Provision for all - Adaptive Signal Control for cities where modal demands are changing - the London Case Study

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Abstract:

The City of London is going through an unprecedented combination of challenges to traditional policy making, including a rapidly changing vehicle mix, the highest petroleum prices on record and a well publicised walking and cycling revolution requiring greater consideration of non motorized users amongst motorized modes.

London is the largest single authority using SCOOT - the world's leading adaptive signal control system developed by TRL, the UK's Transport Research Laboratory. With 2000 intersections in London under SCOOT control and a program to increase this number to 3000 by 2014, SCOOT is one of the single most important congestion relief measures that Transport for London have under their control. But SCOOT is more than just traffic control; it now aligns with new policies by allowing much greater consideration of pedestrian needs.

Dynamic demand of pedestrians wishing to cross at SCOOT controlled intersections is now possible with the latest release of the SCOOT kernel, giving operators a much required platform to ensure all road users are catered for equally.

Providing first hand information from London, this paper will explore the potential for existing traffic control technology in North America to learn from international experience of multi-modal decision making, whilst also giving due consideration to traditional aims of transport policy including smoothing traffic flow, reducing CO_2 emissions and improving safety at intersections.

Text:

The SCOOT Urban Traffic Control system is now operating in over 250 cities and towns worldwide. Since the first system was installed there has been a continuous program of research and development to provide new facilities which take into account new technology and policies, and meet the multi-modal requirements of the traffic manager. Recent releases have incorporated many new features aimed at providing priority to public transport and in the last release SCOOT MC3 new strategies to provide benefit to pedestrians at pedestrian crossings were included. In the new version, SCOOT MMX, the multi modal theme is continued with additional facilities to prioritise pedestrians at junctions, a significant update and enhancement of emissions estimates as well as features to improve operation during low flow periods. The latter includes cycle time independence, allowing individual junctions to operate at their optimal cycle time when it is more beneficial than being coordinated and the introduction of 'ghost' stages to reduce cycle times when demand dependant stages are infrequently called.

UTC systems were originally developed to minimise delay to vehicles moving through urban networks. However, in recent years there has been a shift in emphasis away from accommodating the private car and towards more sustainable transport. SCOOT has already been updated to allow priority to be given to public transport, and now the needs of pedestrians are also being considered.

When pedestrian crossings are operating under UTC control, the pedestrian stage is only allowed to occur at specified times during the signal cycle. The SCOOT kernel does not consider pedestrians in its optimisation; the pedestrian stage is allowed to run at the point in the cycle which will minimise delay to vehicles. Thus the main tool of the traffic engineer when considering pedestrians is to constrain the cycle time.

Pedestrians: variable invitation to cross

In the last release, SCOOT MC3 Service Pack 1, a facility was included that allowed users to give greater priority to pedestrians at signalised pedestrian crossings (mid-block crossings). For SCOOT MMX, a new facility targeted primarily at traffic junctions with pedestrian crossing facilities has been developed. In particular it enables priority to be given to pedestrians at sites where the pedestrian demand is high. Where there are large numbers of pedestrians waiting to cross the green man invitation period (and hence the overall time available to pedestrians to cross) can now be extended.

SCOOT is generally based on improving road based traffic performance. The region cycle time is determined through a philosophy of operating the most heavily saturated node in a coordinated network at no greater than a preset target degree of saturation. This target degree of saturation parameter which is normally 90% is determined by the user using the 'isat' value. Setting 'isat' to 90 ensures that, if possible, the most heavily saturated node in the coordinated region operates at no greater than 90% saturation. When flow levels increase, the cycle time throughout the network will rise trying to satisfy this criterion until the 'isat' limit is reached. Pedestrians have not been considered at all in the calculations, the time they receive as an invitation to cross period or the duration they have to wait is an outcome of road based traffic performance. As the cycle time increases in response to greater traffic demand there will be longer intervals between successive pedestrian stages and hence increased pedestrian waiting times.

The objective of the new development has been to modify SCOOT to enable the length of the pedestrian invitation to cross period to be increased in response to higher pedestrian demand, without increasing the region cycle time. In particular it enables priority to be given to pedestrians at sites where the pedestrian demand is high.

Care was required to ensure that the longer pedestrian period does not result in longer cycle times due to the reduced vehicle green times. Longer cycle times will result in longer waiting times for pedestrians and this would defeat the objective. To ensure that the cycle time is not affected, an increase in the pedestrian green time is coupled with an increase in the 'isat' value. This will have the effect of potentially increasing the delay to vehicles on the busiest links of the junction.

Users are able to set up to 4 priority levels. For each pedestrian priority level users can specify the increase in pedestrian green time (in seconds) and the 'isat' value to which the vehicle degree of saturation at the junction is allowed to rise.

Measuring Pedestrian Demand and Capacity

Pedestrian capacity has at least two elements, the capacity of the waiting area and the effective capacity of the crossing itself. At present local authorities do not have detectors installed which can determine the demand in either of these areas.

One measure that is currently available is the knowledge of when a push button is first pressed to demand a pedestrian stage or phase. The rolling average, or other smoothed measure, of the time relative to the end of pedestrian green can be used as a proxy for pedestrian demand. It does not provide a measure for a particular signal cycle, but provides an average level over a longer period. This measure has been included as part of this development and can be used to automatically determine when to increase the length of the pedestrian variable invitation to cross period. Its use is optional.

When detectors are installed that can count pedestrians it should be possible to provide a measure of demand relative to capacity. However, the measure of pedestrian demand will need careful consideration. Some pedestrians cross the road against the traffic signals, therefore, they would not be included in any calculation of the time required to service those who do cross in the green man. However, such pedestrians should not be ignored. The number crossing against the signals could be taken as a measure of failure to meet the requirements of pedestrians. At least they represent some measure of vehicle green that is not fully utilised.

The main benefit of the development is that it will enable a pedestrian priority policy to be implemented. At sites where pedestrian demand exceeds current pedestrian capacity there should be an improvement in safety. Monetary benefits are difficult to quantify, but the new development should ensure that pedestrian friendly policies are implemented in an efficient and controlled way.

Bus Priority and iBUS

Bus priority facilities have been available in the SCOOT Urban Traffic Control system for many years. Additional functionality has recently been added to take advantage of the new Bus management and information system in London called iBus which uses GPS technology to track buses through the network.

With iBus, buses are detected for priority purposes using detector locations configured in the on-bus computer and hence are also known as “virtual detectors”. The predefined virtual detector coordinates are compared with the location of the bus obtained from the on-bus navigation system to trigger a priority request. This system eliminates the need for on-street hardware to detect buses and provides much more flexibility in the number of detectors and their locations.

A big advantage of the system is that it can provide detection of buses without the need for the installation of additional street hardware. This means that there is little cost in providing additional detection points. Accordingly the bus priority logic in SCOOT has been enhanced to allow for multiple detection points on the approaches to traffic signals, including a cancel detector when the bus passes through the junction.

SCOOT provides three methods of optimising signal to give priority to buses: extending the current green signal (an extension), causing succeeding stages to occur early (a recall) or by omitting intermediate stages (stage skipping). Once the bus has passed through the signals, a period of recovery occurs to bring the timings back into line with the normal SCOOT optimisation.

For example, for the three stage junction illustrated in Figure 1, if a bus is detected towards the end of Stage "1" it will receive an extension as shown in Figure 2. If the bus is detected during a red period it will receive a recall (i.e. stage 2 and stage 3 are shortened so that stage 1 starts earlier) as shown in Figure 3. It may also benefit from stage skipping, when stage 3 is one that may be skipped. Figure 4 shows the result, where stage 2 has been shortened and stage 3 completely omitted from this cycle.

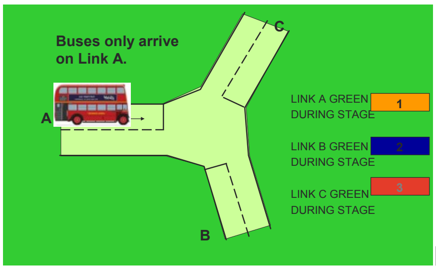

Figure1

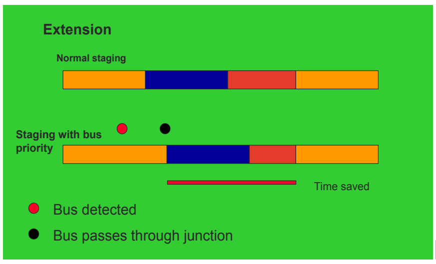

Figure 2

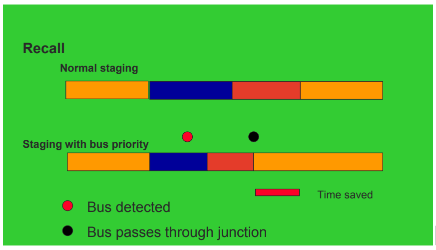

Figure 3

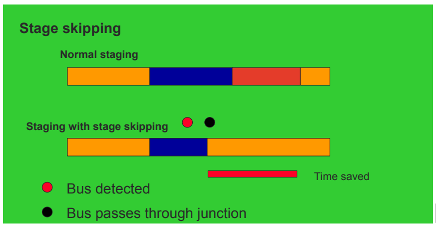

Figure 4

Extensions can be awarded centrally, or the signal controller can be programmed to implement extensions locally on street (a local extension). Extensions awarded in the controller can be advantageous as they eliminate the round-trip transmission delay between outstation and instation, typically 3 to 5 seconds. (Currently in the London UTC system the transmission lag is 5 seconds). That allows the system to grant extensions to buses that arrive in the last few seconds of green. The feature is especially important where link lengths are short, or where bus stops are located near to the stop line. SCOOT is still in control as it sends a bit each second to permit local extensions only when the saturation of the junction is sufficiently low. Techniques for programming the signal controller have been developed and implemented in London.

One of the main advantages of providing priority through SCOOT is that the extent of priority given to buses can be controlled. Extensions and recalls can be restricted depending on the saturation of the junction as modelled by SCOOT. This is managed by specifying target degrees of saturation for both extensions and recalls. The recall target saturation is normally set so that the junction does not become over saturated. Non-priority stages will be run to the target saturation value. In the case of extensions the target saturation may be set so that some over saturation is allowed. An extension will not be granted if to do so would result in the degree of saturation of a link at the node exceeding the target value. This means that bus priority will be most effective at junctions that have spare capacity. Stage skipping has extra controls to limit the frequency of skips in addition to those that prevent skipping of a stage whose degree of saturation is over a user set level.

In many countries, including the United Kingdom, stage skipping is not common practice and its implications on safety need to be carefully considered. Of particular interest is the potential effect on regular users of a junction who become familiar with the normal operation, particularly when they should receive a green at the next stage change. When a stage is skipped, this normal order is interrupted. Users anticipating their green could be caught out when the bus stage, rather than their expected stage, is given green. No adverse effects were observed in the trials in London where great care was taken with the implementation. It is recommended that the principles used in the trials should be adhered to:

- Pedestrian stages should not be skipped – a possible exception is where the pedestrian phase being skipped occurs more than once per cycle.
- When stage skipping is to be introduced at a junction, the stage order should be

reviewed as it may be desirable to re-order the normal stage sequence. This is especially likely at junctions where it is not permitted to skip a particular stage.

In order for SCOOT to provide priority to buses it is necessary for them to be detected some way before the stopline. SCOOT then models the bus travelling down the link and crossing the stopline using the configured journey time from the detector to the stopline, the modelled traffic queues on the link and the colour of the traffic signals. Buses are modelled by SCOOT as queuing with other vehicles, which allows buses to be given priority even though other vehicles may delay them. The effect of bus lanes can also be modelled, including those which end before the stop line.

In practice, because of the variability of the actual behaviour of the bus and the queueing traffic, the modelling cannot be assumed to be perfect. When giving priority to buses by providing extensions, therefore, it is prudent to allow extra green time above the expected journey time to ensure that the bus has crossed the stopline. The amount of this extra green time is determined by the value of a further SCOOT data parameter: BVARY.

The setting of the BVARY parameter is currently something of a dilemma. A high value for BVARY would ensure that all buses given an extension would pass through on green but would provide unnecessarily long green times on many occasions resulting in higher delays to traffic on opposing stages. A low value of BVARY may lead to some buses not getting through on the green.

Bus priority at traffic signals in London to date has thus required buses to be detected downstream of bus stops on signal approaches, to allow the journey times of buses from the detector to the stopline to be predicted with acceptable accuracy. This sometimes leads to detectors being sited much closer to the stopline than desirable. With bus stops, the key problem is high and variable bus dwell times, with variability being too high to allow detection upstream of the stop. Recent changes in bus operations which are expected to reduce bus dwell times at stops include the introduction of flat fares, off-bus ticketing, and the introduction of articulated buses with 3 doors for passenger boarding and alighting.

The new development in SCOOT is designed to take advantage of the new technical innovations introduced into London with iBus, which allows for multiple detections on a link, and the changes in bus operations which should reduce the variability in bus dwell times. In particular, the bus priority logic in SCOOT has been enhanced to allow a cancel detector when the bus passes through the junction. The maximum value for the bus journey time has also been increased. These two developments provide for ‘predictive priority’ where buses are initially detected earlier, possibly before reaching the bus stop.

The introduction of a cancel detector should help to overcome the dilemma in setting the BVARY parameter in SCOOT. The cancel detector will allow an extension to be terminated when a bus has crossed the stopline. It will therefore be possible to set a high value for BVARY which reduces the chance of a bus being given an extension but in fact being stopped by the lights. Once the indication that the bus has reached the cancel detector is received then the stage will be terminated avoiding the unnecessary extra green time being given to the bus and so reduce disruption to other traffic.

The original SCOOT bus priority logic was based on the assumption of immediate implementation, i.e. that for maximum efficiency bus priority should be given as soon as a bus is detected, subject to constraints such as BAUTH (maximum extension allowed) and BESAT (degree of saturation constraint). So if a bus is detected during green, an extension may be granted, which is implemented by extending the current green. Conversely, if a bus is detected during red, a recall is implemented as soon as possible, with stages being shortened and run in succession until a stage is reached which is green to the bus. Then, the stage remains green until the bus has left the link.

For shorter journey times, the assumption is valid and results in bus priority being given as soon as possible for a bus. For longer journey times, however, the assumption may not be valid, and can result in very long greens or priority not being given.

The original logic also made the assumption that when a bus is detected in red a recall will always be beneficial. No check was made as to when the green would start, and it is possible that the recall would cause the green to start earlier than is required. The assumption is reasonable for the situation with short journey times, as there will be at most a few seconds of wasted green. For longer journey times, the original logic could result in a large amount of wasted green time.

The SCOOT logic has now been modified so that it will operate satisfactorily with long journey times. This has been accomplished by introducing a system of delayed implementation. This means that, if the bus is too far away, it will delay the preparation of the extension or recall until it is at the correct stage in the cycle for the logic to operate as intended, and so that the extension or recall will be implemented when it can be used by the bus, thus avoiding wasted green time.

The development to allow multiple detection points, cancel detectors and long journey times should make it possible to give higher levels of priority to buses. By detecting the bus earlier, possibly before the bus stop, the number of times that an extension can be given will be increased. Earlier detection might also increase the benefit due to a recall. There will be some inefficiency introduced due to the increased variability in journey time which needs to include any bus stop dwell time. As long as the variability in the bus stop dwell time is not too high this should be mitigated by the addition of a second downstream detector and a cancel detector. The method of initial detection of the bus before the bus stop has been termed 'predictive priority'. The results of a study to determine the benefits of predictive priority are given later in this paper.

The introduction of real-time passenger information systems such as iBus also allow a bus's location to be compared against a schedule, and in this way priority can be differentiated by a bus's adherence to schedule. 'Differential priority' allows SCOOT to provide different levels of priority according to how late a bus is or to prioritise specific bus routes. The advantages of this approach are:

- by providing priority to late buses only and hence to fewer buses, a higher level of priority may be given and the disbenefit to other traffic is reduced
- greater improvement in the regularisation of the service and hence the waiting time of passengers will be reduced

To enable differential priority in SCOOT, a priority level must be associated with the other information about the detection of a bus. This priority level (or bus importance factor) is then used to determine what priority can be given for the bus. Bus priority levels are permitted in the range 0 to 6.

The mechanism for determining the priority level for a given bus is located outside SCOOT. SCOOT receives the priority level, but does not know how this was produced. For an Automatic Vehicle Location (AVL) or bus management system, the priority level may depend on the behaviour of the bus relative to a headway or timetable. For a selective vehicle detector (SVD) system, there may be no information available about the identity of the bus, so a fixed priority level could be defined for all buses detected on a certain link, or on a specific detector.

Differential priority is particularly useful in improving the regularity of high frequency bus services which run on a headway principle.

The benefit to buses gained through providing SCOOT priority varies considerably, and is dependent on the scope for increasing or decreasing the lengths of signal stages. At junctions where the non-priority stages are already at or close to their minimum length, there is little scope for providing priority through recalls. Assuming that stages are not running close to their minimum lengths, the benefits of priority are then very dependent on the traffic conditions. Reductions in delay as high as 50% are achieved when the degree of saturation is low. Whereas, at high degrees of saturation, the reduction in delay is of the order of 5 - 10%. In extensive trials in London reduction of delay of around 4 seconds per bus per junction are typical. The increase in delay to general traffic is similarly dependent on the degree of saturation. At low degrees of saturation the increase is small and insignificant, whereas at high degrees of saturation the increase in delay to general traffic can be large. The disruptive effect of providing priority by recalls is much greater than by extensions. Giving recalls to buses on a side road can be particularly detrimental as it reduces the green time as well as disrupting the coordination along the main road.

The number of buses being given priority is also an important factor, particularly at higher degrees of saturation. Benefit per bus decreases as bus flow increases, due to competing/conflicting priority calls, but total passenger benefit remains substantial at bus flows as high as 120 buses/h/junction.

Stage skipping can provide additional to those obtained through extensions and recalls. When restrictions are at their minimum level, stage skipping gives good benefits in the range 2.5 to 6 seconds per bus per junction, depending on the junction and flow conditions. Typically where the skipped roads are not too busy, the extra saving in delay, due to stage skipping, averages about 4 seconds per bus. At junctions where the links being skipped are busy, the benefit may be as low as 1 second per bus even if the skipping is uninhibited. This low benefit is due to an increase in queues of general traffic delaying buses.

On average there is a small increase of about 1 second per vehicle in the delay to general traffic when stages are skipped. The main disbenefit is to traffic on the side road being skipped. At junctions where the links whose green is skipped are busy, it is necessary to use the stage skipping saturation parameter to avoid large increases in delay to general traffic.

Extensive simulation testing has been carried out to investigate the effects of providing differential priority. The study considered both bus services that run according to a fixed timetable and bus services that run according to a fixed headway (normally high frequency services). Some of the main findings were:

- For both fixed headway and timetabled services, the highest average reductions in journey time are given by strategies that provide priority to all buses. In general, the more buses that received priority the higher the average reduction in journey time.
- For both fixed headway and timetabled services, using differential priority generally minimises the increase in delay to other vehicles, which is greatest at the highest flow level.
- For fixed headway services there is no improvement to regularisation (standard deviation of headway) for non-differential priority strategies.
- The strategies that provide priority only to late buses improve regularity and reduce passenger wait time the most.
- For timetabled services, non-differential strategies do provide good improvements to regularisation. However, the differential priority strategies provided the highest benefits.

TRL carried out a further study to determine the benefits of 'predictive priority', in particular, detection of buses upstream of a bus stop. A simulation of Farringdon Road/Rosebury Avenue site in London was carried out using the VISSIM micro-simulation package. TRL have developed an interface between VISSIM and the SCOOT kernel, enabling SCOOT to control the traffic signals in VISSIM in the same way that it would control traffic signals on street with simulation speeds significantly faster than real time.

The main interest of the simulation work was to study the effect of SCOOT bus priority at the Farringdon Road/Rosebery Avenue junction (03/031). However an important consideration is the effectiveness of SCOOT in maintaining the coordination between junctions in a network. Therefore, two additional junctions were set up with VISSIM. To the north, the junction between Rosebery Ave and Amwell St and to the south the junction between Rosebery Ave and Theobald's Road and Gray's Inn road were added.

Having set up this 3 node network with VISSIM and interfaced it with the SCOOT kernel, it was necessary to set up the SCOOT detectors and SCOOT data and to go through a validation process similar to that carried out when setting up SCOOT on street.

The simulation study has concentrated on link 03/031v which has a bus stop 18 metres from the stop-line. Bus detectors were placed at two locations. One was downstream of the bus stop, with a journey time of 3 seconds to the stop line. The other was upstream of the bus stop with a journey time of 16 seconds plus the dwell time at the bus stop. There was no cancel detector used in this study. The SCOOT input file determined which detector SCOOT took its information from.

Two bus services were studied. On one service the buses were scheduled to arrive at three minute intervals. On the other service buses were scheduled to arrive every ten minutes. Two different dwell times were used in the study, so that the effects of the dwell time could be determined. Both bus services ran with the same dwell time. The first dwell time used was 10 seconds with a standard deviation of 2, and the second dwell time was 20 seconds with a standard deviation of 6 seconds. The latter is closer to the dwell times observed on street. The average bus journey time for the upstream detector (including the dwell time) input into SCOOT was determined by measuring a sample of buses. For the dwell time distribution (10,2) it was 26 seconds. For the dwell time distribution (20,6) it was 36 seconds.

Initially the simulation runs were carried out with the vehicle inputs based on the busiest 30 minute peak period. However, the network was very congested and the calculated delays fluctuated wildly depending on the random number seed used. It was therefore decided to reduce the car and HGV flows by 28% which made the simulation results more consistent.

It was thought that one of the reasons for high variations with high flows was due to the nature of the model. The bus stop was kerbside, rather than in a lay-by, and because there was only one lane, cars queued behind the bus when it was stopped at the bus stop. Whilst this may be realistic for the site in question, it will not be typical of all sites, where cars are able to pass buses whilst they are stopped.

SCOOT bus priority is controlled by a number of parameters. The maximum extension allowed, known as the Bus Authority (BAUTH), was set to 20 seconds. Bus Vary (BVARY) is the additional extension time added to the average bus journey time to allow for the variability in journey time. If SCOOT is not able to grant the full length of required extension, it opts for recalls instead. Values of BVARY of 2 and 6 seconds were tried. Two values of transmission lag (RXLAG) were used. To simulate local extensions where the detector only needs to communicate with the traffic signal controller box on street the RXLAG was set to 1 second. Conversely, central extensions take 5 seconds for the communications to occur, so the detector information going to SCOOT was delayed by setting RXLAG to 5.

Each simulation run modelled 11 hours of traffic, but data from the first hour was not used because it is during this hour that the traffic builds up from an initially empty network. 10 runs each with different seeds were completed for each set of parameters. The average of each dependant variable was taken and the standard deviation measured. The latter was used to calculate error bars to 90% confidence level.

Table 1. Results of VISSIM simulation study.

Run Parameters					Critical link				Network	
					Delay to buses		No. of extensions		Delay to cars	
Detector	BusPriority	Rxlag	Bvary	Dwell						
					Mean	Err	Mean	Err	Mean	Err
DOWN	busprio=ON	rxlag=1	busvary=2	10,2	69.6	3.7	0.0	0.0	57.2	13.3
DOWN	busprio=ON	rxlag=1	busvary=6	10,2	66.2	2.6	8.6	2.0	50.3	1.2
DOWN	busprio=ON	rxlag=5	busvary=2	10,2	66.0	2.0	0.0	0.0	54.5	2.9
DOWN	busprio=ON	rxlag=5	busvary=6	10,2	66.0	2.0	0.0	0.0	54.5	2.9
DOWN	busprio=ON	rxlag=1	busvary=2	20,6	65.2	1.5	0.0	0.0	61.0	8.8
DOWN	busprio=ON	rxlag=1	busvary=6	20,6	65.5	2.2	4.3	1.2	64.5	10.4
DOWN	busprio=ON	rxlag=5	busvary=2	20,6	64.7	1.1	0.0	0.0	62.5	5.2
DOWN	busprio=ON	rxlag=5	busvary=6	20,6	64.7	1.1	0.0	0.0	62.5	5.2
UP	busprio=ON	rxlag=1	busvary=2	10,2	66.5	4.5	66.7	5.9	63.0	21.1
UP	busprio=ON	rxlag=1	busvary=6	10,2	60.5	2.4	39.7	5.1	49.6	1.1
UP	busprio=ON	rxlag=5	busvary=2	10,2	62.9	1.1	58.0	6.5	60.0	7.6
UP	busprio=ON	rxlag=5	busvary=6	10,2	60.7	1.8	42.4	4.3	58.2	3.5
UP	busprio=ON	rxlag=1	busvary=2	20,6	59.9	1.4	34.6	4.4	62.1	7.0
UP	busprio=ON	rxlag=1	busvary=6	20,6	60.6	1.2	28.2	2.5	59.7	5.7
UP	busprio=ON	rxlag=5	busvary=2	20,6	62.6	2.9	31.4	4.9	58.9	4.4
UP	busprio=ON	rxlag=5	busvary=6	20,6	61.4	1.5	25.8	2.8	55.9	3.8
	busprio=OFF			10,2	69.8	2.1	0.0	0.0	56.8	5.5
	busprio=OFF			20,6	70.3	3.6	0.0	0.0	56.4	4.0

The results of the study are summarised in Table 1. The main variable of interest is the delay to buses on the critical link. This was highest when bus priority was off. For all scenarios, providing priority reduced the delay to buses when a bus detector downstream of the bus stop was used. However the highest benefit to buses was achieved when the upstream bus detector was used. In the case of an RXLAG of 1, BVARY of 2 and Dwell time of 20,6, compared to the No Priority case, there was a decrease in bus delay of 5.1 seconds (7.25% decrease) for the downstream detector. This improved to a delay saving of 10.4 seconds (14.8% decrease in delay) for the upstream detector.

The reason can be seen by looking at the number of extensions granted. These provide the bus with much greater savings than recalls. When the downsteam detector is used, extensions were only granted when the bus vary (BVARY) was set to 6 and RXLAG was 1. Even then, fewer than 10 extensions were granted in the 10 hour period.

Overall there is no significant change in the delay to vehicles in the network. This may to some extent be due to the nature of the network and the fact that cars cannot overtake stationary buses on the critical link. Providing priority to buses will also help the vehicles queued behind them.

The effect of the transmission lag (RXLAG) is to reduce the amount of time available to SCOOT to provide central extensions. A high RXLAG means that SCOOT is aware of the bus when it is closer to the stop line, effectively shortening its journey time. It does not affect recalls as they are always central.

For this network it can be seen that the effect of the transmission lag is very small. For the downstream detector location, where the effect might be expected to be greatest, there are very few extensions. However, it is noticeable that there are no extensions at all when RXLAG is 5. This is due to the proximity of the downstream detector to the stopline: it is only three seconds journey time away.

For the upstream detector, it appears that the journey time is large enough such that the extra time for transmission when RXLAG is 5 has no significant effect. In contrast to RXLAG, BVARY extends the journey time. It is added to the journey time when calculating extensions to allow for the variability of journey time.

In terms of delay to buses and cars the BVARY parameter also has little effect in this network. However it is noticeable for the upstream detector that there were more extensions with a BVARY of 2. This is because of the maximum extension, BAUTH, which was set to 20. SCOOT calculates the extension required, which, depending upon the point in the cycle, could be as much as the journey time plus BVARY. If the extension required is greater than 20, SCOOT does not grant an extension at all. In contrast, for the downstream detector, no extensions occurred when BVARY was 2, because the journey time was so short. It was noticeable that in this network a high value of BVARY had no detrimental effect on the delay to other vehicles. This is probably because of the fact that cars cannot overtake buses and there is likely to be a queue of vehicles behind the bus which will be able to take advantage of the extended green time. In networks where cars can overtake buses a high BVARY will generally result in wasted green time unless a cancel detector is deployed to end the green once the bus has got through.

The simulation study has shown that the new bus priority development in SCOOT has very good potential for increasing the benefits to buses. On the network studied there was a decrease in bus delay of around 10 seconds when using a detector upstream of the bus stop (predictive priority) compared to around 5 seconds when using a downstream detector. This was achieved with no overall increase in delay to other vehicles. The Farringdon Road/Rosebury Avenue network was unusual in that vehicles were unable to overtake buses on the critical link, nevertheless the good potential of predictive priority has been demonstrated.

A second trial is planned around the Ball's Pond Road/Southgate Road junction, where vehicles are able to overtake stationary buses. It is expected that this will demonstrate the effectiveness of 'predictive priority' in a more typical situation as well as showing the effectiveness of using a cancel detector. An on-street trial is also planned for this site.

Provision for cyclists?

SCOOT has for many years had specific functionality for cyclists but arguably only when there are dedicated cycle lanes and facilities. Demonstrating its international pedigree, this work was originally commissioned to enable Beijing to use SCOOT.

As London invests in Cycle Superhighways, the successful Barclays Cycle Hire Scheme planning to expand, and with modal shift moving to cycles all around the world, work is starting to investigate the impact of cycles on dispersion factors on shared links and on junction saturation flows, leading to future SCOOT kernel enhancements to support this important modal shift.

The London case study

The world's leading adaptive control system is moving to multi-modal, with its latest kernel MMX 2010 taking another step in that direction. In practical deployment, London is gearing itself up for this next wave of technology to smooth the traffic flow.

In 2009 London moved forward with a business case for increasing its investment in SCOOT to put a further 1000 intersections under SCOOT control. London did have 6000 signalised intersections with 2000 intersections currently under SCOOT.

As part of the business case, Transport for London and TRL devised a programme of simulations to examine the benefits of SCOOT over Fixed Time. On-street trials are a costly business, and could not be financed or delivered in the time required. A desktop study was therefore conducted, looking at the following traffic control scenarios:

- Fixed Time
- SCOOT
- SCOOT with raised cycle time

The following traffic flow scenarios were modelled:

- Existing flow
- 10% increase
- 20% increase
- Incident

The model outputs measured were:

- Vehicle delay
- Vehicle stops
- Emissions (PHEM)

The results of the study were:

- Over the morning peak period (5 hours) the model predicted that SCOOT would cut emissions
- Vehicle stops and delays were all reduced with SCOOT active
- Models predicted annual user benefit, per junction, between £89,200 and £107,100

The overall user benefit in the first year, per node, is: £90,000 (using 2009 Value Of Time). This excludes:

- Vehicle operating cost (wear and tear, fuel, etc.)
- Social cost of carbon reductions (£70 / tonne)

The business case was approved and since January 2010, a further 300 SCOOT junctions have come on line, with the remaining 700 to be deployed by 2013.

Since the study was completed, for each and every new intersection that comes on line a before and after study is captured. These further results conclude that:

- SCOOT is delivering a 12.5% reduction in delay
- SCOOT is delivering a 4.6% reduction in the number of times vehicles have to

stop as they travel through the network

In order to be ahead of available technology, SCOOT now provides for the dynamic demand of pedestrians wishing to cross at SCOOT controlled intersections, giving operators a much required platform to ensure all road users are catered for equally. This has seen some use in London, but not widely spread. As next generation traffic detectors come to market, pedestrian and cycling detection need to be tested, validated and approved to ensure the facilities are maximised.

London has 8800 buses serving millions of passengers each day. SCOOT bus priority and iBus are key components of this important modal shift. For those that travelled on London's buses, even 10 years ago, they were dirty, unreliable and overcrowded. Things are certainly changing for the better and traffic control is playing its part.

London also has its own tram network. SCOOT can facilitate LRT priority, allowing tram stages to run on demand and then recovering to normal traffic operation afterwards. This has not yet been used in London, but in the last year all junctions around the Croydon tram and on the major A23 corridor into London have been put under SCOOT control, to enable better Journey Time Reliability.

SCOOT is currently installed in Canada in Red Deer and Halifax

References

(1) Bretherton, D, Bodger, M and Cowling, J. 'SCOOT – Managing Congestion, Communications and Control' in Proceedings of 12th World Congress on ITS, San Francisco, 6-10 November 2005