, with pedestrians having priority over vehicles by operating the crossing as if under zebra control.

This method of operation could improve facilities for pedestrians by giving them priority over vehicles as opposed to waiting for a registered demand to be serviced. The option could also reduce vehicular delay through a reduction in lost time.

The key difficulties for the viability of this option is the display and the enforcement of the zebra control (i.e. ensuring pedestrians have priority). This could be achieved by extinguishing all aspects except the amber traffic aspect, which would flash (effectively replacing the Belisha beacon at a conventional zebra crossing). Alternatively the installation could revert to quiescent all red to both traffic and pedestrians. It would be possible to permit the crossing pedestrian to elect whether to use the crossing as a zebra, or alternatively to press the pedestrian demand unit which would reinstate Puffin control by turning the vehicle signal from flashing amber through 3 seconds of constant amber to red. Once the pedestrian had crossed, the crossing would revert to flashing amber to traffic.

However, the use of flashing ambers would not currently be viable as under the Pelican Crossing Regulations they indicate that vehicles could proceed if no pedestrians are already on a crossing, rather than that vehicles should stop to allow pedestrians to commence crossing. As discussed for the flashing amber signals at junctions, the current use of flashing amber would need to be phased out and drivers educated on its revised application for it to be successfully implemented.

Changes to operation of mid-block pedestrian crossings would require changes to the current standards for pedestrian crossings; there is currently no provision for permitting pedestrian crossings to be turned off outside of peak periods.
This option would rely on the appropriate display of priority for pedestrians over the conflicting traffic stream.
Flashing operation of the amber aspect is not prescribed for Puffin crossings; an alternative method of indicating priority would be required.
Local authorities would need to consider whether such operation provided sufficient benefit over reactive controlled pedestrian crossings including the use of pre-timed maximums.

| OPTION 25 | | |
|---|---|---|
| ECONOMY | Impact on Delay | Small saving to vehicle delay in total lost time experienced at controlled crossings. Puffin crossings should cancel demands if pedestrian moves away from crossing. |
| | VOC | A small reduction could be experienced with vehicles not losing time during the pedestrian stage (preceding intergreen, pedestrian green and proceeding intergreen). |
| ENVIRONMENT | $CO_2$ emissions | Emissions should be reduced slightly as the lost time at a pedestrian crossing should be less than giving way to a pedestrian at a zebra crossing. |
| | Electricity consumption | 20% saving to daily consumption. |
| SAFETY | Change in accidents | Disadvantage in terms of safety for pedestrians as no longer a controlled crossing point |
| | Legibility to drivers | Enforcing or even displaying that zebra control (i.e. Pedestrian priority) is in operation will be the key issue. Flashing signals at pedestrian crossings currently advise that vehicles could proceed if no pedestrians are on crossing. |
| LEGISLATION | Changes required | This would require changes to current standards for the use of Puffin crossings and the disassociation of flashing amber from use with Pelican crossings. |
| DESIGN | Changes in geometry/layout | Sufficient visibility of approaches would be needed on safety grounds. |
| | Additional equipment | None required, programming changes |
| | Departmental specifications & guidelines | An LD algorithm would need to be developed to switch effectively between methods of operation. |

# 13 Effects on Electricity Consumption

## 13.1 Overview

13.1.1 The issue of our carbon footprint in general is of global concern. The EU target to reduce carbon emissions by 20% from 1990 levels by 2020 is currently under review to increase this figure to 30%[42]. A major part of the drive for a reduced carbon future includes addressing the carbon footprint of transport related systems; measures include embracing energy saving technologies for traffic signals and reducing vehicle delay and journey times by optimising the performance of installations.

13.1.2 This Chapter considers the energy saving potential of retrofitting incandescent traffic signal aspects with LEDs, a process many local Authorities are already undertaking. It is intended to quantify the potential power consumption savings separately from considering options for signal operation in LD periods; the two issues both seek to reduce the carbon footprint of installations, however the provision of LED aspects can be undertaken irrespective of the method of operation.

## 13.2 Power Consumption

13.2.1 Incandescent lamps consume around 57W at full power and 34W when dimmed, compared with typical LED consumption of around 17W at full power and 8W when dimmed.

13.2.2 The UK Energy Research Centre issued a “Traffic Signals Quick Hit Report”[43] in 2006 comparing the consumption of UK traffic signals using both incandescent and LED lamps. The report concluded that incandescent lamps in all UK traffic signals required round 18MW of power, compared with around 6MW if LEDs were used. Over the period of a year, the consumption would equate to 158GWh using incandescent lamps and 53GWh with LEDs. The paragraphs below estimate the potential savings in 2009, providing an estimate of the annual power consumption under both lamp types.

13.2.3 In addition, the impact of turning traffic signal heads off is considered, specifically turning every third head off during LD periods.

### Assumptions

13.2.4 The following assumptions were made, based on relevant statements within the UKERC report and additional assumptions where required:

- Averaged over a year, lamps subject to night-time dimming would be on full power for 50% of the day, dimmed for the remaining 50%. It is recognised that some authorities do not dim traffic signals in well lit areas. The assumed power consumption has therefore been averaged at 46W for incandescents and 13W for LEDs;
- The number of traffic signal installations in 2009 has been calculating using the results of the 2000 Traffic Survey by the Traffic Control User Group, as per the UKERC report. With the same 3% growth assumed, it has been calculated that there are an estimated 34,000 traffic signal installations within the UK;
- The proportions of traffic signal installation types have been derived from the UKERC data, and validated against statistics for 2009 for Leeds city centre provided by Leeds City Council. It is estimated that, country-wide, around 18,000 traffic installations are pedestrian crossings, the remaining 16,000 split equally between simple and complex junctions;

[42] EU (2008) *Carbon Reduction Strategy*
[43] UKERC (2006) *Quick Hits: Traffic Signals*

- Pedestrian crossings normally provide either 4 or 6 signal heads for traffic movements with 2 pedestrian signal heads. Assuming a 50% split between 4 and 6 heads per installation, an average of 7 signal heads per site has been assumed;
- Each signal head is assumed to have one aspect lit at any time, thus does not account for the time when red and amber aspects on a traffic signal head are shown together.
- Simple junctions have been specified as those with up to four arms, typically with 3 signal heads on each approach, thus 12 signal heads for traffic movements has been assumed. The 2000 TCUG survey data suggested only 60% of junction have controlled pedestrian crossing facilities, therefore 60% of 8 signal heads (4.8) have been assumed for simple junctions, giving a total number of heads per ‘simple’ junction as 16.8; and
- Complex junctions have been estimated using the same methodology as for simple junction, but with 5 arms, giving a total of 26 signal heads for a typical ‘complex’ junction.

***Results***

13.2.5 **Table 10** below suggests the potential savings for changing all traffic signals from incandescent lamps to LEDs. Clearly some installations have either been installed or retrofitted with LED heads, however statistics are not available.

**Table 10 –** Estimated power consumption savings converting Incandescent to LED

| | Signal Heads | | | Total Wattage (MW) | | Yearly Consumption (GWh) | | Yearly Savings (GWh) |
|---|---|---|---|---|---|---|---|---|
| **Installation type** | **No. of sites** | **No. of signal heads per site** | **Total no. of heads** | **Incan-descent** | **LED** | **Incan-descent** | **LED** | **Incandescent to LED** |
| Simple junctions | 8,000 | 16.8 | 134,400 | 6.1 | 1.7 | 53.6 | 14.7 | 38.9 |
| Complex Junctions | 8,000 | 26 | 208,000 | 9.5 | 2.6 | 82.9 | 22.8 | 60.1 |
| Pedestrian Crossings | 18,000 | 7 | 126,000 | 5.7 | 1.6 | 50.2 | 13.8 | 36.4 |
| **TOTAL** | **34,000** | | **468,400** | **21.3** | **5.9** | **186.7** | **51.3** | **135.4** |

13.2.6 These calculations for the power consumption of incandescent and LED signal heads are similar to those calculated by the UKERC (variations attributed to differences in assumptions). The estimated saving of 135 GWh/year is equivalent to the power consumption of a city of 157,000 inhabitants, for example Peterborough.

13.2.7 For comparative purposes, the estimated power consumption savings of turning off every third signal head during LD periods have been estimated. Assuming that this would be permitted for 5 hours per day, for example overnight, the daily consumption would be:

(Ch x 19) + (0.67Ch x 5) = 22.35 x Ch kWh, where Ch is the hourly consumption.

13.2.8 The resultant saving would therefore be equivalent to a reduction in effective wattage of less than 7%, offering less significant savings than changing traffic signals to operate with LED aspects. If LED aspects are already in use, the saving is reduced further. Table 11 below indicates the potential saving in turning off every 3rd signal head in the UK during LD periods.

**Table 11 –** Estimated saving from turning every 3rd signal head off for 5 hours per day

| | Total Wattage (MW) | | Yearly Consumption (GWh) | | Yearly Savings (GWh) | |
|---|---|---|---|---|---|---|
| **Installation type** | **Incandescent** | **LED** | **Incandescent** | **LED** | **Incandescent** | **LED** |
| Simple junctions | 5.7 | 1.6 | 49.9 | 13.7 | 3.7 | 1.0 |
| Complex Junctions | 8.8 | 2.4 | 77.2 | 21.2 | 5.7 | 1.6 |
| Pedestrian Crossings | 5.3 | 1.5 | 46.8 | 12.8 | 3.5 | 0.9 |
| **TOTAL** | **19.8** | **5.5** | **173.9** | **47.8** | **12.8** | **3.5** |

13.2.9 It is clear the carbon footprint of traffic signals will decrease in line with reducing their electricity consumption. Changing incandescent lamps to LEDs will realise the most significant saving in terms of consumption and lifespan, hence many local authorities are retro-fitting existing traffic signal installations.

13.2.10 Turning off individual traffic signal heads during LD periods would reduce power consumption; however, the scale of this saving when compared to providing LED signal heads is low, and would not be considered justifiable if such an action had a detrimental impact on safety. It has to be assumed that the designers of signal installations specify the minimum number of signal heads to ensure safe control of traffic. The deactivation of some signal heads would therefore be providing an under-signalled junction.

13.2.11 It is suggested that the case for retro-fitting traffic signal heads with LED aspects would be a more preferable method of reducing power consumption than introducing measures that might affect the safety of highway users. A key obstacle in retro-fitting LED heads is the cost of changing controllers to provide the appropriate lamp-monitoring and compatibility with the chosen manufacturer's LEDs. Incandescent traffic signal controllers have minimum power load requirements which LED signal heads can operate under. For an LED signal to be used with an old controller, it requires additional equipment to artificially add a resistive load to raise the LED to an acceptable power load (which can reduce the life of the LED and largely negate the power-saving benefits of LEDs). Given the safety critical nature of red lamp monitoring this feature must be included; however reductions in installation costs through improved compatibility between controllers and LED technologies would make it easier to retrofit modern technologies into existing installations.

# 14 VISSIM Modelling of Options

## 14.1 Introduction

14.1.1 The options detailed in Chapter 12 have been assessed against qualitative factors including safety, environmental benefits and road user legibility to ascertain whether they are suitable to take forward for future development. One of the key objectives for examining alternative methods of control during LD periods is to reduce the carbon footprint of installations, including reductions in vehicle emissions and delay.

14.1.2 This Chapter details the micro-simulation modelling carried out on the key options, with the aim of outputting comparable journey times and vehicle carbon emissions for a number of different traffic flow scenarios. The micro-simulation modelling software used was VISSIM.

14.1.3 VISSIM is capable of generating a number of random permutations for traffic distribution. However, for the purpose of comparison it is useful to consider identical traffic patterns for each scenario.

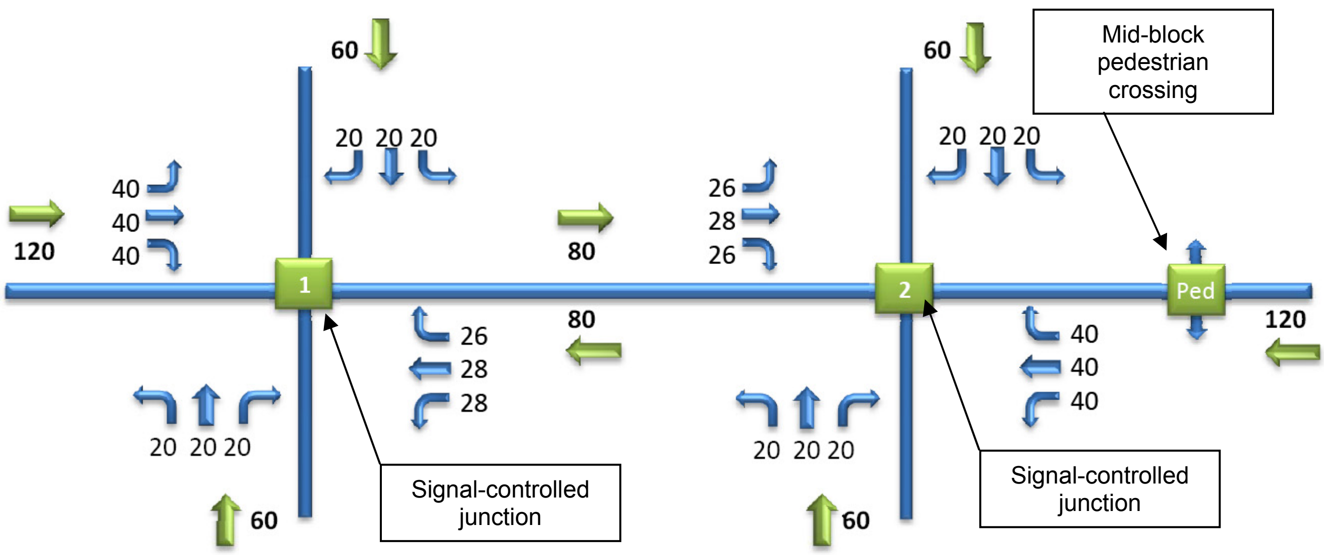
## 14.2 Modelled Network

### *Network layout*

14.2.1 The micro-simulation is intended to quantify the relative benefits of implementing various LD control options. To ensure results are comparable a hypothetical controlled network was created within which the signal control models could be tested.

14.2.2 The indicative network consists of two signal controlled crossroads a distance of 750m apart and a Puffin pedestrian located 500m to the east of these two junctions. There are no sources or sinks for traffic within the network other than the entry points at the extents of the model. This layout of the model is intended to simulate a highway network with platooning of vehicles caused by upstream installations. **Figure 10** illustrates the network used for the micro-simulation modelling.

**Figure 11** – Example turning count diagram for entry flows within the VISSIM model



***Traffic Flows***

14.2.3 The effectiveness of certain methods of signal control during LD periods might depend on the absolute traffic flows on both the major and minor road approaches to an installation. It could also be affected by the ratio of major road to minor road traffic.

14.2.4 To determine the influence of traffic flows on the method of operation selected, a series of traffic scenarios have been modelled for combinations of major road to minor road. The combinations provide 5 minor road flows for each major road flow. This ensures the rate of change of journey times and carbon emissions can be ascertained as the minor road flow increases for each major road flow specified.

14.2.5 The flows scenarios are listed in ***Error! Reference source not found.*** below. They dictate the major and minor road entry flows, not two way flows at each installation.

**Table 12** – Flow scenarios modelled for each method of operation

| Major Road entry flow (veh/hr) | Minor Road entry flow (veh/hr) | | | | |
|---|---|---|---|---|---|
| 60 | 20 | 30 | 40 | 50 | 60 |
| 90 | 30 | 45 | 60 | 75 | 90 |
| 120 | 60 | 75 | 90 | 105 | 120 |
| 150 | 60 | 90 | 105 | 120 | 150 |
| 180 | 60 | 90 | 120 | 150 | 180 |

14.2.6 **Figure 11** illustrates the assumptions made for traffic distribution within the modelled network, with a major road flow of 120 vehicles per hour (vph) and a minor road flow of 60vph as an example. To ensure each scenario was comparable, equal turning proportions were assumed for each approach. Pedestrian flows were set at 5 pedestrians per hour at each entry to the network. The distribution of pedestrians within the network is initially determined by VISSIM, however this dispersal was fixed after an average distribution was taken.

14.2.7 The permutations for traffic distribution generated in VISSIM are used to simulate variable arrival patterns within the modelled network, more realistic than assuming uniform distributions. To ensure identical traffic patterns were used, 10 random permutations were selected and an average identified for use within all option models.

***Traffic Signal Options***

14.2.8 Ten LD traffic signal options, deemed to be likely to have the most significant impact on vehicle delay and emissions, were modelled. These comprise:

- UTC (Fixed Time);
- VA operation;
- VA operation with quiescent all red;
- MOVA operation;
- MOVA operation with Q.A.R;
- CMOVA operation;
- Nearside pedestrian detection installed at junctions;

- Flashing amber shown to all approaches. Given this is not permitted in the UK the use of priority markers and conflict points was used to simulate a priority system; and
- Amber signal displayed to the minor road approaches, signals switched off on major road approaches; and
- Low minimum green values.

14.2.9 Other options identified for future consideration have not been modelled within this study. These include the following options.

- Adaptive SCOOT UTC – VISSIM does not model SCOOT. A SCOOT computer system would be required to output the necessary information to develop options within VISSIM;
- Switch off all signals, vehicles or pedestrians reinstate signal control – this option is considered an electricity saving option. Users would not experience any change over current methods of operation, as detected vehicles would reinstate full signal control;
- Switch off all signals, pedestrians reinstate signal control – the impact of this option is similar to switching off all signals in LD periods. It is likely the majority of users would cross the road without reinstating the pedestrian crossing during LD periods.
- Switch off all signals, revert to priority mode of operation– it is considered that this option would invoke a similar behaviour to introducing flashing amber to all approaches, requiring all approaches to navigate a junction with caution;
- Display Variable Message 'Give Way' signs to the minor roads, switch off signals on the major roads – The operation of this option is the same as displaying a flashing amber to the minor road and switching the signals off on the major road;
- Use timetabled pre-timed maximum green at mid block pedestrian crossings – the impact of changing the operation of the mid-block pedestrian crossing alone could not be quantified within this model, its performance would be affected by the method of operation at the adjacent junctions; and
- Revert Puffin crossing to priority mode of operation– as with pre-timed maximum greens, a pedestrian crossing would benefit from an additional micro-simulation exercise to quantify the benefits of operating under priority mode of operationduring LD periods.

## 14.3 Results

14.3.1 The journey time output within VISSIM provides a total travel time (in seconds) for all routes within the modelled network, for example eastbound and westbound main road journeys and turning movements onto minor roads. The carbon emissions are also route based, calculating the number of grams of carbon generated by all vehicles using each of the routes.

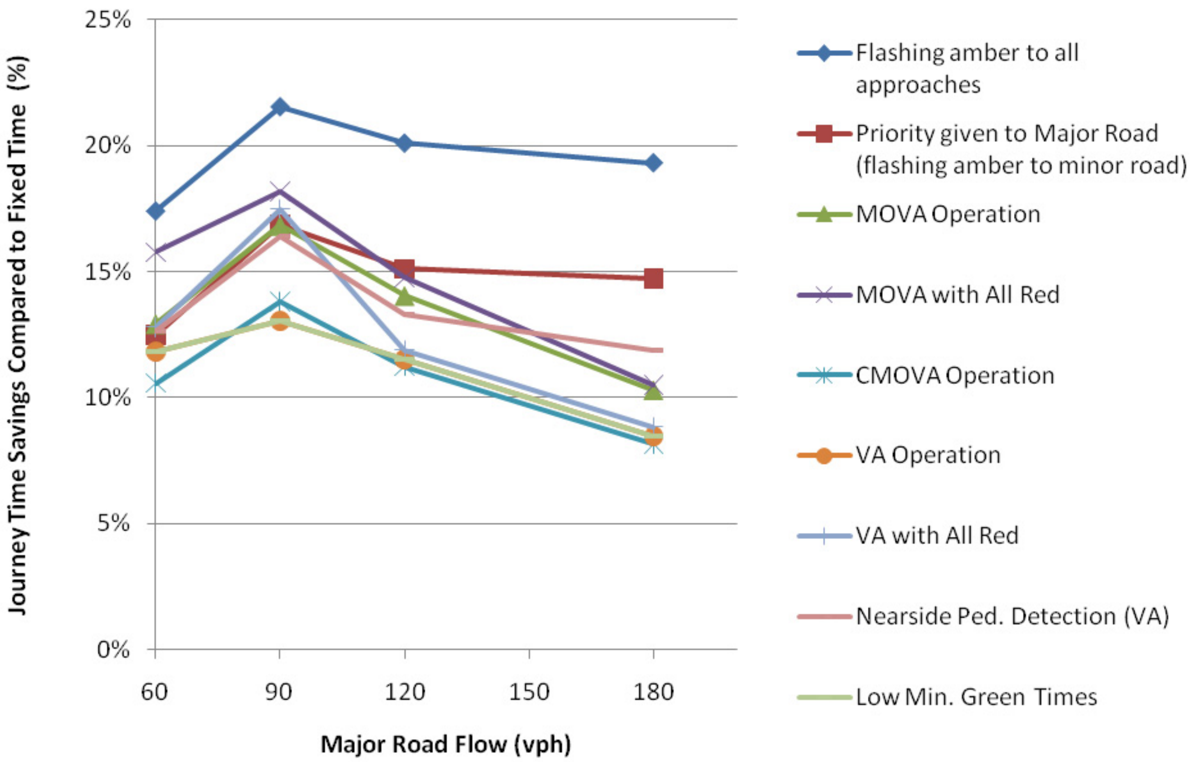
14.3.2 In order to provide representative results to apply in other networks, each LD option is reported as a percentage change in the modelled network performance in comparison to the fixed time (UTC) option. The fixed time option was developed using the TRANSYT traffic signals software to derive an indicative set of LD signal timings with a 60 second cycle time. Absolute values for journey time savings and emissions are not used as these only relate to the modelled network.

14.3.3 Full results for journey times and carbon emissions for all flow scenarios listed in ***Error! Reference source not found.*** are included at the end of this Appendix. To indicate the performance of each modelled option as traffic flows increase, increasing major road flows were plotted against the percentage performance change for a major/minor flow ratio of 2:1.

### *Journey Time Results*

14.3.4 **Figure *12*** below illustrates the results for the average network journey time performance for all modelled LD options. The graph is based on a major to minor road flow ratio of 2:1.

**Figure 12 –** Network journey time savings compared with fixed time operation with a major/minor flow ratio of 2:1




- Displaying flashing amber to all approaches records the highest saving to journey times within the modelled network, followed by priority operation (minor roads give way) and MOVA installations.
- All results are within a 10% range, however priority mode of operation can realise twice the benefit of CMOVA operation
- The safety concerns of implementing flashing amber to all approaches during LD periods make it problematical to recommend over full signal control given the differences between performance.

14.3.5 Displaying flashing amber signals to all approaches realises the most benefit for journey times, with a saving of around 20% when compared to fixed time operation. The performance of the remaining LD priority option, displaying flashing amber to the minor road with traffic signals switched off on the major road approaches, was around 5% lower compared with fixed time operation than displaying flashing amber to all approaches. The option performance compared with LD options retaining full signal control fluctuates depending on the traffic flows;

on flows up to 90vph the option performs in a similar fashion to many of the signal controlled options, with the benefits increasing steadily from 12% to 17% over the fixed time option. As traffic flows increase above 90vph, the savings for all options start to decline; the decline continues as the modelled major road flow increases to its maximum (180vph), at which point the signal controlled options record savings averaging around 10%. The relative decline as flows increase for the LD option displaying flashing amber to the minor road is small, with a reduction to 15% where the major road flow is 180vph.

14.3.6 Considering the signal controlled options in isolation, MOVA operating with quiescent all red provides the highest saving, experiencing a peak of around 18% at 90vph on the major road (a greater saving than displaying flashing amber to the minor roads) reducing to 11% as the traffic flow on the major road reaches 180vph. MOVA reverting to the main road stage realises a slightly lower benefit, due to the higher intergreen time required to change to the main road stage to service a demand on the minor road. Compact MOVA, operating without the upstream IN detection of full MOVA, realises a similar benefit to VA operation averaging around a 10% saving.

14.3.7 The options based on VA operation did not operate as well as the MOVA related options, though the differences between the two averaged around 3%. VA operating with a quiescent all red stage performs better than VA reverting to a main road stage, the same as occurs with MOVA operation. Utilising nearside detection at VA installations to cancel pedestrian demands when they are no longer required provides an additional saving to journey times, a saving which increases as traffic flows rise. This behaviour is expected; if the network is relatively quiet and vehicle arrivals are sporadic, the benefit of cancelling pedestrian demands might not be fully realised. As traffic flows increase, the likelihood of a pedestrian stage delaying traffic also increases, consequently any cancelled pedestrian demands will have a more noticeable effect. It is believed that the use of nearside pedestrian could be beneficial at installations during LD periods or under normal operation.

14.3.8 It should be noted that the LD option proposing low minimum green values under VA operation had a negligible effect when compared with normal VA operation (thus occupies the same area as the VA option on **Figure 11**). Marginal improvements were seen for route performance; however with traffic demands low the full benefit of reducing the minimum time for a phase was not observed.

14.3.9 The primary conclusion to the journey time performance of LD options is that the benefits attained by each of the LD options are within a 10% range for any of the major road flow scenarios compared with fixed time operation, providing benefits between 10% and 20% compared with fixed time operation. This suggests that the LD option displaying a flashing amber signal to all approaches achieves twice the benefit of VA and CMOVA operation though only 5% more than options including MOVA and nearside pedestrian detection. It should be noted that the real impact of these savings will be wholly dependent on the scale of application. A 10% saving to the total journey time for a single installation will be negligible, however an option applied to a large network would realise a more substantial benefit.

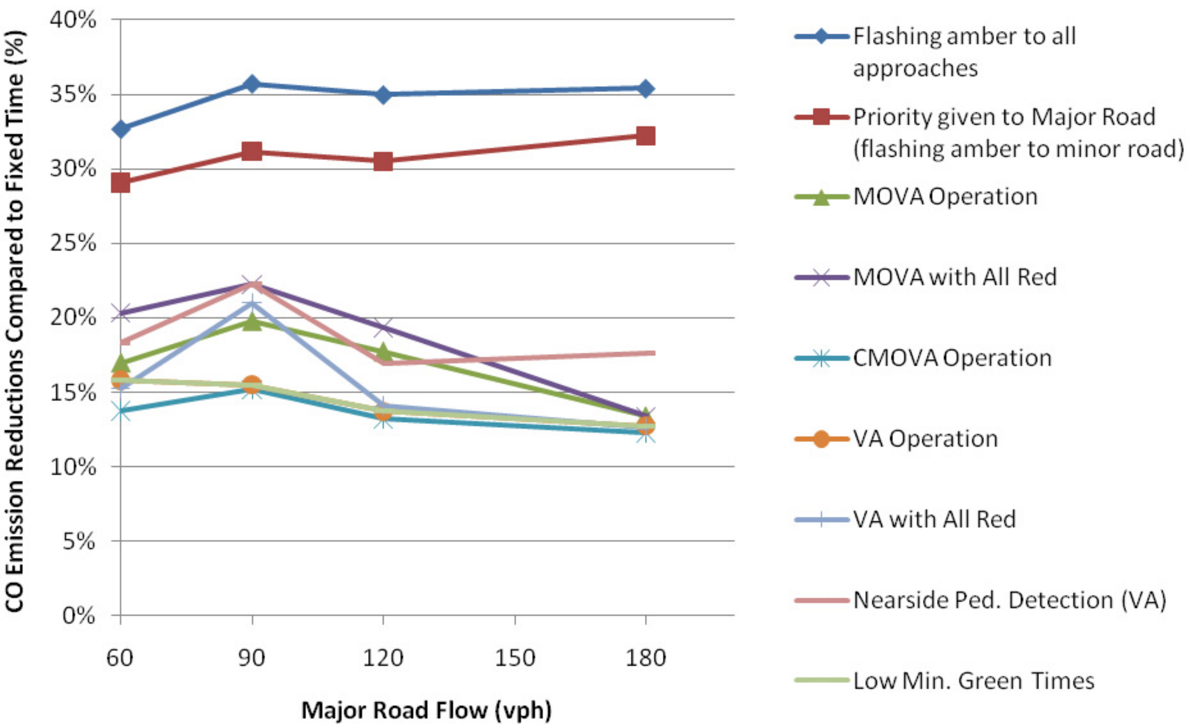
14.3.10 Though options reverting to priority operation might perform well during LD periods compared with fixed time signal control, the benefit over methods of operation such as MOVA is relatively small when flows are around 90vph or lower. Priority options displaying flashing amber to all approaches have been recorded to have a negative impact of safety, identified in the safety review of overseas traffic signal control (Chapter 6). In addition, obstacles to implementation including local authority concern over safety and the significant education programme that would be required would make it very difficult to implement this option within the UK. Providing a defined priority, for example making the minor road give way to the major road, would be more appropriate if the priority can be clearly displayed to drivers on approach to a junction.

### *Carbon Saving Results*

- Displaying flashing amber to all approaches records the highest reduction to carbon emissions times within the modelled network. The ranking of options is similar to the reductions reported for journey times.
- To realise a significant benefit, options would need to be implemented over a large number of installations.
- The justification for reverting to flashing amber to all approaches is difficult given the safety concerns over driver understanding and accident numbers.

14.3.11 **Figure 12** below illustrates the results for the average network carbon emission ($CO2$) performance for all modelled LD options. The graph is based on a major to minor road flow ratio of 2:1.

**Figure 13** – Network carbon emissions reduction compared to fixed time operation with a major/minor flow ratio of 2:1



14.3.12 It is evident that the LD options reverting to priority mode of operation realise a higher saving than those retaining full signal control, more marked than the results for journey time reductions. Displaying a flashing amber signal to all approaches records an average saving of around 35% over the fixed time model; displaying an amber signal to the minor road, switching off the signals on the major road records an average saving of around 30%. The carbon emission reductions due to the options retaining full signal control range from around 13% to 20%.

14.3.13 The ranking of signal controlled options in terms of carbon emission reductions is similar to that shown in the journey time results. MOVA operating with a quiescent all red stage performs the best, with compact MOVA and VA outputting the lowest reduction in carbon emission compared with fixed time operation. It is noted that the addition of nearside detection to the VA option resulted in it outperforming normal MOVA operation.

14.3.14 When entry flows increase above 90vph on the major road the performance of the LD options retaining full signal control, compared with fixed time operation, declines as flows increase. This is likely because as the adaptive control methods start to manage increasing numbers of vehicles, the installations will begin to behave more like fixed time operation; stage lengths will increase towards the maximum greens, demand dependent stages will be called more frequently.

14.3.15 The carbon savings of three of the LD options improve compared with fixed time operation as flows increase. These include the LD options reverting to priority mode of operationand the addition of nearside pedestrian detection to the VA installations. The behaviour of the priority mode of operation options is expected; as traffic flows increase the fixed time operation will delay more vehicles on arms shown a red signal. With priority operation, the carbon emissions are lower compared with fixed time operation as vehicles which would previously have been held on a red signal are permitted to gap seek. The benefit to carbon emissions recorded with the addition of nearside detection to the VA installation model can be attributed to the reduction in lost time.

14.3.16 It is noted that the fluctuations in carbon emission reductions when compared to fixed time operation for each option in isolation are relatively small. For example, though the flashing amber option experiences an increase in carbon emission savings as flows increase, the range of percentage change compared with fixed time operation is around 3%.

14.3.17 As concluded of the results for journey time performance of options, the absolute savings achievable by each of the options will depend on the scale of application. The relative savings between options and signal control options will be small at a single installation; it would take a significant number of installations to generate a carbon emission reduction to justify the risk associated with removing signal control.

## 14.4 Summary

14.4.1 It is apparent that the options proposing to remove signal control during LD periods realise more benefit than those options retaining full signal control. The overseas review of installations displaying flashing signals to all approaches shows that collision rates do increase with the change in operation. In addition, local authorities within the UK have showed concern at such methods of operations. Defining the priority for an installation during LD periods, making the minor road give way to the major road, would realise a similar benefit to flashing amber to all approaches with the ability to retain a level of safety, provided priority can be clearly displayed to drivers on approach to a junction.

14.4.2 The introduction of new technologies to improve the efficiency of adaptive traffic signal control systems could be implemented to realise benefits of a similar degree to the LD priority options. The results suggest that use of nearside pedestrian detection at junctions would be of particular benefit during LD periods and during normal operation.

# Option Development

# 15 'Short List' Options

## 15.1 Introduction

15.1.1 This Chapter summarises the options from Chapter 3 deemed suitable for further consideration. Each of the options has been classified as one of three categories based on the development necessary for them to be implemented effectively. The categories are as follows:

15.1.2 **Short term** - Options that could be implemented without any change to current technology or equipment, legislation and guidance. These generally include options that are currently in use within the UK, however might not be actively used by some authorities;

15.1.3 **Medium term** - Options that will require changes to current legislation, or technological advances to be made in order for them to work effectively; and

15.1.4 **Long term** - Options that will require significant changes to legislation, technology or driver education before they could be considered for use within the UK.

15.1.5 This Chapter also summarises the options that have been discounted following the assessment process (the NATA assessment summarised in Chapter 12 plus the VISSIM modelling described in Chapter 14.

## 15.2 Short Term Options

15.2.1 The following options could be considered for implementation during LD periods under current regulations:

***SCOOT/UTC Low Cycle time (Option 1)***

15.2.2 This option imposes a maximum cycle time on a network conducive to LD operation. This lower cycle time would be the shortest period during which every installation in the network could achieve a cycle running each stage at or close to its minimum green time. The advantage of this in UTC systems is that waiting times for vehicles would be reduced, as stages would cycle more quickly. It should be noted that lowering cycle times will reduce or remove the ability for SCOOT to adjust the split of green times to demanded phases. This option would involve revisions to network timetables and UTC/SCOOT parameters.

***Utilise VA as a fallback for UTC/SCOOT (Option 5)***

15.2.3 This option is widely used in the UK as a method of operation during normal and LD periods. Applying this strategy at a new installation or retrofitting within an existing installation would require detection on all approaches.

***Utilise MOVA as a fallback for UTC/SCOOT (Option 7)***

15.2.4 Though MOVA is a well established alternative method of operation within the UK, it is usually used at isolated installations. It is increasingly being used as an alternative method of operation for networks during periods when co-ordination is not required. To install MOVA to an existing controller requires an add-on unit to be provided and the appropriate detection. MOVA is generally more appropriate at higher speed sites so applications may be limited,

***Utilise CMOVA as a fallback for UTC/SCOOT (Option 8)***

15.2.5 As with MOVA, the technology to implement CMOVA is readily available. It provides a more suitable alternative to MOVA in low speed urban environments, and is also cheaper to install. Omitting the IN detector removes some of the benefit of MOVA operation; however developments in detection technology could improve the viability of this option.

***Install VA at isolated junctions (Option 9)***

15.2.6 The majority of isolated installations within the UK use vehicle actuated technology to control traffic. Despite its extensive use, there is potential to improve the efficiency of its operation through developments in the use of detection.

***Install MOVA/CMOVA at isolated junctions (Option 10)***

15.2.7 As with VA, MOVA/CMOVA is classified as a method of control for isolated junction; it is used extensively within the UK. Its inclusion as a short term option is intended to promote the research and development of detection technology to improve efficiency and reduce installation and maintenance costs.

***Install VA with quiescent all red operation (Option 11)***

15.2.8 To provide this method of operation to make VA operation more responsive an installation must have detection installed on all approaches. It is an existing facility in current controllers, and should require no additional hardware.

***Install MOVA with quiescent all red operation (Option 12)***

15.2.9 The requirements for MOVA operating under quiescent all red are the same as for VA; any MOVA installation will already have detection on all approaches. Improvements to detection technology would allow MOVA installation and maintenance costs to be reduced for new locations and retro-fit installations.

***Provide Puffin crossing technology at junctions (Option 16)***

15.2.10 This option provides Puffin crossing technology at junction installations to remove the delay caused by unnecessary pedestrian stage calls. It is recognised that additional cost will be associated with providing equipment and re-cabling; on a four arm junction an upgrade might cost in the region of £7.5-10K if the majority of the infrastructure (e.g. pole locations) remains the same.

***Use timetabled pre-timed maximum greens at mid block pedestrian crossings (Option 17)***

15.2.11 Timetabled pre-timed maximum green times at mid-block crossings are currently in use within the UK. Employing such operation would require changes only to the specification for the method of operation however during LD conditions the crossing would become more responsive to pedestrian demands, with little impact on vehicular flows.

***Retain current operation under LD periods (Option 18)***

15.2.12 If there are site specific conditions affecting the implementation of alternative LD operation, retention of the current method of operation might be the only alternative.

***Switch off all traffic signals (Option 23)***

15.2.13 Switching signals off is currently in use within the UK, however only at roundabouts where the traffic signals are normally used to control specific arms during peak periods. It is noted that the use of part time signals is declining due to the identification of an increase in collisions.

## 15.3 Medium Term Options

15.3.1 The following options could be considered for implementation during LD periods in the medium term. The majority of options require changes that will make no apparent difference to drivers, rather they are intended to optimise the operation of signal controlled installations during LD periods:

***SCOOT/UTC Extra Low Cycle Time (Option 2)***

15.3.2 Removing the need to allow time for demand dependent stages within a network environment would reduce the cycle time and increase the efficiency of installations. The implementation of this method of operation would involve modification of the SCOOT kernel.

***Adaptive UTC/SCOOT system (Option 3)***

15.3.3 Option 3 is a combination of Option 1 and 2. This option would operate by dynamically, assessing traffic flows and minimising the cycle time based on LD criteria being met and reacting to demand dependent stages not being called.

***Use low minimum green values (Option 13)***

15.3.4 VISSIM modelling indicates that reducing the minimum green times has only a small effect on the operation of a traffic signal installation; the impact of the option is wholly dependent on the arrival patterns of vehicles. Where perhaps only a single vehicle registers a demand on an approach, a lowered phase minimum could provide only enough green for that vehicle to proceed before changing stage quickly to service another demand. Further research could ascertain the viability of reducing the minimum green times as low as 2 seconds, which would allow installations to cycle more quickly during LD periods.

## 15.4 Long Term Options

15.4.1 The following options could be considered for implementation during LD periods as a long term prospect:

***Utilise SCOOT detection loops for MOVA (IN detectors) (Option 6)***

15.4.2 This research has concluded that VA detection utilising SCOOT loops would not be practicable. MOVA operation requires upstream detection which would lend itself to shared loop detection with SCOOT systems. The key advantages of this option over a full MOVA installation are the savings in the installation costs; however there is currently an incompatibility between the location, dimensions, configuration and data output of MOVA and SCOOT loops. In order for this option to be considered, the technology and software must be developed to resolve these incompatibilities.

***Switch off all signals, vehicles or pedestrians reinstate signal control (Option 15)***

15.4.3 This option is not intended to improve the operational efficiency of signal controlled installations; it is proposed to reduce the electricity consumption thus the carbon footprint of an installation by turning it off when no vehicles are in the vicinity. For this method of operation to be viable, significant development of detection technology would be required, in particular the use of wide area detection to monitor the presence of road users. For vehicles, upstream loops (for example SCOOT loops) should provide the appropriate distance over which to detect vehicles and reinstate signal control. Where existing loops are not available, a cost effective method for providing upstream detection would be required. Wide area pedestrian detection would ensure that signal control is available if a pedestrian crossing facility could be demanded.

***Display Variable Message 'Give Way' signs to minor arms, switch off signals on major arms (Option 22)***

15.4.4 This option is intended to remove the confusion of changing the method of operation of a signal controlled junction to priority operation during LD periods. The LD operation would ensure the appropriate give way signs and markings are displayed as would be expected at a priority junction. The issue of pedestrian crossing facilities remains; the controlled pedestrian facilities would need to be turned off during periods when the junction was operating under priority operation. Legislative changes might also be required.

***Revert signalised mid-block crossings to priority mode of operation (Option 25)***

15.4.5 This method of operation would improve facilities for pedestrians by giving them priority over vehicles. The option could also reduce vehicular delay through a reduction in lost time. Flashing amber signals is not recommended for indicating this priority due to its current use for Pelican crossings in the UK. Authorities will need to consider the justification for this method of operation in terms of the savings compared to reactive controlled crossing facilities such as pre-timed maximum green timers.

## 15.5 Options not taken forward

15.5.1 The following options have been removed from the list of viable options:

- *Utilise SCOOT loops for LD VA capabilities (Option 4)* – The location of SCOOT loops at the upstream end of links would be inaccurate in predicting vehicle arrivals given factors which might affect the approach speeds of vehicles;
- *Rationalise the number of signal heads in operation (Option 14)* – Current signal head provision ensures sufficient visibility from each approach. To reduce would impact on the safety of a signal controlled installation;
- *Display flashing amber to all arms (all approaches have equal priority) (Option 19)* – Flashing ambers performed the best in the micro-simulation modelling, but only offered marginal additional benefit over comparable options. There are also safety issues with this option - misinterpretation with Pelican crossing control, combined with lack of defined priority,;
- *Display flashing amber to the major arms, display flashing red to minor arms (Option 20)* – The use of flashing red aspects to indicate vehicles can proceed with caution would create a high degree of confusion and misunderstanding, as in the UK flashing red lamps mean 'Stop' at wig-wag signals;
- *Display flashing amber to minor arms, switch off signals on major arms (Option 21)* - This option performed fairly well in the micro-simulation tests, but has the same inherent problem with misinterpretation of flashing amber aspects; and
- *Switch off traffic signals, but permit pedestrians to reinstate signal control (Option 24)* – This option operates in a similar fashion to Option 19; no specific priority is given to any movement. This represents a significant safety risk In addition, users might be confused with the inconsistent use of traffic signal control between vehicular movements and pedestrians

## 15.6 Conclusion

15.6.1 Short term options represent measures that can be implemented using current technologies and legislation. Improving the responsiveness of existing traffic control systems to both traffic and vulnerable road users as is advocated by the DfT has been shown to produce results that are similar to some of the medium and long term options in terms of managing carbon emissions, whilst maintaining safety levels and introducing delay benefits.

15.6.2 It is considered that the medium term options could provide additional benefits over existing signal control of installations with small changes to software and guidance. It is therefore recommended that these be considered for further research to identify the scale of benefits to vehicle delay and carbon emissions, in particular the development of SCOOT systems to operate dynamically.

15.6.3 The long term options, including methods of operation not currently used within the UK, will require more detailed research to ascertain the behaviour of UK motorists, the safety of operation and the practicalities of providing alternative methods of control.

# 16 Further Development of Options

## 16.1 Introduction

16.1.1 The short- and medium-term options identified in Chapter 15 are predominantly technical changes to the operation of the signal installation which would be imperceptible to the general user but provide benefits in traffic responsiveness. Of the 4 long-term options, there are two in particular that it is felt could benefit from further appraisal, and perhaps be developed into on-street trials.

16.1.2 This Chapter also summarises the use of wireless detection to reduce installation costs.

## 16.2 Switch all signals off and revert to priority operation

***Benefits***

16.2.1 VISSIM micro-simulation assessments suggest that switching signals off on the main road and displaying flashing amber on the minor (to indicate the need to give way) would have a major beneficial effect on both journey times and emissions compared with other LD strategies. However, there are legal and logistical barriers to implementing this in the UK.

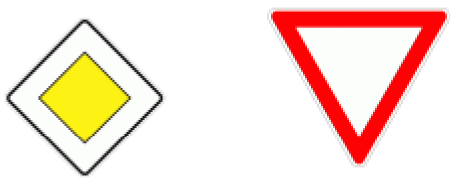
***Obstacles to its introduction***

16.2.2 In the UK, flashing amber aspects are currently only used at Pelican crossings as specified in the ZPPPCRGD, and their legal significance specifically relates to pedestrians. Whilst it would be possible to amend the Regulations, flashing amber signals would need to be removed from use at Pelican crossings before an alternative use could be considered. It might also be difficult to instil the different meaning of flashing amber aspects into the average British motorist.

16.2.3 In certain European countries the signs shown in **Figure 14** (contained within the Vienna Convention) are often mounted alongside or beneath the signal heads. Although UK signing generally complies with the Vienna Convention these signs are not defined within TSRGD hence UK drivers are unfamiliar with their meaning.

16.2.4 An operational and legal issue would be the Stop line. The geometries of signal- and priority-controlled junctions differ in terms of visibility. When traffic is held at a red signal, the stop line is generally located well back from the carriageway edge of the conflicting road; hence the visibility requirements for priority mode of operation could be compromised.

**Figure 14** - European Priority Signing



'Priority' sign 'Yield' sign

***Means of Overcoming Obstacles***

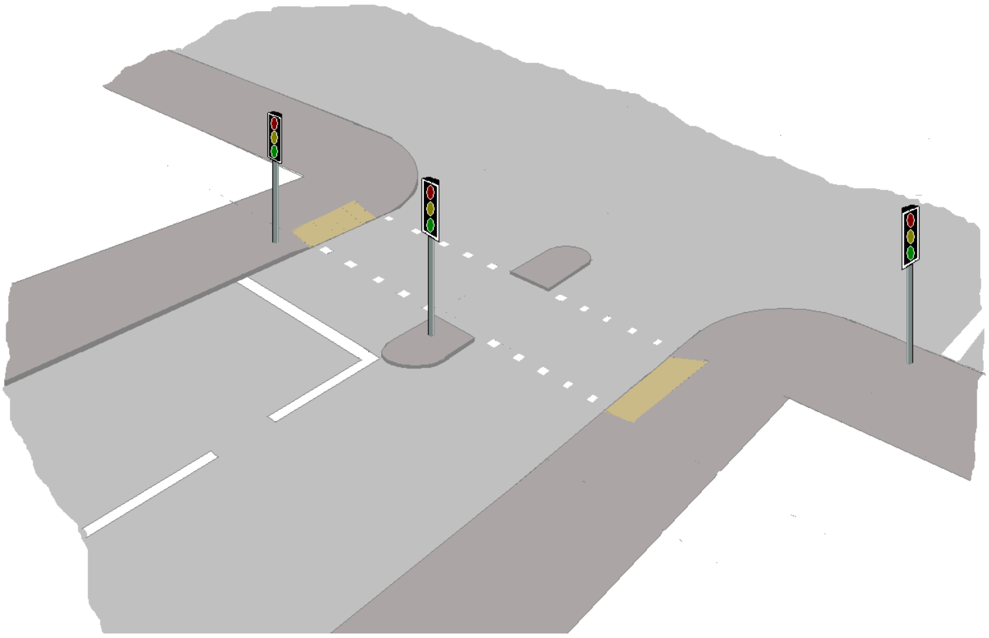
16.2.5 Ideally, during periods when the signals are switched off traffic on the minor road should stop at the edge of the main road carriageway to enable drivers to confirm that it is safe to proceed. Initially provision of a second Stop line (Diagram 1002.1 400mm wide) located at that point, together with one or more Stop signs (Diagram 601.1), was considered. However, the two Stop lines only differ by width, and it was felt that this would lead to driver confusion. It is therefore suggested that a Give Way line (Diagram 1003) and signs (Diagram 602) would be more appropriate, for which changes to TSRGD would be required.

16.2.6 It might seem that the existence of two lateral lines in quick succession would be confusing to drivers. However, this has precedent in the UK – at part-time signalled roundabouts, the signal Stop line is followed by the roundabout Give Way line (Diagram 1003.1), which is ignored by drivers when they are given priority by the signals. It should also be noted that when roundabout part-time signals are not operative, there is no 'priority' signing whatsoever to traffic on the circulating carriageway.

***Sample layouts***

16.2.7 **Figure 15** represents a typical minor arm approach to a signal-controlled junction. Informal pedestrian crossing facilities are indicated by markings to Diagram 1055.1, and a Stop marking to Diagram 1001 (generally 200mm wide in urban areas, 300mm elsewhere) indicates the point at which traffic must stop when the signals are operative. The following examples of possible options have been developed to indicate the difficulties likely to be encountered in implementing part-time signalling at such a junction. The examples would require extensive legislative changes, and are offered here merely as an indication of potential approaches to the problem.

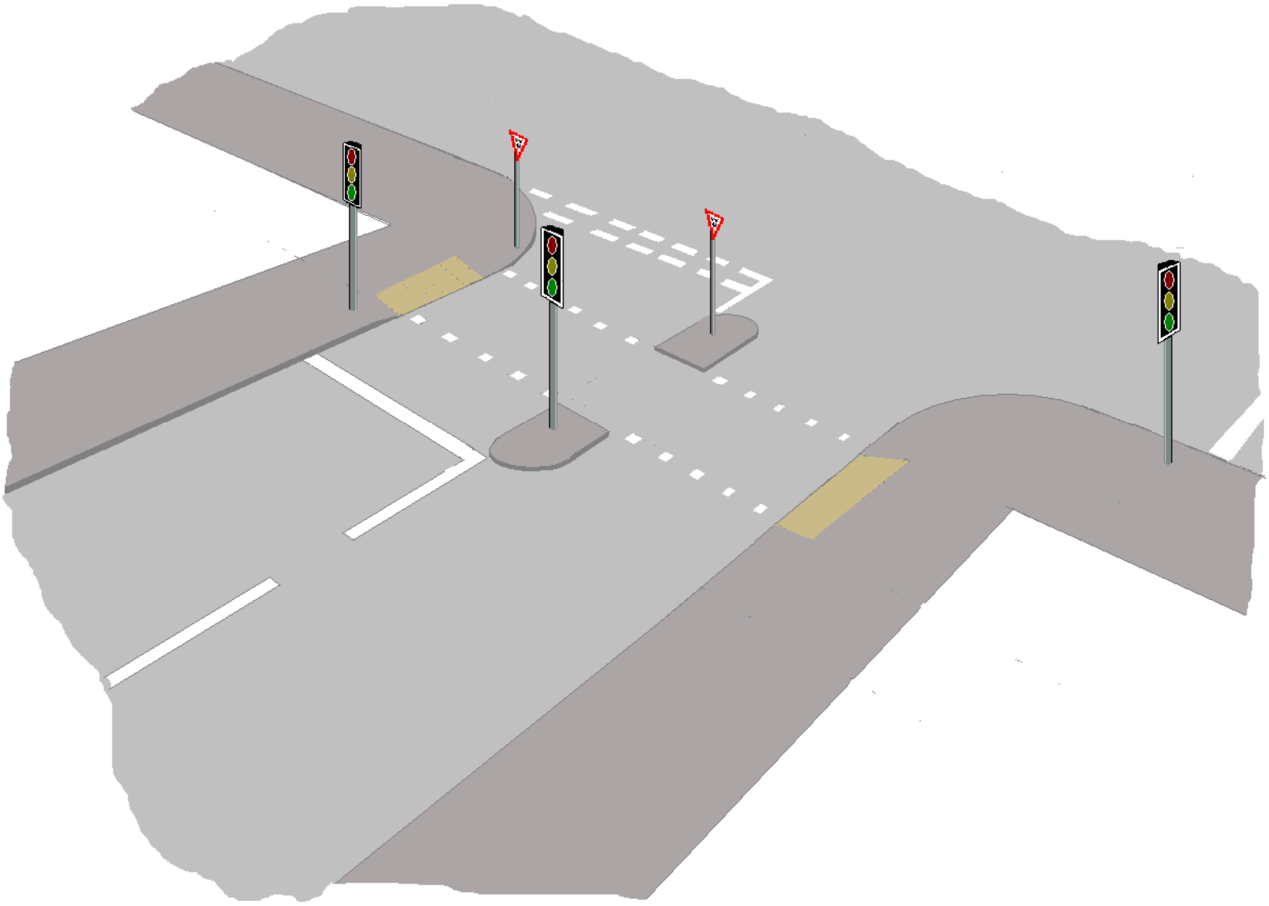
**Figure 15** – Existing layout of minor road.



16.2.8 **Figure 15** illustrates a possible layout of signing and road markings that could be used to indicate priority mode of operation on the minor road during LD periods. A Give Way marking to Diagram 1003 is shown in line with the extended edge of carriageway of the main road, and two Give Way signs to Diagram 602 located on the nearside and offside of the approach lane. These should be located between 1.5m and 12m from the Give Way line in accordance with the Traffic Signs Manual (TSM)[44]. Depending on site geometry, it could be possible to locate them adjacent to the traffic signal poles.

16.2.9 There could be perceived conflict between the markings and signing, although the arrangement is not unlike that at existing part-time signalled roundabouts.

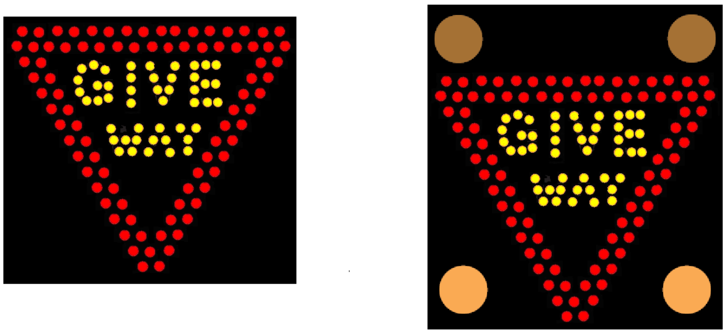
**Figure 16** – Possible signing to denote minor road priority operation.



16.2.10 There is increasing use of Variable Message Sign (VMS) throughout the UK, with their continued use suggesting that drivers understand their meaning. Changes in legislation would be required to introduce a VMS with a Give Way sign as shown in **Figure 17**. This design could incorporate flashing amber lights if felt appropriate. There are implications of such a provision, including the changes that would be required within TSRGD to permit a part-time Give Way sign. Monitoring of the signs would be necessary such that signal control is restored if the signs fail.

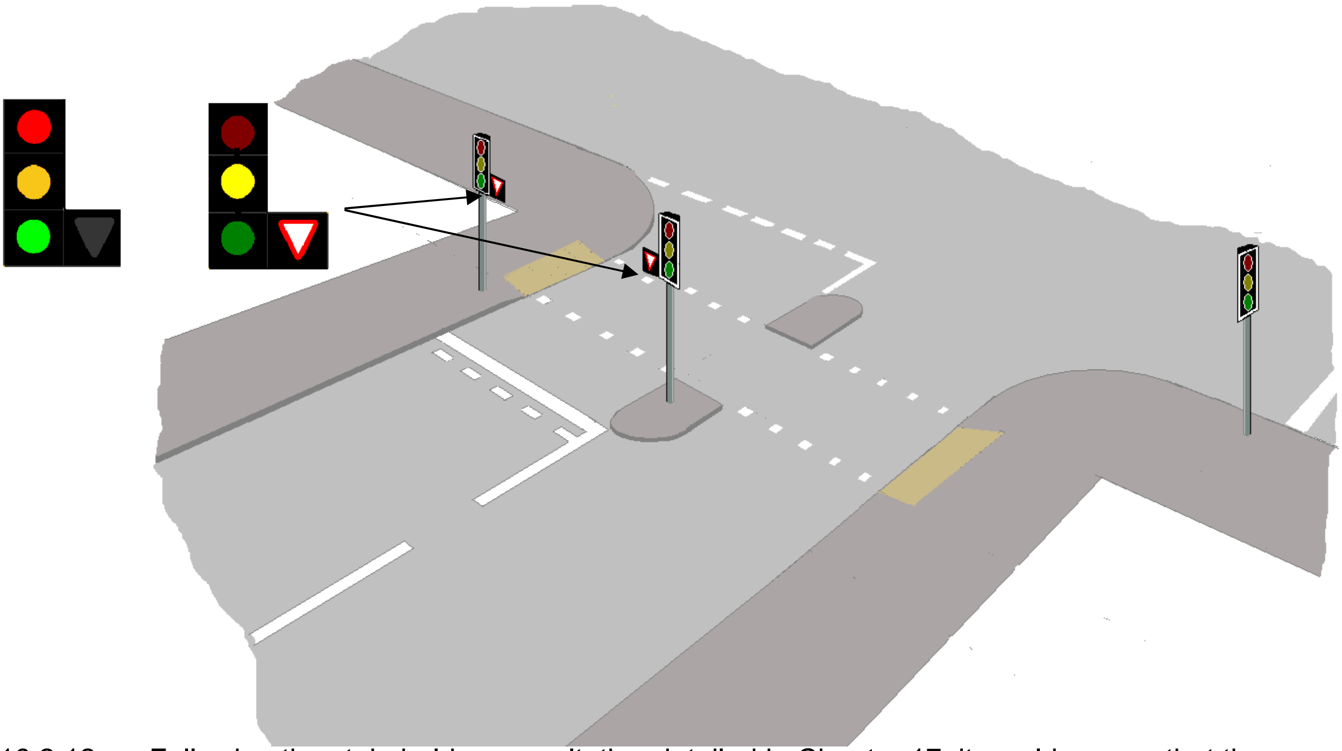
[44] TSO (2008) *Traffic Signs Manual Chapter 3*

**Figure 17** – Variable Message Give Way sign – possible configurations




16.2.11 The preceding application would involve significant additional street furniture and ducting. A less intrusive option could be to locate indicative Give Way Ahead signs (Diag 501) adjacent to the signal heads on the minor road, with a Give Way line (perhaps similar to the roundabout Give Way marking Diag 1003.1) at the edge of the major road running lane, as shown in **Figure 18**. The signs would present a blank face during signal controlled periods. An alternative stop line might also be needed to emphasise the alternative control methods.

**Figure 18** – 'Secret' Give Way sign – possible configuration



16.2.12 Following the stakeholder consultation detailed in Chapter 17, it would appear that the concept of flashing amber on the minor road and switching off the signals on the major road would be a more acceptable solution, possibly without the Variable Message Give Way sign.

## 16.3 Utilise SCOOT detection loops for MOVA operation

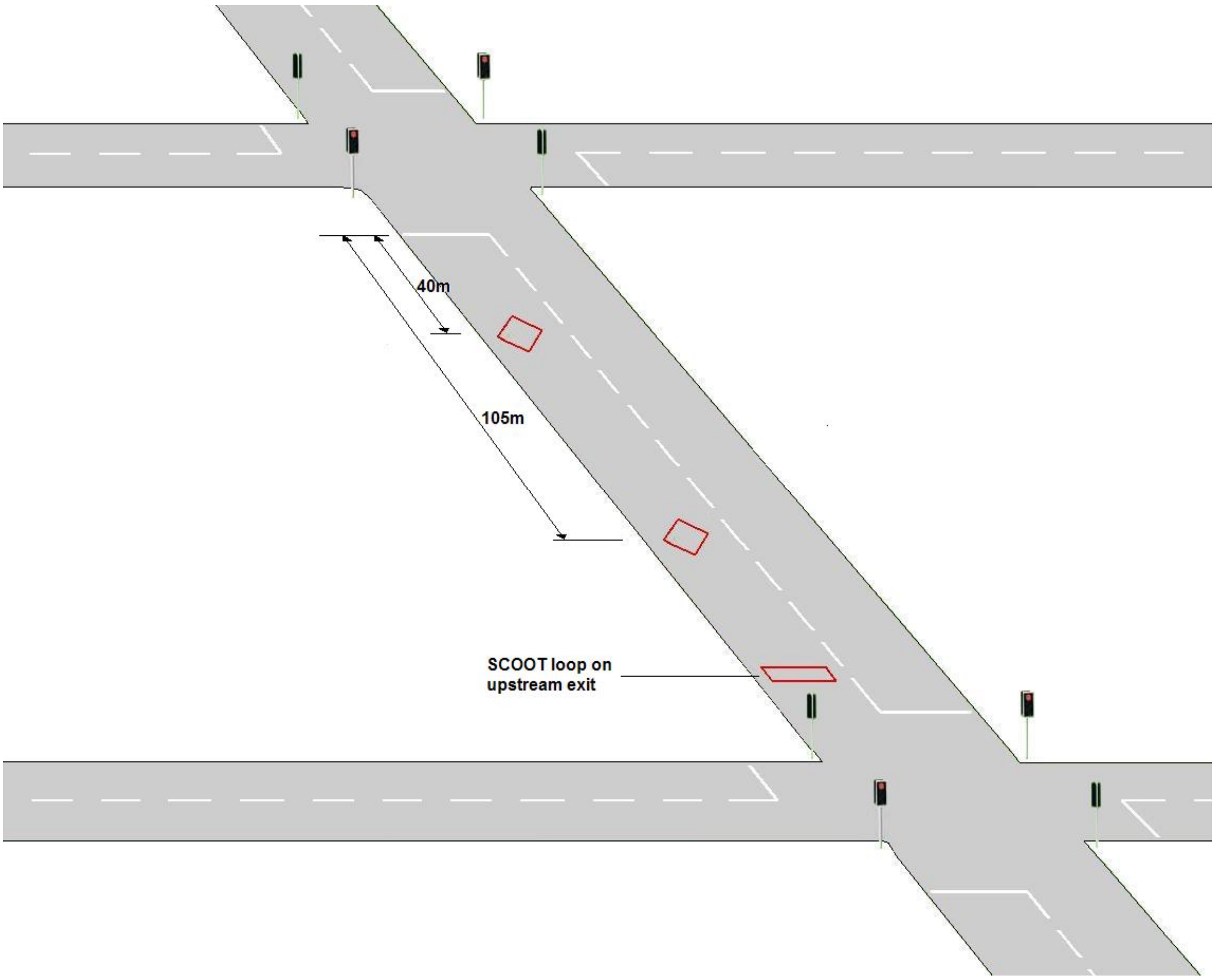
***Benefits***

16.3.1 This option highlights the potential benefit of using one type of detection for multiple methods of operation, which could make the installation of alternative LD methods of operation more economically viable.

16.3.2 MOVA operation in particular is well suited to LD conditions for its ability to respond efficiently to a range of traffic demands. By measuring saturation on each approach and producing its own signal timings and cycle times to balance both queues and vehicle delays, it can optimise an installation in both congested conditions and when demand is low.

16.3.3 Currently, providing MOVA within a SCOOT UTC network requires two separate sets of detection, the upstream loops for SCOOT operation and the X-loop/IN loops detection for MOVA operation. The locations of the different loops within a network environment are illustrated in **Figure 19** below, using a 30mph road as an example. It should be noted that CMOVA can be used in low speed urban environments, and does not require the upstream IN detector; in this instance sharing detection is not likely to be viable.

**Figure 19** – SCOOT/Full MOVA detection location requirements



16.3.4 The locations for the detection required for SCOOT and MOVA operation is relative to the downstream stop line, and will be site dependent. SCOOT loops are usually sited at the upstream end of a link, thus the distance between junctions will dictate loop positions. MOVA loop locations are determined by the cruise speed of vehicles on the approach; the range of distances from the stop line for the X-loop and IN-loop are specified in TRL's MOVA data setup and use, however the IN-loop could be up to 150m from the stop line.

16.3.5 As an example of traffic control systems sharing detection, if an upstream SCOOT loop could be configured to output data suitable for SCOOT operation during normal operation and data required from an IN-loop for operation MOVA in LD periods, the benefits of installing full LD MOVA control could be realised with a similar installation cost of Compact MOVA. At present full MOVA requires ducting from downstream controller to both the X and IN detection, which could be up to 150m from the stop line; the use of the SCOOT loop as an IN detector could allow full MOVA to be provided with only the add-on unit for the controller, the detection supplied by existing SCOOT loops and the X-detector.

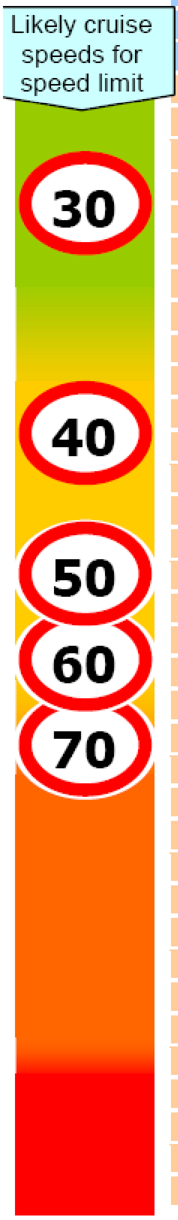
***Obstacles to its introduction***

16.3.6 The location of the detection for both SCOOT and MOVA is based on providing accurate and efficient control of vehicles as they pass through traffic signal installations. As such, the guidance provided for siting the detection is specific in the optimum location for each loop. As previously noted, CMOVA can be used in low speed urban environments and designed to remove the need for the upstream IN detector; in this instance sharing detection might not be viable (provided CMOVA is suitable).

16.3.7 For this option to be acceptable, the optimum range for the IN detector must correlate with the optimum location for the upstream SCOOT loop. The suitability will therefore depend on factors including length of the link, and the 15th-percentile speed. **Figure 20** taken from TRL's MOVA Data Setup and Use[49] illustrates the required locations for the MOVA detection.

16.3.8 Whereas MOVA is restrained regarding location, SCOOT is less so; it can be configured to operate effectively dependent on the location the loops have placed, provided there is enough distance to allow the traffic signals to respond to the prevailing traffic conditions.

**Figure 20** – MOVA loop detector locations[45]




| CRUISE SPEED metres/sec. | X-detector distance (m) Centre of loop to stop line: Ideal 3.5 seconds | X-detector distance (m) Centre of loop to stop line: maximum 4.0 seconds | IN-detector distance (m) Centre of loop to stop line: Ideal 8.0 seconds | IN-detector distance (m) Centre of loop to stop line: Maximum ▪ 10.0 seconds |
|---|---|---|---|---|
| 8.0 | 33 | 37 | 69 | 85 |
| 8.5 | 35 | 39 | 73 | 90 |
| 9.0 | 37 | 41 | 77 | 95 |
| 9.5 | 38 | 43 | 81 | 100 |
| 10.0 | 40 | 45 | 85 | 105 |
| 10.5 | 42 | 47 | 89 | 110 |
| 11.0 | 44 | 49 | 93 | 115 |
| 11.5 | 45 | 51 | 97 | 120 |
| 12.0 | 47* | 53 | 101 | 125 |
| 12.5 | 49* | 55 | 105 | 130 |
| 13.0 | 51* | 57 | 109 | 135 |
| 13.5 | 52* | 59 | 113 | 140 |
| 14.0 | 54* | 60 | 117 | 145 |
| 14.5 | 55* | 60 | 121 | 150 |
| 15.0 | | | 125 | 155 |
| 15.5 | | | 129 | 160 |
| 16.0 | | | 133 | 165 |
| 16.5 | | | 137 | 170 |
| 17.0 | | | 141 | 175 |
| 17.5 | | | 145 | 180 |
| 18.0 | | | 149 | 185 |
| 18.5 | | | 153 | 190 |
| 19.0 | | | 157 | 195 |
| 19.5 | | | 161 | 200 |
| 20.0 | | | 165 | 205 |
| 20.5 | | | | |
| 21.0 | | | | |
| 21.5 | | | | |
| 22.0 | | | | |
| 22.5 | | | | |
| 23.0 | | | | |
| 23.5 | | | | |
| 24.0 | | | | |
| 24.5 | | | | |
| 25.0 | | | | |

At cruise speeds in excess of $15ms^{-1}$ the distance from the stop line for X-detectors may depend more on other factors particularly the need for accurate calculated minimum timings

Cruise speeds above $20ms^{-1}$ are higher than would normally be expected even on the fastest of roads. Seek expert advice before placing detectors beyond the above distances

16.3.9 Current detection connection requirements and incompatibilities with other control systems would need to be overcome. SCOOT loops output flow and occupancy levels only to a Data Transmission Unit which relays back to the central control system, thus no physical connection is required between the SCOOT loop and the downstream controller. There is usually a delay/lag of around 2 seconds accounting for the data collection and transmission lag. If the SCOOT loop could be used as the IN-detector, a suitable loop would be required to output the accurate saturation data required for MOVA. In addition, the current transmission lag experienced by SCOOT would make accurate MOVA operation difficult. For example, approach speeds of 10m/s could experience accuracy variations of up to 20m.

[45] Transport Research Laboratory (2009) *MOVA Data Setup and Use*

### *Means of overcoming obstacles*

16.3.10 To allow use of a SCOOT loop for MOVA IN detection, the technology and software to overcome the configuration and data requirement differences must be developed. Each method of operation should be configurable to use different types of detection to the same degree of efficiency as current loops.

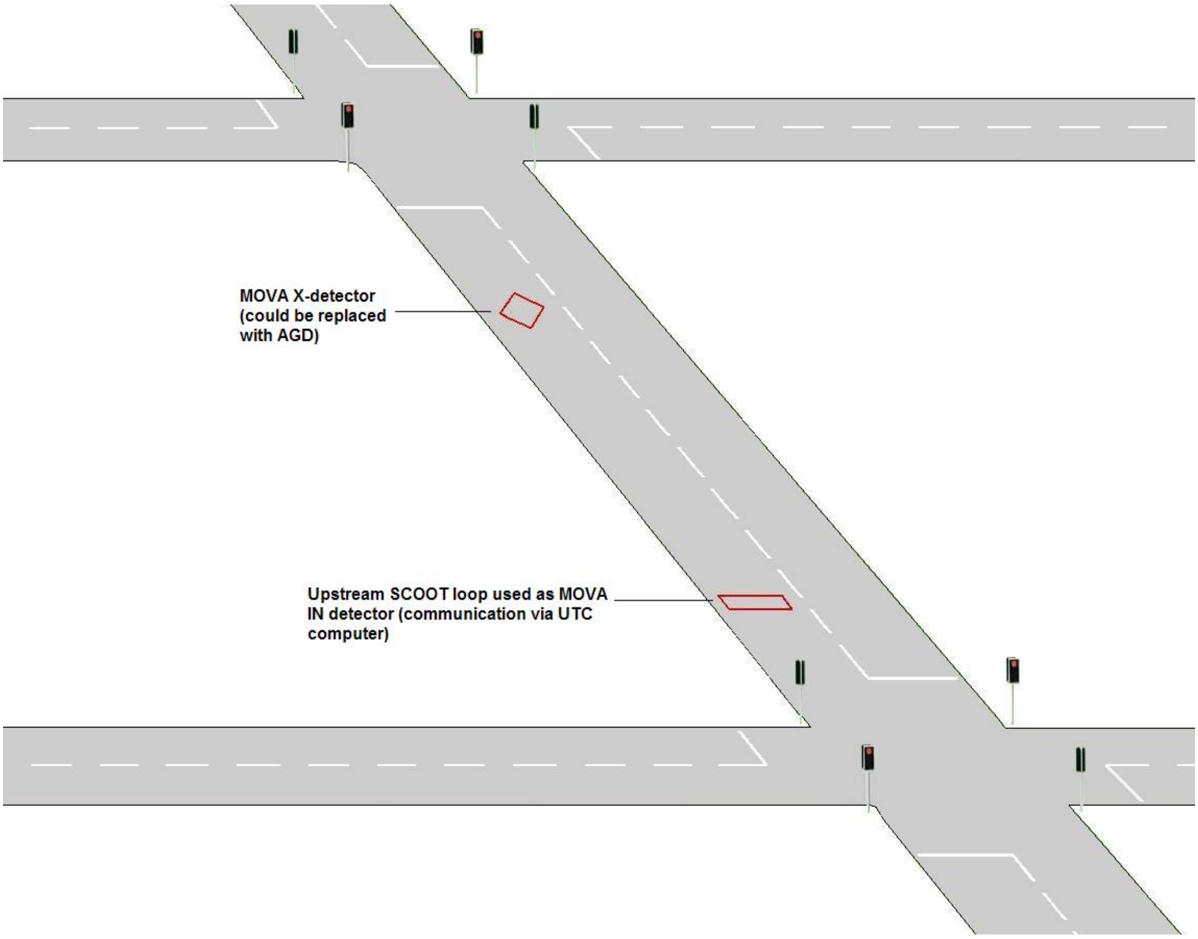
16.3.11 The main benefit of sharing the SCOOT loop with full MOVA is the savings to installation and maintenance costs, thus making the installation of such LD operation more viable. Therefore a method of communicating between the SCOOT loop and the downstream controller MOVA unit without the need for extensive ducting would be beneficial. Utilising the existing SCOOT infrastructure and updating software to communicate with the MOVA unit would be feasible, but the aforementioned lag could reduce the viability of the option. A more preferable option would be the use of wireless radio communications to remove the lag. Above Ground Detection is available for use with SCOOT and MOVA, the key issue is developments in the reliability of these systems and the ability to configure them for use with two methods of operation.

16.3.12 Aside from technological advances and development of traffic signal control software, the implementation of this option will depend on experienced engineers determining the appropriate location for the detection that it provides an efficient traffic signal control method at all times of the day.

### *Sample operation*

16.3.13 **Figure 21** illustrates the rationalised detection for using the SCOOT loop for MOVA IN detection. If wireless communication could be used to communicate between the upstream IN loop and the controller, only localised ducting would be required at the junction under review. The need for upstream ducting even for the X-loop could be removed if AGD could replace its function.

**Figure 21** – Use of SCOOT loop for MOVA operation in LD periods



## 16.4 Conclusions

16.4.1 If the technique of reverting to priority operation was to prove viable for LD application following on-street trials, there could be the potential to deploy these principles at junctions where signals are only required during peak periods. It is not uncommon to justify signalisation at a junction based solely on peak period demands. Outside of the peaks, demands might be low enough that the junction operates more efficiently under priority operation. Obviously other aspects such as pedestrian and cycling demands must be considered, and as with part-time signals at roundabouts the disbenefits could outweigh the benefits. Nevertheless, it is considered that this concept of reverting to priority operation could have advantages at certain locations, and could be explored further.

16.4.2 Retaining signal control , the concept of introducing shared detection is intended to improve the viability of installing alternative LD operation by reducing installation and maintenance costs. In particular wireless detection and communication with downstream controllers would allow this flexibility. With Above Ground Detection (AGD) used as a replacement for loops under LD MOVA in addition to its role during normal operation, the installation and maintenance costs would be reduced further.

16.4.3 It should be noted that the option to use SCOOT loops for MOVA IN-detection might only be applicable in certain locations based on conditions. An alternative to implementing full MOVA control is to install Compact MOVA (CMOVA) within a low speed SCOOT network for LD operation. As this only requires the X-loop the installation costs are lower.

## 16.5 Further development of existing traffic signal technologies

### *Detection*

16.5.1 One of the key costs associated with providing traffic signal control at an installation is the installation and maintenance of detection. Though the majority of traffic signal equipment is located at the installation itself, detection is usually required all approaches. Loop detection requires ducting to be installed within the verge or footway from which the carriageway loops are connected to the controller.

16.5.2 Loop detection can be adversely affected by a variety of factors; weather plays an important part as the movement of pavement in cold or warm weather conditions can break or expose loops. The replacement of a loop is a significant task, requiring a new cut to made, a new loop to be installed and for it to be calibrated for use. The development of more efficient detection to replace loops and the need for physical connection through ducting would reduce the maintenance, and speed up installation, of traffic signal installations.

16.5.3 Above ground detection (AGD) is already used within the UK at many installations where the range of the detector permits it; if there is an issue with the AGD then it is more straightforward to replace than an inductive loop. Where detection is required further upstream, for example MOVA on higher speed roads or for upstream SCOOT detection, inductive loops are still the most common method. Alternatives to this include the use of wireless magnetometers embedded in to the carriageway which are more easily replaced than inductive loops. Wireless technology can be used to link these to the controller to remove the need for ducting. Although these systems are in use within the UK at select sites their use is not widespread; some systems have been developed that manufacturers state adhere to certain detection specifications, however for these to be widely accepted their compliance must be demonstrated. Trials are currently being undertaken on these systems.

16.5.4 The critical factor that will determine the viability of expanding the use of wireless detection is reliability. They must provide the same level of reliability of operation that is supplied by the physical connection of a wired system, else the efficiency of operation of an installation is reduced or safety issues may arise. The responsibility to provide such a high level of reliability lies with the manufacturers, however this is led by the requirements of local authorities wishing to use their systems to lower their installation and maintenance costs.

16.5.5 Local authorities wishing to use wireless detection should be requiring the manufacturer to guarantee a level of reliability for the situation in which it is to be used; if it can then be proved that the technology performance is consistent then the DfT and other local authorities could support its wider use and broader acceptance within the UK.

16.5.6 **Figure 22** below illustrates an example operation of wireless detection on a single approach.

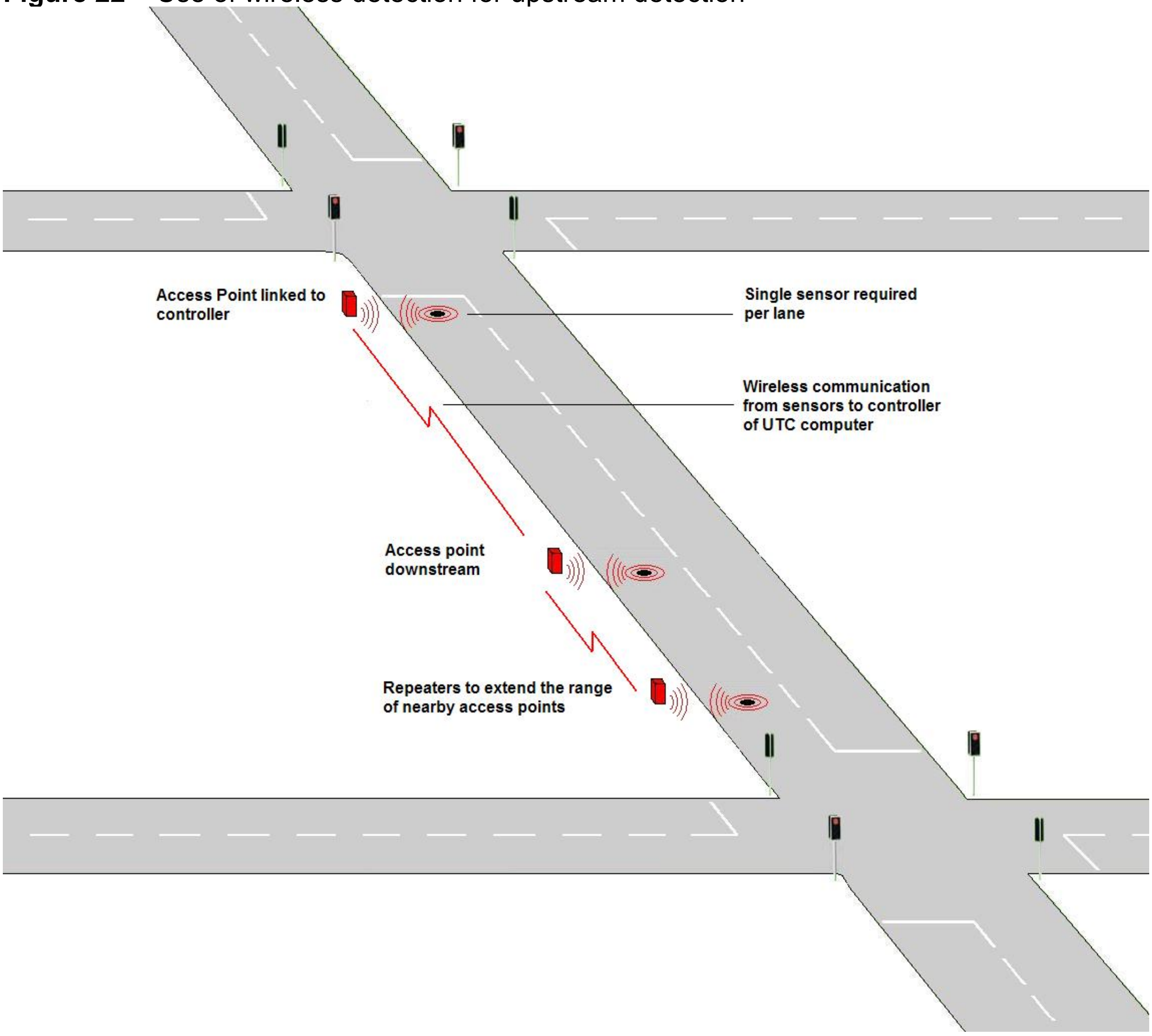
16.5.7 Case Studies of the use of wireless detection have indicated the potential cost savings; one Local authority observed a saving of around £60,000 with the installation of 3 junctions[46]. Further savings can be achieved from the minimal disruption to traffic during installation and maintenance.

***LED Provision***

16.5.8 Future consideration for the retro-fitting of LED signals heads to replace incandescent signals is discussed in Chapter 13. The cost of providing LED signals at existing installations is increased by the need to change the controllers to supply compatible red lamp monitoring and voltages. The reduction of installation costs is dependent on commercial efforts to standardise the monitoring requirements for LEDs and the compatibility of controllers with the various manufacturers' technologies.

[46] Editorial (2009) *Wireless Traffic Monitor Pays its Way*, IHIE Highways, vol.78 no.8, p59

**Figure 22** – Use of wireless detection for upstream detection



# Stakeholder Consultation

# 17 Stakeholder Consultation

## 17.1 Introduction

17.1.1 The study has identified a number of options that could be deployed to reduce unnecessary delays to traffic during LD periods. It is important to obtain the opinion of those with a vested interest in the operation of signal controlled installations and highway safety, to highlight concerns and possible additional signal control developments.

17.1.2 Key stakeholders for the introduction of alternative traffic control strategies include scheme designers, policy decision makers and road users. A consultation document was produced to summarise the research undertaken and options developed; stakeholders were then invited to comment and rate potential options for managing traffic in LD periods. The scores represent a value between 1 and 5, where:-

- 5 = Always consider (standard practice);
- 4 = Would consider;
- 3 = May consider;
- 2 = Would not consider; and
- 1 = Would definitely not consider.

17.1.3 Invitations to respond were sent to local highway authorities, the Police, the AA and members of the Traffic Systems Group. 11 local authority (LA) responses were received, in addition to the Association of Chief Police Officers (ACPO) and the Transport Research Institute at Edinburgh University.

## 17.2 Scope of questions

The survey covered the following topics:

- *General LD control comments focused at LA's* - whether consultees would consider alternative LD control following research, and their current use of LED signal heads to reduce energy consumption of installations;
- *Feedback on Short Term Options* – scores and comments on the options deemed that could be implemented without any change to current technology or equipment, legislation and guidance, including options that are currently in use in the UK;
- *Feedback on Medium Term Options* – scores and comments on options that would require minor changes to current regulations, or technological advances to be made in order for them to work effectively;
- *Feedback on Long Term Options* - scores and comments on options that would require significant changes to legislation, technology or driver education before they could be considered for use within the UK; and
- Opportunity for general feedback – any other feedback from consultees.

## 17.3 Results

### *Introductory questions*

17.3.1 Local authority feedback regarding current use of LD control methods and measures to reduce energy consumptions indicate that some actions are taken to improve the efficiency and operation of traffic signals during LD periods. 91% of the authorities revert to a different method of control during LD periods, the preference being taking junctions off UTC/SCOOT on to isolated VA. Where this is not appropriate, authorities maintain co-ordination using alternative UTC plans or CLF. Reverting to VA from SCOOT is either performed via a timetable or automatically based on flow levels.

17.3.2 82% of the local authorities claim to be taking positive action towards replacing existing incandescent heads with LED units, with 73% specifying new installations are LED based. The outstanding issues with retrofitting to existing installations are the age and compatibility of existing infrastructure, including requirements for replacing cabling and ensuring appropriate lamp monitoring can be provided; many authorities are looking at the business case for retrofitting or are considering ongoing replacement programmes.

***Conclusion of introductory questions***

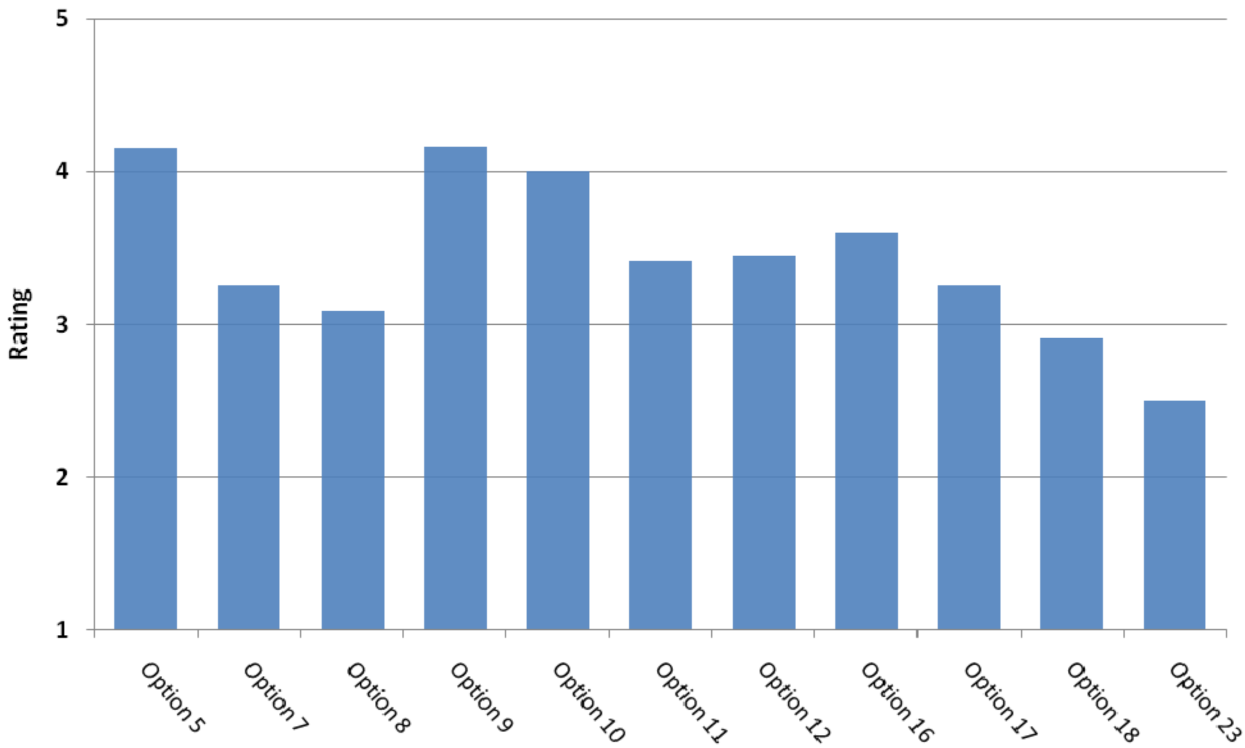
17.3.3 The majority of local authorities use alternative control methods to reduce delay during LD periods. The decision on the most appropriate operation is made on a site specific basis, including whether installations are networked or standalone, whether co-ordination must be maintained and with consideration for cost and maintenance of using certain methods of control.

17.3.4 A significant proportion of LAs are actively seeking to reduce energy consumption at traffic signal installations by changing from incandescent lamps to LEDs. The key issue in retrofitting LEDs is the incompatibility between the LED and equipment used at many existing sites. Business cases are often required to justify changing the controllers to provide lamp monitoring.

*Short Term Options*

The average score for each of the short term options is shown in **Figure 23** below.

**Figure 23** - Average rating for short term options



17.3.5 The results indicate which methods of control are preferred by local authorities (and third party consultees); given the short term options are those which are already operational within the UK, the trends and comments correlate to those obtained during the initial local authority survey on current LD traffic signal use.

17.3.6 For networks utilising UTC, including fixed time or SCOOT control, VA is preferred as the method of operation in LD periods. MOVA is used by some authorities, becoming more commonplace at new installations and some comments suggesting MOVA being retrofitted wherever possible. One authority is planning to use MOVA with UTMC outstations, allowing the UTMC common database to determine the most appropriate mode of operation based on real time parameters (not necessarily traffic based). A general concern with the use of MOVA is the cost of installation and maintenance of the loops, perhaps explaining why reverting to VA control is so prevalent. Similar concerns were noted of CMOVA, with limited deployment due to the associated costs with maintenance.

17.3.7 Isolated junctions run either VA or MOVA; both options are used by local authorities based on site specific conditions and cost of installation. It is noted that the justification for using MOVA is generally based on addressing peak congestion levels rather than LD, given the capacity-optimising attributes of MOVA during heavy traffic conditions.

17.3.8 The use of quiescent all red at VA or MOVA installations is varied. The average score indicates that it is used, but not as standard practice. Feedback from the stakeholders suggests that many authorities do not use this facility at all, and those that do implement it on a site by site basis. One authority highlighted a concern over its use at installations with pedestrian crossing facilities; if pedestrians see a red aspects displayed to traffic they might assume it is safe to cross whether or not the green man has appeared.

17.3.9 The use of Puffin crossing technology at junctions is sporadic; it is used at some crossings but not consistently due to the cost of the detection. Three authorities specified a desire to augment existing Pelican crossings (with far sided pedestrian units) with the kerbside detection from Puffin crossings; this is to enable efficiency of installations to be increased with reduced costs incurred by authorities.

17.3.10 The use of timetabled pre-timed maximum greens is generally site dependent. The usage of a crossing influences whether it is considered beneficial to provide additional pedestrian priority rather than implementing it as standard practice within a local authority's jurisdiction.

17.3.11 Switching off traffic signals is only commonplace at roundabouts where part-time signals are normally used to control particular movements during peak periods. Feedback from stakeholders confirmed this to be the case. It was noted that the advantages of switching signals off were recognised in some responses, however would only be accepted if treatment of pedestrians under such operation was clarified and an extensive public education programme from DfT was introduced.

### *Conclusions on Short Term Options*

Feedback on currently available methods of operation and their use during LD periods confirms which options are favoured. It identified that the use of quiescent all red is not widely used. In some instances this has been justified through safety concerns over pedestrians misunderstanding the presence of red signals to all traffic movements and failing to observe the pedestrian signal heads. In other instances it is simply not activated. Evidently its use is site specific, however if all authorities gave consideration to using quiescent all red, viable not just in LD periods, signal installations would be more reactive to traffic demands.

Puffin crossing technology has been embraced to varying degrees. Designers might consider that the introduction of Puffin control on traffic engineering grounds is not justified at some sites, thus the cost of additional detection becomes a more significant factor when deciding to upgrade from Pelican to Puffin control. LA feedback suggested detection would need to become more cost effective and more reliable before it would be accepted as standard; in addition authorities believed there could be concerns over the reliability of the current detection which hinders its acceptance.

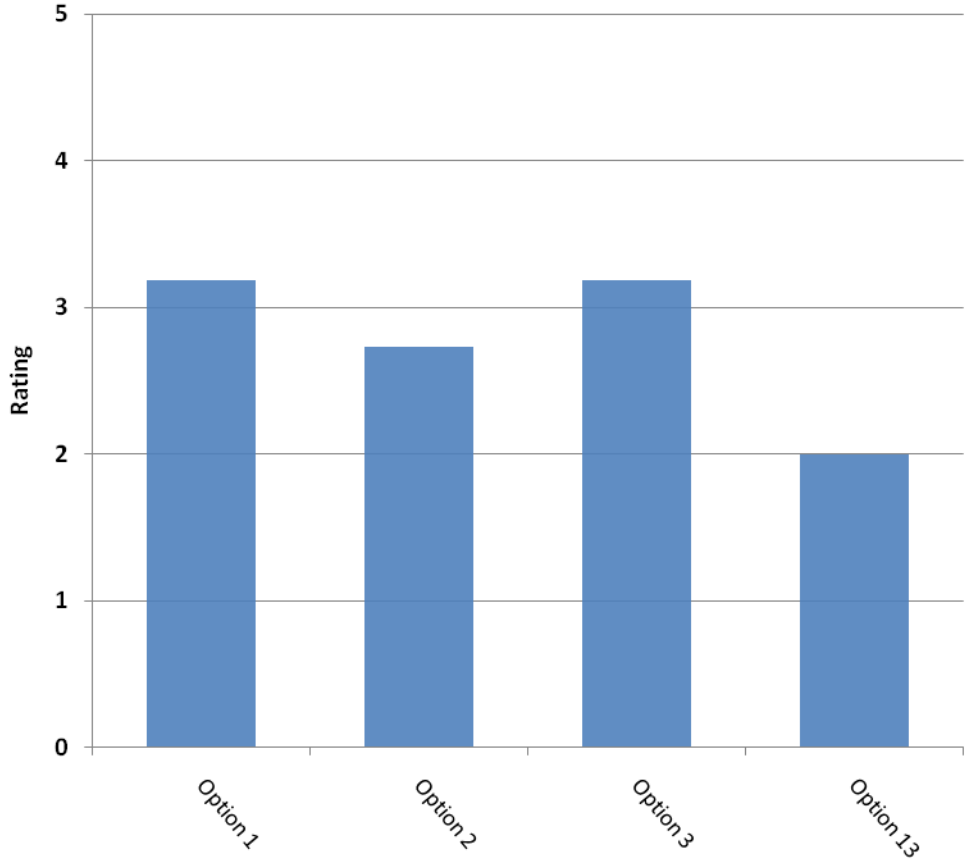
Regarding the requested use of near-side detection with far-side pedestrian signals, the DfT encourages the Puffin Crossing as a crossing in its total form, reducing the number of unnecessary pedestrian phase calls and looking to improve pedestrian safety through variable timing and increasing awareness of traffic movements with nearside indicators. The benefits of Puffin crossings over far-side pedestrian signals have been investigated on numerous occasions. As an example initial findings of a study undertaken by TRL[47] concluded that accident frequencies/severities reduced by around 19% with the installation of Puffin facilities over far-side pedestrian facilities. If a hybrid system were retro-fitted to installations with far-side pedestrian signals, the justification would be for traffic delays only and the safety benefits intended would not be realised by authorities. Therefore the DfT are not considering the use of nearside detection with far-sided signals.

[47] Transport Research Laboratory (2009) *Road Safety Benefits of Puffin Facilities*

### *Medium Term Options*

17.3.12 The average score for each of the medium term options is shown in **Figure 24** below.

**Figure 24** - Average rating for medium term options




17.3.13 The average ratings for the proposed medium term options reflect varying support for each option, depending on the perceived benefits for each stakeholder. The introduction of a capped cycle time for SCOOT regions during LD periods (Option 1) generally received a score of 4 out of 5 by authorities using UTC/SCOOT; authorities with no requirement for SCOOT understandably did not consider it to be of use, thus a low score was given. Some of those authorities that use SCOOT already reduce the cycle time of their UTC network during LD periods, however do not restrict it too much to maintain some flexibility of operation. Other authorities consider that UTC/SCOOT is not suitable for LD operation and revert to VA overnight.

17.3.14 The use of an extra low cycle time option (Option 2) that adapts the network cycle time when demand dependent stages are not called in LD periods was rated slightly below Option 1. It was considered that VA would be preferred over such operation, or that such operation could not realistically be achieved given the flexibility required to allow for demand dependent stages under a regional cycle time.

17.3.15 Option 3 is considered a combination of Options 1 and 2, providing a dynamic system that lowers the cycle time as much as possible during LD periods on the assumption that demand dependent stages are not required, but which can temporarily raise the cycle time of a junction should a demand for that stage be called.

17.3.16 The support for low minimum green times was not widely supported. Two authorities registered an interest in reducing the minimum green times below the currently recommended 7 seconds, where traffic would be particularly light. Other stakeholders noted concern over the safety of this option, in terms of the sharper reactions that could be required by drivers if stages are cycling more rapidly. The benefits of this option over VA were also questioned; if demand is low then a junction operating under VA should be just as effective at responding to vehicle demands.

***Conclusions on Medium Term Options***

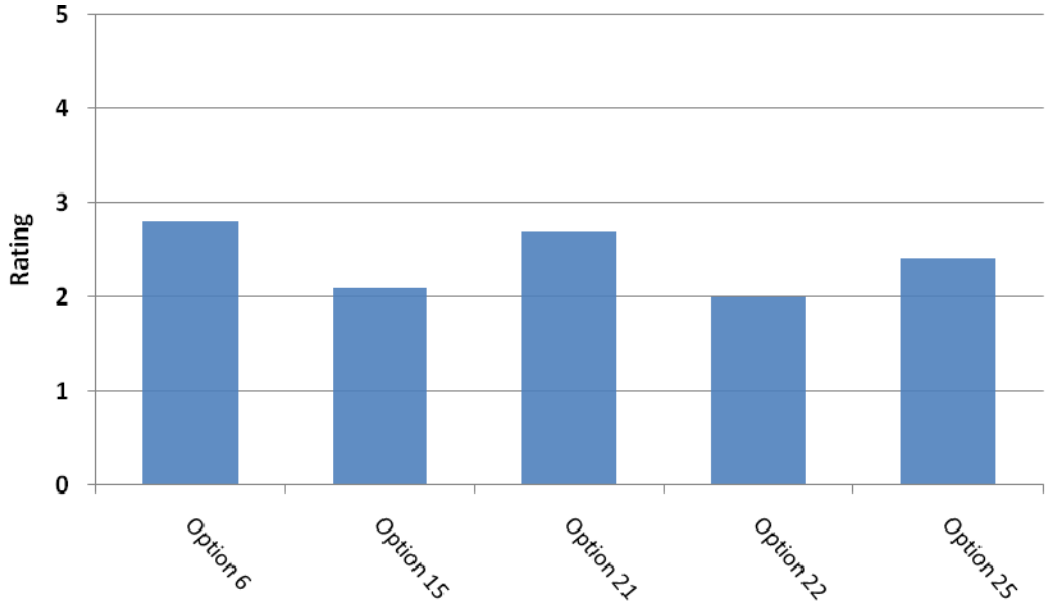
Feedback regarding the medium term options fluctuates between authorities, depending on their size, current use of traffic signals and the perceived benefit of an option to their highway network. Developments to UTC SCOOT systems were well-received by those authorities that used them, such changes will provide benefits to road users under existing infrastructure, without affecting safety. It was noted that the use of low cycle times is currently being developed by TRL for introduction in the next version of SCOOT. Other developments focussed on LD capabilities of SCOOT, for example allowing sub regions to operate on independent cycle times when traffic levels low, are being considered by the SCOOT Steering Group to maximise the benefits of its operation; supporting such developments could provide an effective means of introducing alternative LD control to networks operating under SCOOT.

Some authorities registered an interest in the use of low minimum green times during LD periods, whilst recognising the potential impact on safety. VISSIM modelling of a VA junction with low minimum green times did not realise a noticeable benefit over a normal VA junction. However driver behaviour and reactions to such subtle changes in traffic signals cannot be modelled precisely in VISSIM. The option could reduce driver frustration at signals during LD periods through small changes to signal timings at an installation. A site-trial would be beneficial in determining whether the option provides benefit to drivers, and how it affects the behaviour of both motorists and non-motorised users.

***Long Term Options***

17.3.17 The average score for each of the long term options is shown in **Figure 25** below.

**Figure 25** - Average rating for long term options




17.3.18 The use of SCOOT detection for MOVA operation (Option 6) was accepted as a viable option however concerns were raised over the cost and complexity of implementation over other forms of LD control, for example VA. The validation of the MOVA installation would be particularly difficult unless the distance between the SCOOT loops and the stop line is near optimum for a MOVA installation; it is not desired to introduce a cost saving method of operation if a compromise is made against the operation of MOVA.

17.3.19 Switching off traffic signals at an installation raised concerns during the first LA consultation, due to the potential impact on pedestrian safety of removing controlled crossing facilities. The concerns have been re-iterated; it is considered that switching off signals would only be accepted under the current guidance in TD50/04, at roundabouts and where there are no pedestrian facilities. With regard to the introduction of wide area detection to reinstate signal control when road users are present, feedback suggested the operation would become overly complex, and the lost time associated with the start-up sequence to signal control would be unnecessary as pedestrians might cross before the green man is shown.

17.3.20 Switching traffic signals off on the major road only and using flashing ambers on the minor road to indicate priority received higher ratings than switching all traffic signals off, due to priority between movements being defined. Safety concerns are similar to other options which remove signal control; facilities for pedestrians are considered paramount , and it is unclear whether the presence of turned off signals would be confusing to drivers, as the reason could be either LD operation or that all traffic signals could be off due to a fault. Feedback supported earlier conclusions that the flashing amber would need to be adopted as a national standard for use as a LD control mechanism, and as such upgrading of all Pelican Crossings to Puffins would need to be achieved before this could be implemented. Despite reservations on removing signal control, a number of authorities are keen to participate in site-trials to ascertain driver understanding and the effectiveness of such operation in LD periods.

17.3.21 The option to use Variable Message 'Give Way' signs on the minor roads and switch signals off the major road was designed to allow a traffic signal installation to be turned off and whilst providing equivalent signs and markings to indicate a priority intersection. As with other priority mode of operation options, pedestrian crossing facilities would be uncontrolled, which was noted in stakeholder feedback comments. Whereas the use of flashing amber signals was accepted as providing advantages in terms of network operation, it was considered that this option would introduce additional clutter and increase installation and maintenance costs for local authorities.

17.3.22 The option to revert mid-block crossings to priority operation, that is operate the installation like a Zebra crossing, was not considered to provide a benefit over current LD methods of operation. Current options include the use of pre-timed maximum green times to make signal controlled crossings responsive to pedestrian demand, especially in LD periods when traffic levels are low. It was also considered that pedestrians cross without using the push button units when traffic levels are low, thus using resources introducing and maintaining a new control mechanism would be inefficient.

***Conclusions on Long Term Options***

The two options of most interest to the respondees are the use of SCOOT detection loops for MOVA IN detection, and the use of flashing ambers on the minor road with signals turned off on the major road. Using SCOOT loops for MOVA operation will not be applicable at every installation, like any control method site specific criteria will need to be considered. However the concept of using detection for multiple control types could save local authorities money on installation/maintenance over using different detection, whilst improving the operation of the highway network in LD periods. Developments in detection will be required to be capable of outputting the required data to the controller, and allow the implementation of LD control strategies at a lower cost. Wireless detection has been used by some authorities with varying degrees of success; the current limiting factors include the range of the systems; with some access points reaching only 50m numerous access points would be required for some MOVA installations or if SCOOT loops were to be considered.

The use of flashing amber signals on the minor road and turning off signals on the major road was considered more viable than informing road users of priority using Variable Message 'Give Way' signs to mirror priority intersections during LD periods. The concept of signing the minor road to inform priority was accepted, the issue is the additional street furniture that would be required, the additional maintenance costs and concern over the reliability of VMS. An alternative to the use of VMS to reduce the financial cost and street furniture could be to mount a sign or similar above (or below) the traffic signal head which is either fixed (for example for part-time signals) sign used at roundabouts or which is illuminated during LD periods. The use of LED signal aspects could provide the flexibility to show symbols when under priority operation, for example triangles or diamonds in one of the signal aspects to indicate priority (requiring legislative changes). Such operation would require developments to be made to overcome potential issues with lamp monitoring while operating under LD conditions, however the concept would reduce the need for additional technology and equipment.

# Conclusions and Recommendations

# 18 Conclusions and Recommendations

18.1.1 The research has indicated that the majority of UK local authorities currently employ methods to reduce the environmental impact of traffic signal controlled installations. The approaches taken are broken into two forms, changing the method of operation to reduce to delay to highway users and lowering the energy consumption and cost of installations through the use of LED signal heads and ELV equipment. Improvements to current operation could be achieved through developments to these approaches. **Table 13** below summarises the key conclusions and recommendations from the research in terms of future research, development and street trials. The recommendations include improvements to technology to reduce implementation, maintenance and/or running costs and improve efficiency, improvements to existing methods whilst retaining signal control, and the introduction of new methods not retaining signal control.

**Table 13 -** Recommendations

| **Immediate Solutions** | | |
|---|---|---|
| **Recommendation** | **Obstacles** | **Action/Responsibility** |
| Use LED signals/ELV equipment at new installations | Current technical issues with retrofitting lower power consuming LEDs | Local authority driven action to lower energy consumption. Many already install LED as standard, others do not. |
| Retro-fit LED signal heads/ELV equipment | Cost of retrofitting LEDs to existing equipment including new controllers and providing appropriate lamp monitoring. | Manufacturers have developed retro-fit LED heads, these need to be tested/monitored by local authorities to determine their effectiveness and drive the manufacturer to improve product if necessary. |
| Quiescent all red operation | Authorities not currently using quiescent all red operation reluctant to start; could fail to see benefit. | Local authority traffic signal engineers are responsible for applying the most appropriate method of operation. Site specific assessment must be carried out before implementation. |
| Adoption of Puffin crossings | Puffin crossings more costly when compared to pelican crossings. | The appropriate specifications and good practice guides already exist for Puffin crossing implementation.<br><br>Increased cost effectiveness of detection will only be achieved if uptake is increased, for example group authority purchases of equipment to encourage suppliers to reduce costs. |
| Use Low Minimum Green Times | Minimum green times are safety related timing, particularly when traffic levels are high. Local authority acceptance will vary. | If a local authority trials a reduction in minimum green times in LD periods and monitors its effect, the DfT can support the production of guidance based on the evidence. |
| Developments to UTC/SCOOT for networks, including enforced low cycle times. | Development costs of SCOOT kernel modifications and software upgrades. | UTC/SCOOT developments are being made by the SCOOT steering group. These developments need to be trialled on site to improve operation during LD periods. |

| Solutions to develop | | |
|---|---|---|
| **Recommendation** | **Obstacles** | **Action** |
| Drive improvements to reliability of wireless detection | There is little justification for manufacturers to invest in R&D when purchases are not high volume. | Local authorities wishing to introduce wireless detection need to work with suppliers to provide the level of accuracy and reliability required. If the suppliers can then prove an acceptable level of consistency then this will determine its acceptance within the UK. |
| Consider developments in detection to output data for multiple methods of operation. | R&D costs would likely fall on the manufacturer.<br>The differing distances required by different methods of operation could compromise efficiency of operation. | The action is linked to the introduction of wireless detection; if it can be shown that developed technology is effective then this could lead to its acceptable and approval for use within the UK. |
| Developments to MOVA/ CMOVA detection at standalone installations | A lower cost of installation will likely require developments to detection, which will be defined by the manufacturers. Costs are normally reduced by mass acceptance stimulating development. | As for wireless detection and MOVA/SCOOT detection recommendations, consider benefits and reliability of wireless detection. |
| Reverting to priority mode of operation | Pedestrian safety at installations is paramount, could be compromised at some locations, particularly with respect to DDA provision<br>Changes would be required to current regulations before consideration could be given to this option. | Local authorities or a group of authorities could consider trialling and monitoring the impact of turning off traffic signals at suitable installations (there are some existing sites). Evidence from such trials could then be used to form guidance on the appropriateness of such operation. |

18.1.2 There is some support and justification for permitting traffic signals to be turned off in LD periods. Before this can be considered further investigation will be imperative to ascertain the behaviour of drivers, cyclists and pedestrians. This conclusion has also been reached independently in a 2009 report “Economic impact of traffic signals”[48]. It is recommended that the introduction of a trial be discussed between local authorities that are looking to improve their energy consumption in this way, perhaps through the introduction of a Steering Group or by adding the agenda to an existing Steering Group. The group could then work with the DfT towards introducing it as a viable LD strategy within the UK.

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48 Greater London Authority (2009) *Economic impact of traffic signals* (produced by GLAEconomics)

18.1.3 In order to improve road user intelligibility (and hence safety), operation under priority mode of operation must include the facility to indicate which movements have priority. The review of overseas operation of signals highlighted the increase in right angle collisions when operating under a "4 way stop" arrangement. Options discussed include flashing ambers displayed to the minor road approaches and the use of Variable Message give way signs. Legislation and guidance would have to be changed to remove the current use of flashing amber signals, and all Pelican crossings would have to migrate to Puffin operation over a reasonable period of time.

18.1.4 The use of variable message signs (VMS) to inform priority raised questions over the increased installation and maintenance costs, and reliability concerns. Alternatives to the use of VMS could include mounting a sign above (or below) the traffic signal head which is either the fixed 'part-time signals' sign used at roundabouts or which is illuminated during LD periods. Alternatively, the use of LED signal aspects could provide the flexibility to show symbols when under priority operation, for example triangles or diamonds in one of the signal aspects to indicate priority. It will also be necessary to inform drivers on the priority route that the signals only operate on a part-time basis (to avoid spurious reports of signal faults), and to give clear indication of how they should negotiate the junction during times when the signals are not operating. Site trials will be essential for gauging driver reaction to the different methods, from which a preferred option could be determined.

18.1.5 Turning off traffic signals would render controlled pedestrian crossings inactive; unless there is the ability to reinstate signal control when a PBU demand is placed, the number of suitable applications will be limited. This would be critical for impaired pedestrians who rely on controlled crossings for safer crossings of highways. As discussed in option development, the switch off and switch on sequences would need to be lower than the current specified time in TR2500 to be viable, otherwise pedestrians will cross before the sequence has completed. This form of operation would be benefit from site testing in tandem with the option to turn signals off.

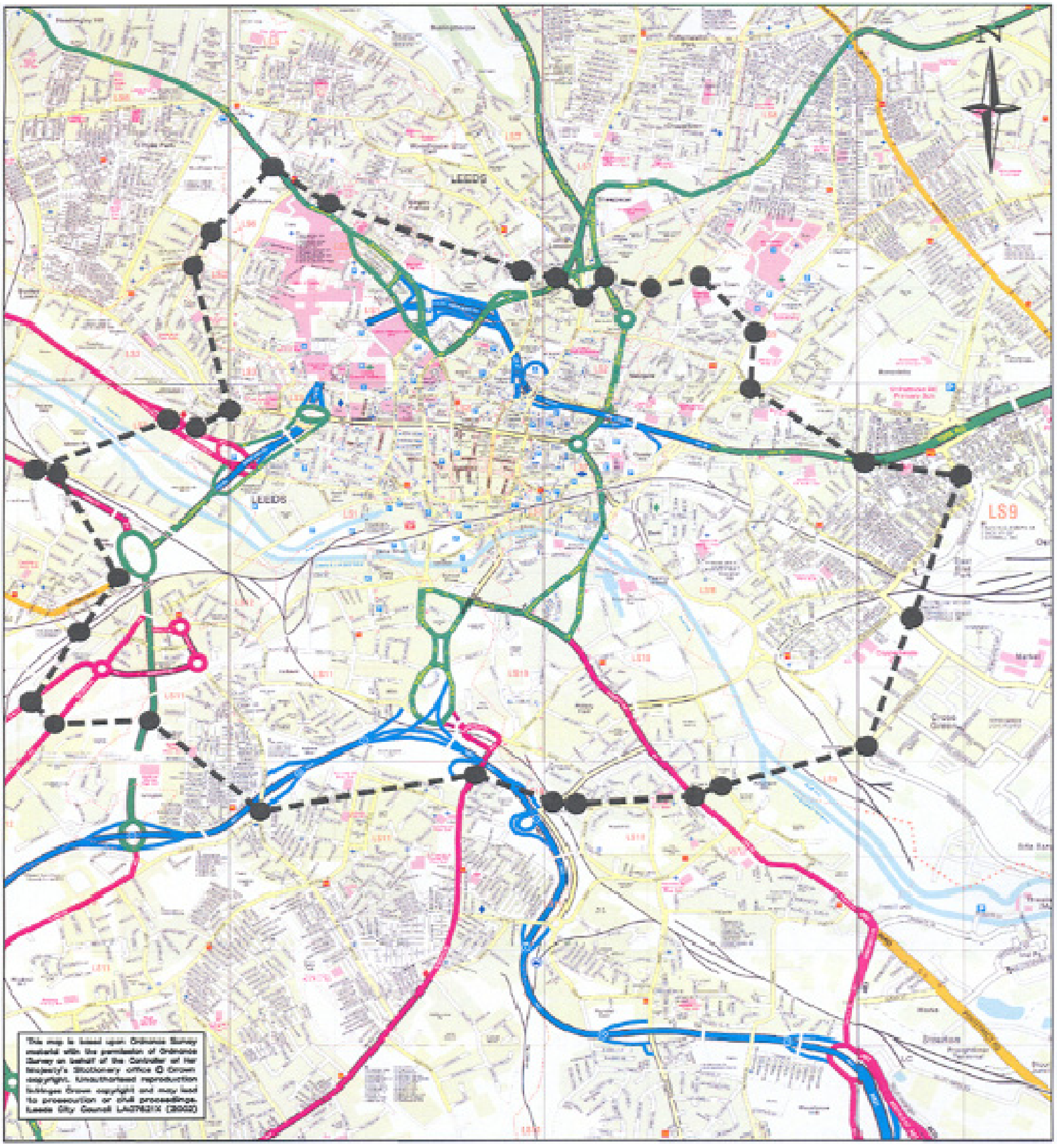
18.1.6 It is clear that the choice of which LD operation would be most appropriate for a specific site will be dependent upon individual characteristics of that site, and based on numerous criteria that must be assessed by the engineer. However it can be seen that there are opportunities for embracing developing technologies and making minor changes to installation parameters that could reduce installation and maintenance costs and improve the efficiency of LD methods of operation that retain signal control and its intrinsic safety over priority operation. These include improvements to equipment, for example detection and use of low voltage equipment, and trialling whether low minimum green times should be considered permissible during LD periods. Software developments to improve the efficiency of operation of traffic signals in LD periods should be actively encouraged, for example developments to UTC/SCOOT operation to make it more flexible during LD periods whilst retaining the ability to provide coordination when necessary.

# Appendices

# **Appendix A –** Determination of Low Demand Flow Criteria

18.1.7 In order to provide guidance on quantifying LD flow characteristics, analysis has been carried out on some sample cordon data for Leeds city centre (**Figure 26**). The data consists of one-way traffic flows in 15 minute intervals over a whole week, and the cordon crosses about 12 major roads (‘A’- class) and 20 minor roads. For the purposes of this study, inbound flows from 00:00 on Monday to 24:00 on Friday have been analysed.

**Figure 26 –** Leeds City Centre cordon



18.1.8 Although individual flows for each approach were not available, the aggregated flows for all inbound cordon points ranged from 297 vehicles in the 15-minute period from 03:15 to 03:30, to 8,945 vehicles between 07:30 and 07:45, with a total 24-hour flow of 378,174 vehicles. Assuming a major/minor flow ratio of 2:1 suggests that one-way flows on any major road will range from around 1 vehicle per minute in LD periods to 27 per minute in the peak period.

18.1.9 **Figure 27** illustrates the pattern of 24-hour traffic volumes in 15-minute intervals throughout the working week, both as a proportion of the highest 15-minute flow (left axis) and of total daily flow (right axis). **Figure 28** enlarges the graph for the period from midnight to 6:00am.

**Figure 27 –** 24-hour cordon flows, Leeds city centre

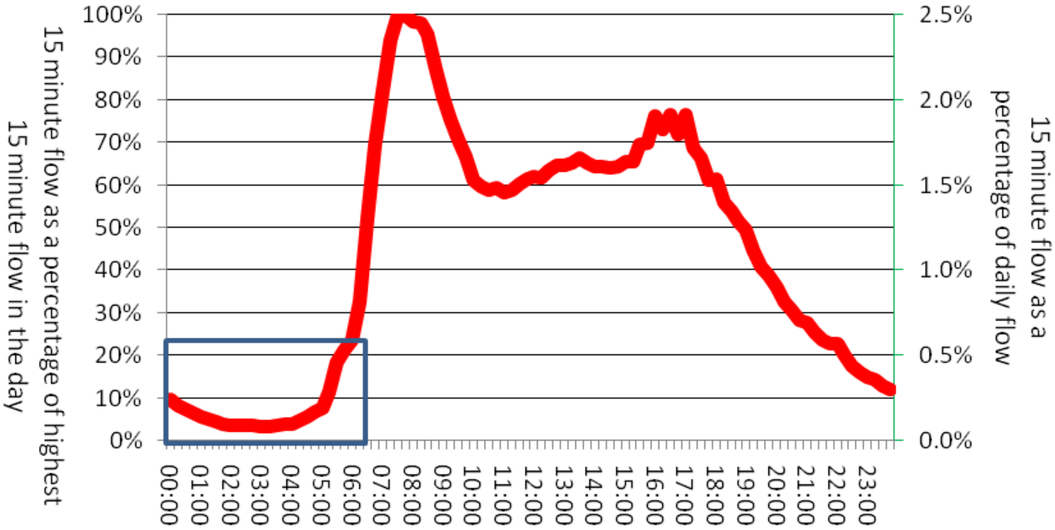
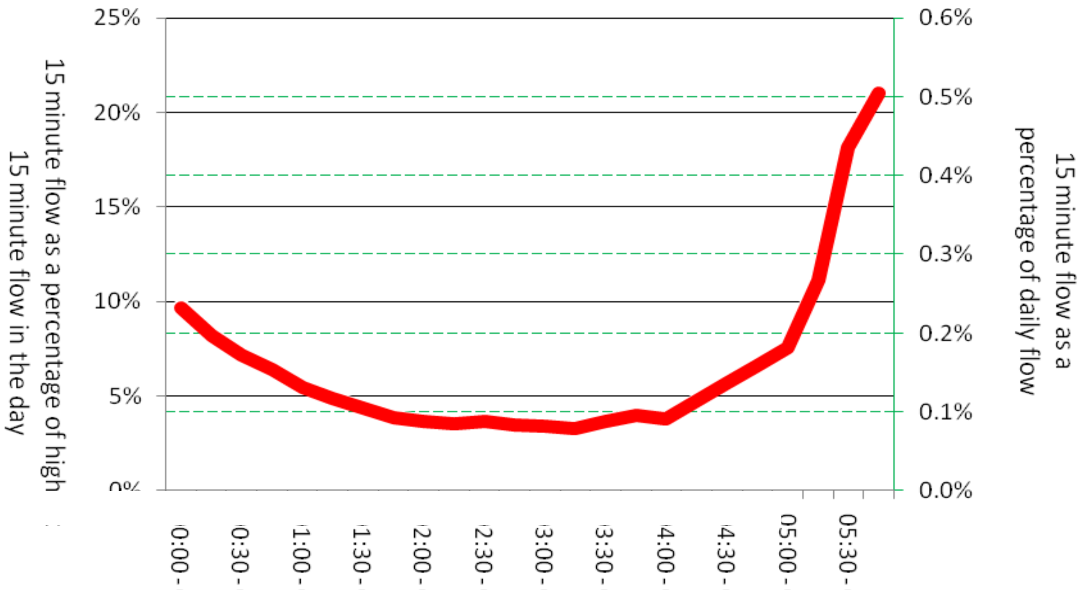


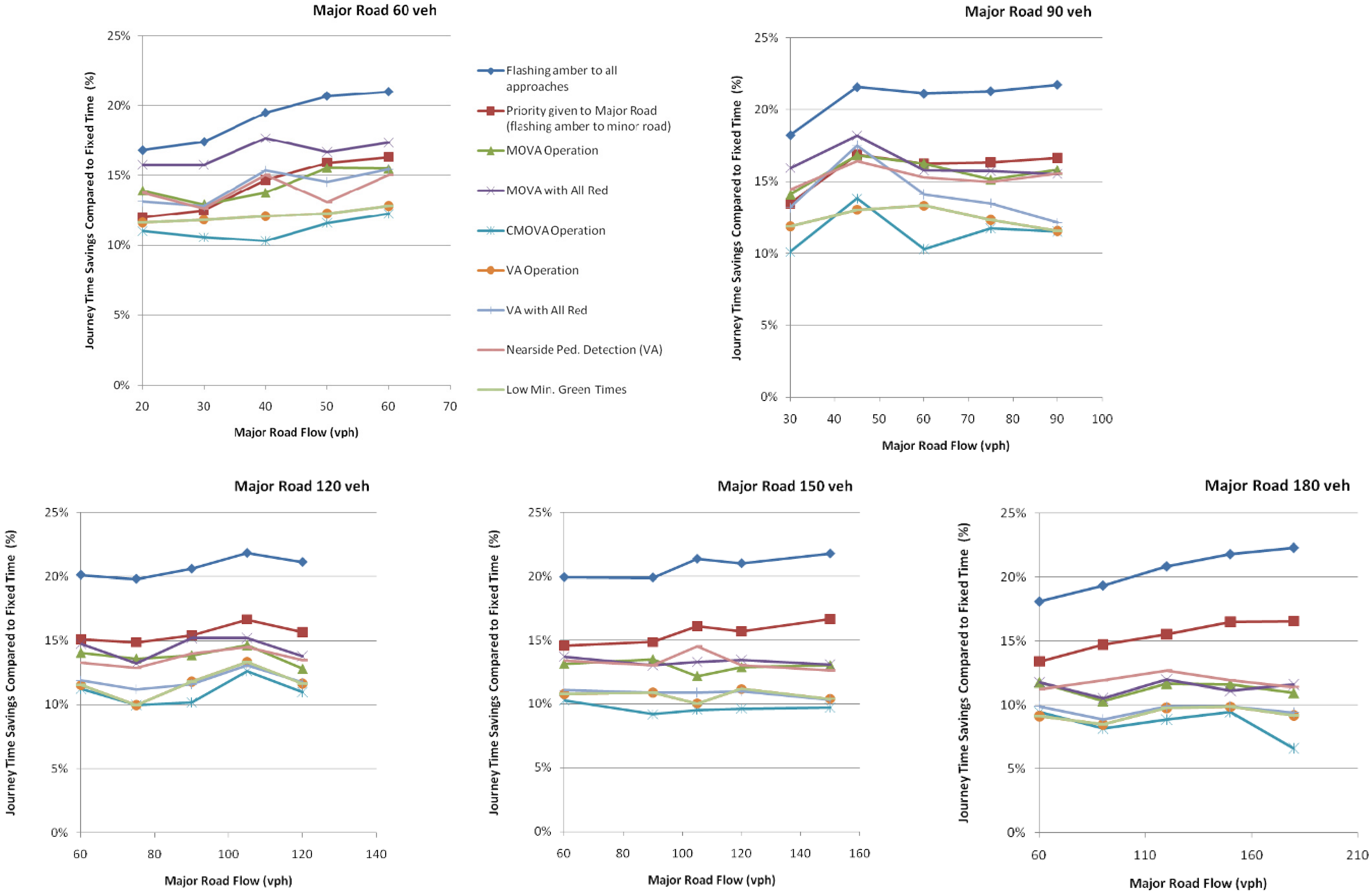

**Figure 28 –** Overnight cordon flows, Leeds City Centre



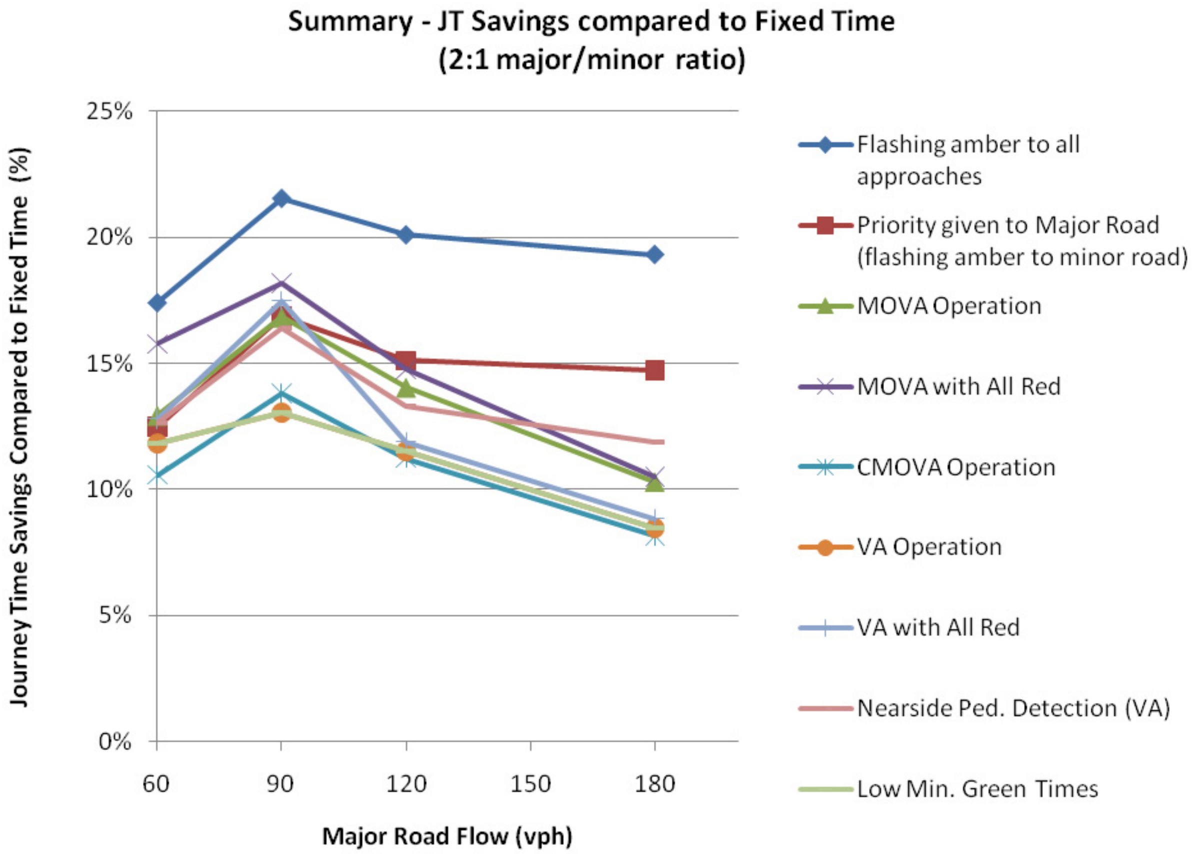

18.1.10 It can be seen that the lowest flows occur between 01:30 and 04:30, when flow rates are less than 1% of the daily flow. Using the 2:1 major/minor assumption described earlier, this would suggest that major road one-way flows of less than 1 vehicle per minute (60vph) could be considered to represent LD.

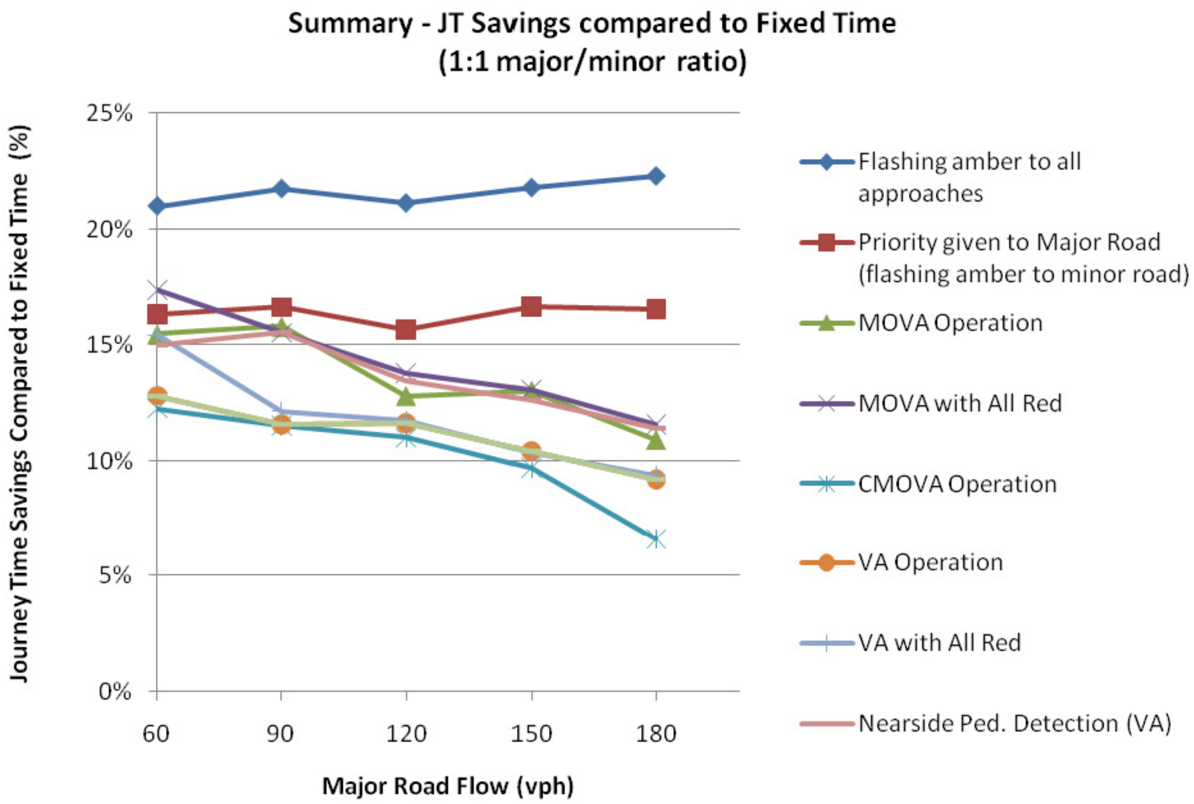
## **Appendix B -** VISSIM Modelling Full Results

Impact of LD options on journey times, compared with fixed time operation – All scenarios for major to minor flow ratios

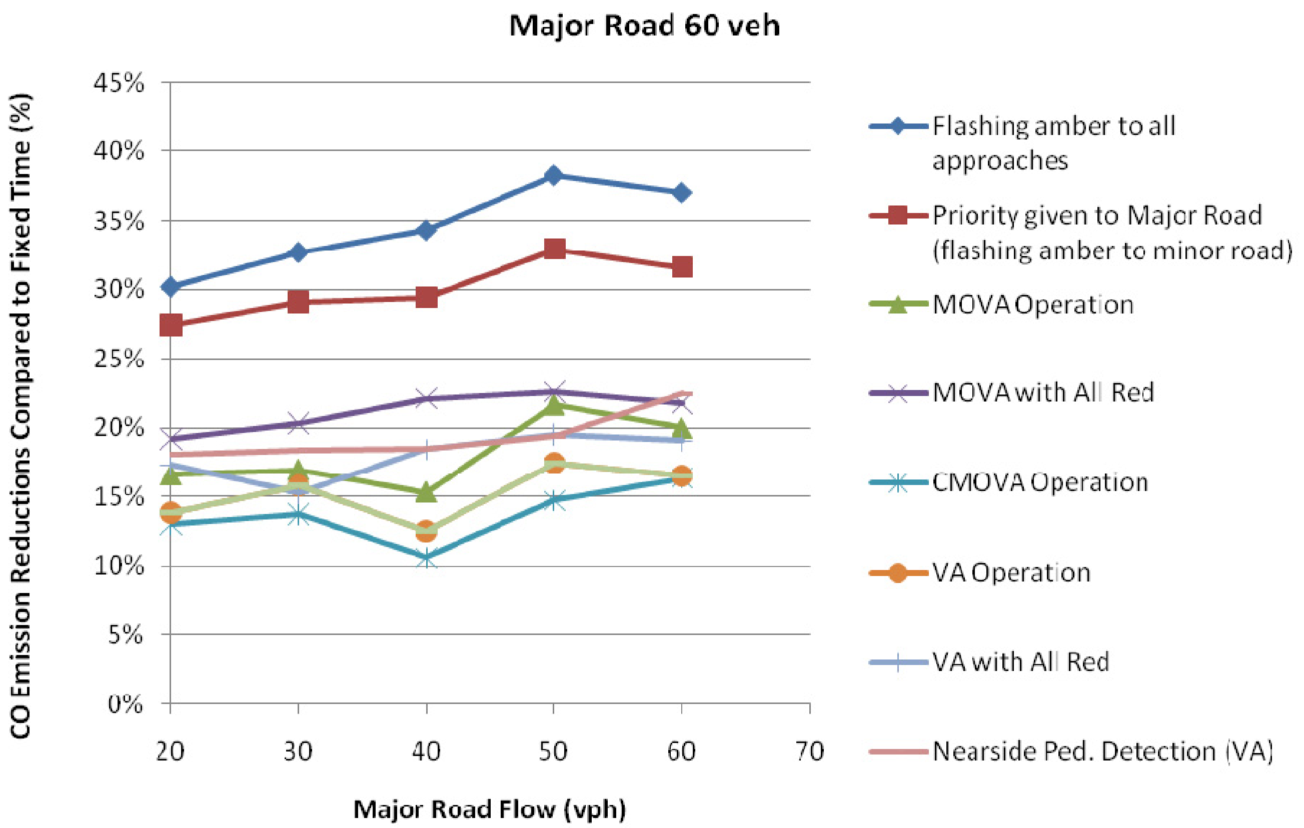


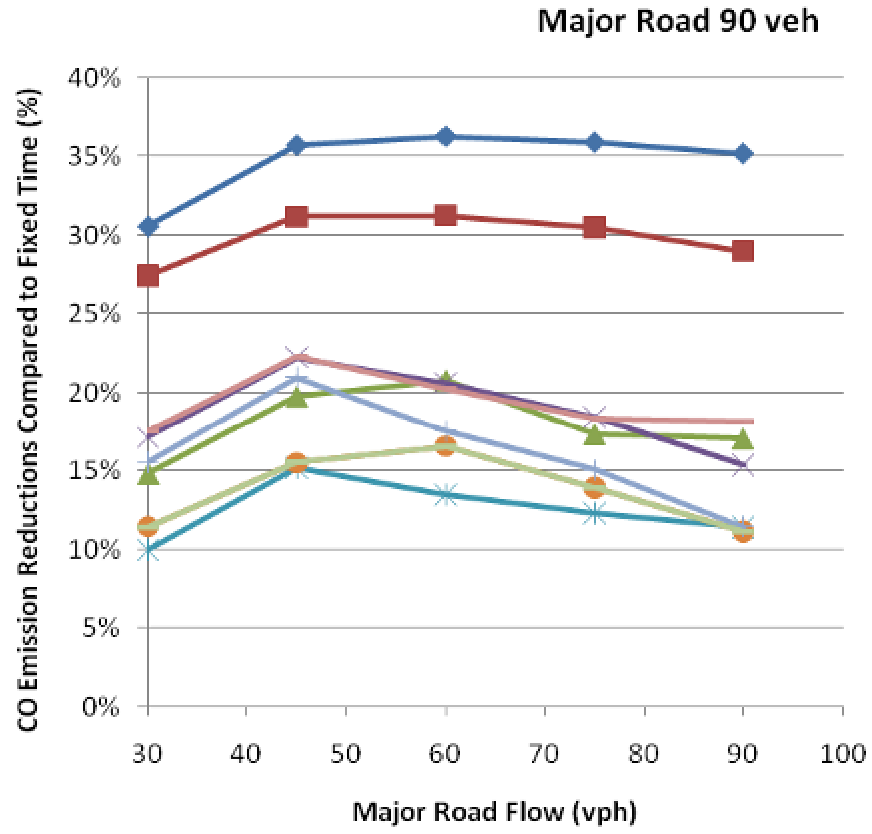
Impact of LD options on journey times, compared with fixed time operation – Summary of option performance as traffic flows increase

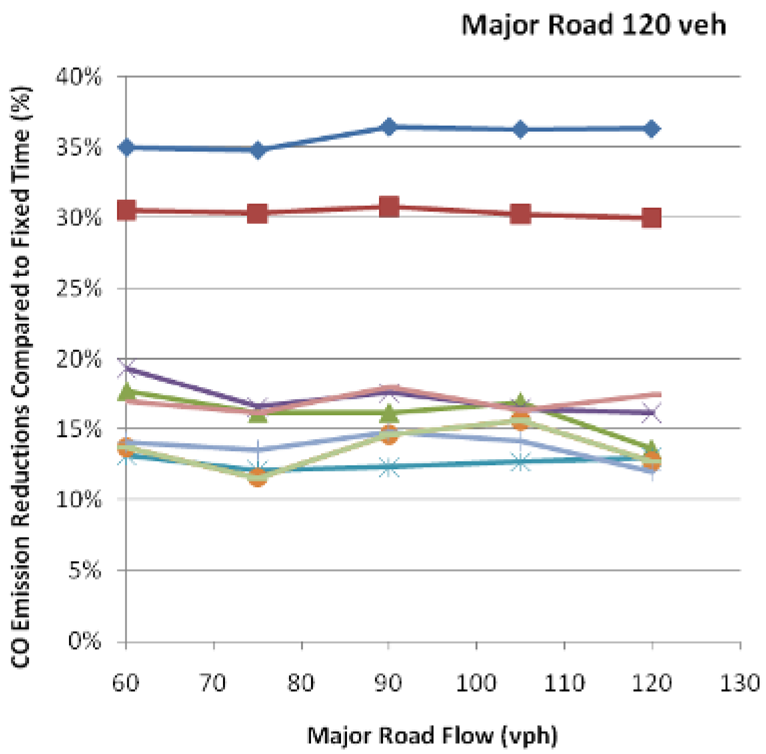


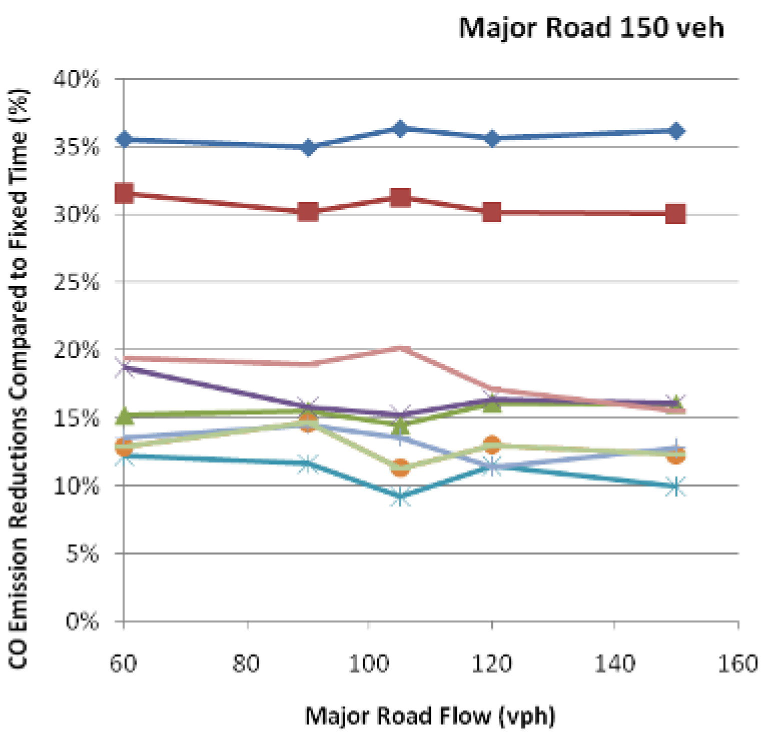



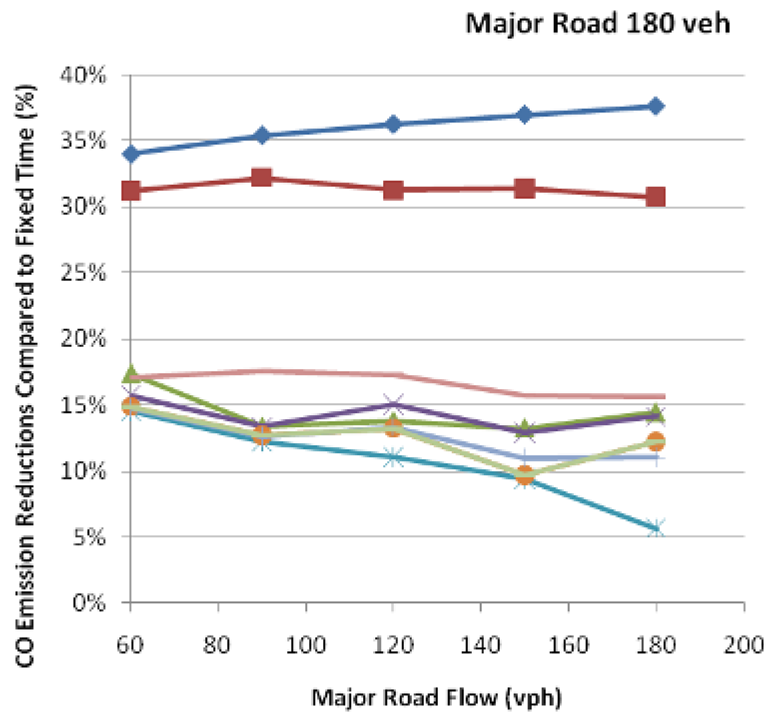
Impact of LD options on carbon emissions, compared with fixed time operation – All scenarios for major to minor flow ratios



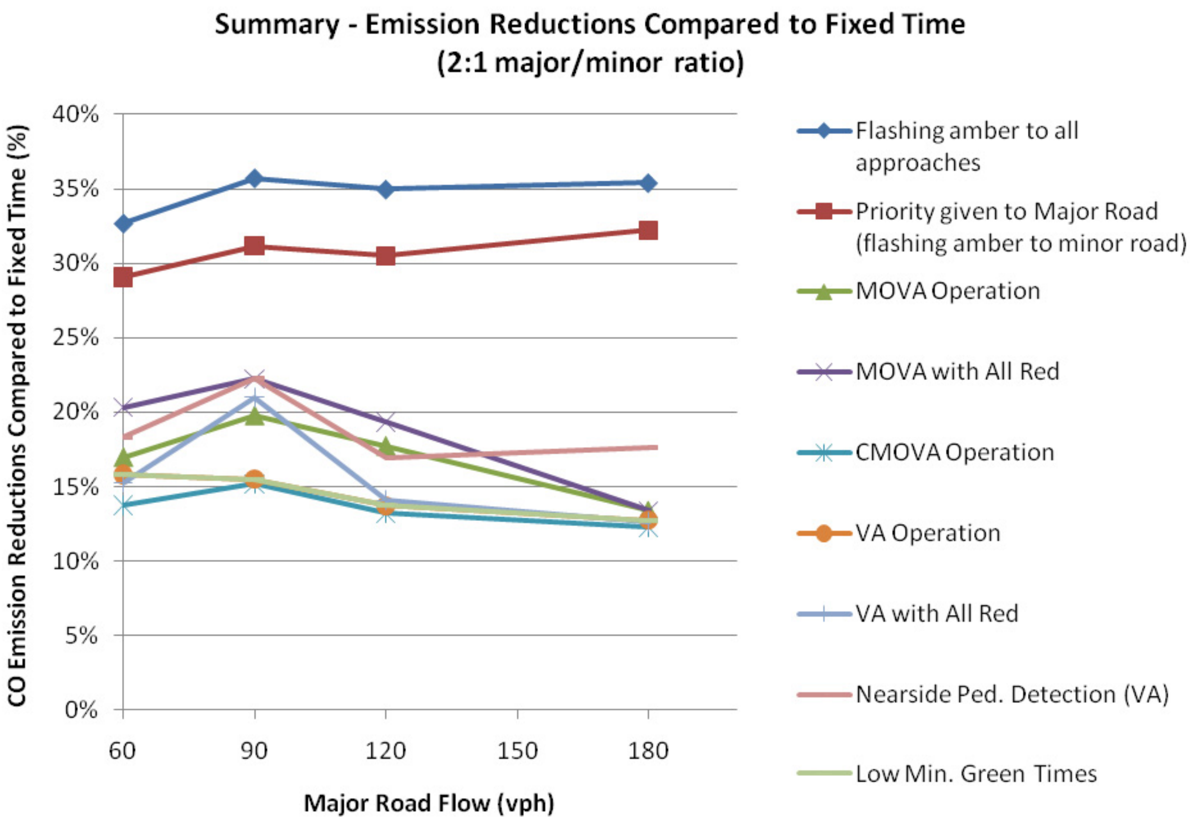



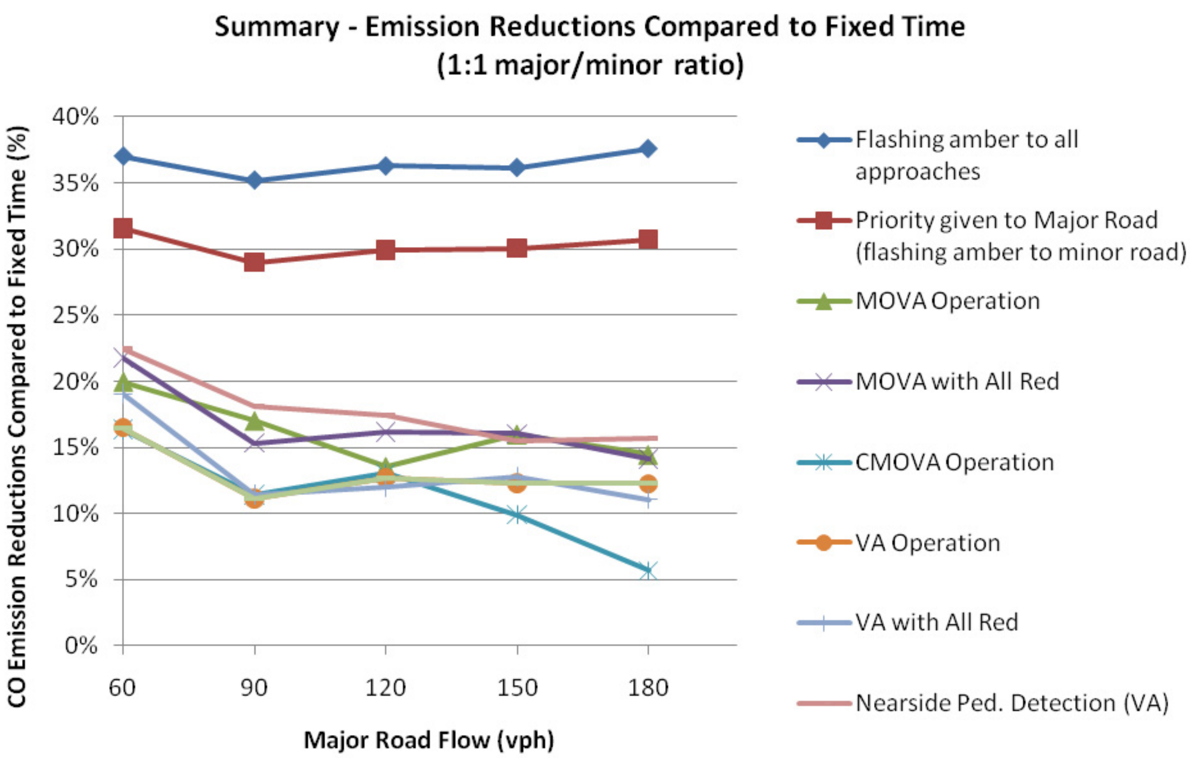



Impact of LD options on carbon emissions, compared with fixed time operation – Summary of option performance as traffic flows increase



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