Advice Leaflet 2: Congestion Management in SCOOT

SPLIT

CYCLE and

OFFSET

OPTIMISATION

TECHNIQUE

Introduction

This leaflet is one in a series about SCOOT and should be read in conjunction with Advice Leaflet 1. It expands on the congestion management features available in SCOOT to supplement the general guidance on the SCOOT Urban Traffic Control System.

More information on SCOOT is available at: www.scoot-utc.com

Congestion Management

Congestion is an increasing problem in our towns and cities. From the outset the optimisers in SCOOT have acted in a way so as to help to control congestion. SCOOT links are assigned a congestion importance factor (CGIF) when the system is set up. This allows SCOOT to operate basic queue management as it will act to minimise queues on links with a higher congestion importance. Over the years a number of additional facilities have been provided. These include 'local' facilities such as the ability to specify fixed offsets for congested conditions; SCOOT will automatically move the offset to these congestion offsets as congestion increases. SCOOT also includes tools to carry out more sophisticated queue management such as the gating facility. Gating is used to limit the flow of traffic into a particularly sensitive area by restraining traffic on user specified roads. It can act at a distance so that queues can be relocated to areas where they are less of a problem. SCOOT MC3 has introduced a congestion supervisor to help engineers to obtain maximum benefit from the management facilities

‘SCOOT Congestion’

Congestion is a commonly used word, but less frequently defined. In urban networks, ‘congestion’ on a link becomes particularly important when the queue on the link spills back to exit block the upstream junction and prevent vehicles discharging from that junction. SCOOT detectors are normally located at the upstream end of the link. Consequently a stationary queue over the detector is an excellent indicator that the upstream junction is, or is about to be, exit blocked. ‘SCOOT congestion’ is defined as the proportion of the signal cycle that there is a queue over the detector. Continuous occupancy of at least 4 seconds is taken to indicate a queue.

Normal SCOOT operation optimises the signal timings to minimise network delay. However, because of the importance of preventing exit blocking and the potential for grid lock, extra logic is invoked when an optimisation includes any congested links.

Congestion Importance Factor

SCOOT will respond to a stationary queue over the detector by increasing the green time to the congested link to reduce the queue and exit blocking. How much extra green time is given is controlled by the user by specifying the congestion importance factor for each link.

Where a major junction would be blocked the link will have a high importance, but entry links to the coordinated area, where there is not an upstream junction to block would normally have a small importance factor. The user is able to flexibly control the reaction to congestion depending on its network effects.

Short links

Short links, whether in the general network or on the circulatory carriageway of a roundabout or gyratory are particularly sensitive to the offset along the link. A short link cannot store many vehicles; therefore, if the upstream junction is not green to the main feeder stage when the short link is green, that green time can be largely wasted; a potential major cause of congestion.

Maintaining a good offset on a short link can be a problem. Because it is a short link with little storage capacity, the queue in the red will frequently reach the detector. Once a queue has formed over the detector there is no useful information available from the detector for offset optimisation. Consequently, left to its own devices, SCOOT may not control the offset as well on critical short links as on longer ones.

The congestion offset facility has been provided to ensure good control and avoid loss of throughput on such links. In addition, users can set a fixed / biased offset on the link to permanently constrain the offset towards the desired value for congested conditions. Congestion offsets can also be used to select which approach arm will be green if exit blocking occurs.

The congestion supervisor (see below) introduced in SCOOT MC3 will calculate congestion offsets for short links that are causing congestion.

Additional Congestion Information

In some situations taking action on the congested link is not the most effective way of managing a problem. There can be a need to take action at a distance using the congestion link facility. One such situation is where there is a minor junction, or signalised pedestrian crossing between two important junctions as shown schematically in Figure 1.

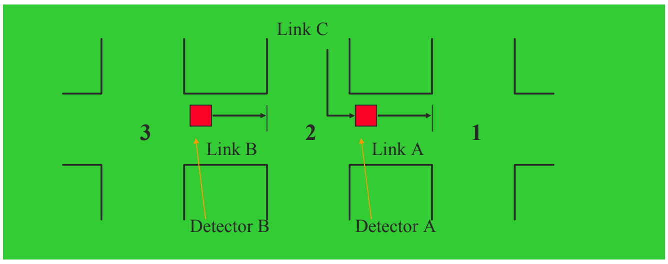

Figure 1

Here junctions 1 and 3 are important and their operation should not be interfered with unduly by queues on links A or B. Node 2 is shown as a junction and link C a minor link. It could also be a pedestrian crossing when there would be no link C, just a fixed length pedestrian stage stopping traffic o link B. In either case, queues back to detector A on link A are not of great concern as exit blocking node 2 will not have a major impact. It is more important to maintain the green time for the major North-South flows through junction 1 rather than to give extra green to link A to avoid blocking node 2.

However, if the queue from junction 1 reaches all the way back to detector B on Link B, then it does present a serious problem as it will exit block junction 3, an important junction. The normal action of the congestion logic will be to attempt to increase the green time to link B at node 2, but without much effect. As link C is a minor source of traffic the corresponding stage will be running close to its minimum, there is little if any extra green available to link B. Similarly if node 2 is a pedestrian crossing, the pedestrian stage will be a fixed length and the congestion logic will not be able to increase the green time to link B.

Node 2 is neither the cause of the problem nor where it can be relieved. To take effective action it is necessary to increase the green time to link A at node 1. Specifying link A as the congestion link of link B and using a high congestion importance factor for the congestion link will increase green to link A in response to congestion on link B.

The congestion link facility can also help operation of a filter link. Filter links controlled by an exit loop cannot become congested in SCOOT because of the location of the detector. The congestion link logic can be used to cause congestion on the parallel straight-ahead link to increase green time for the filter link where queues are predominantly caused by lack of capacity for turning traffic.

Gating

A stronger form of action at a distance is provided through the SCOOT gating facility, which is designed to relocate queues away from sensitive areas of the network to more acceptable locations. A congestion offset can move a queue to a different arm of a junction; gating can relocate it to a completely different node.

The 'sensitivity' of an area may be due to environmental factors or lack of space for a bus-lane to by-pass the queues as well as for traffic reasons, such as to avoid lock-up of a gyratory. Gating is most beneficial to general traffic where:

- a gyratory may grid-lock, particularly if there is a restriction on a major exit
- there is a substantial amount of cross-movement traffic

The technique is not universally applicable, not least because there may not be anywhere acceptable to relocate queues to. Good benefits have, however, been found in trials[1]: preventing lock up of the gyratory system in Kingston-upon-Thames, for bus priority in Southampton and reducing emissions in a local centre on a major radial in Birmingham.

Gating in Kingston-upon-Thames

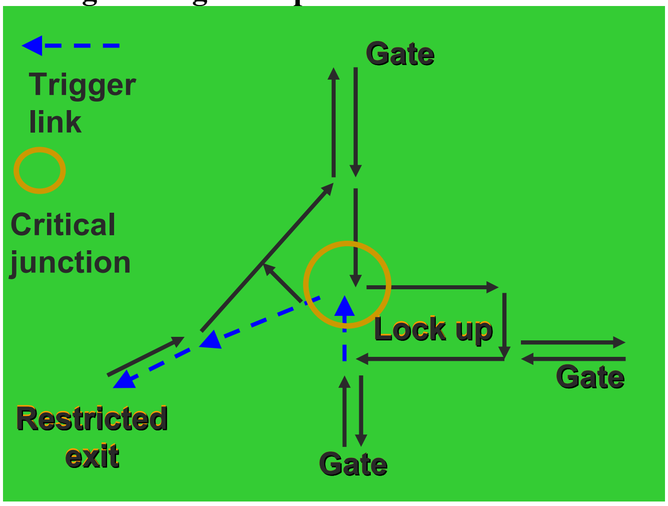

Figure 2: Kingston network

In Kingston, traffic leaving the town centre and gyratory system to the West is restricted by the capacity of the river bridge and roundabout on the far side of the bridge. The restrictions are all outside the SCOOT controlled area. The capacity is such that more traffic can leave the gyratory than can exit over the bridge. Without gating queues build back to the critical junction shown in Figure 2 at busy periods. If the critical junction is exit blocked for long then the gyratory system will lock up. Once it has locked up, it takes a long time to recover resulting in very large delays.

With SCOOT gating, the links leading to the restricted exit are defined as trigger links as shown in Figure 2. Once the congestion or degree of saturation exceeds the critical value on any of these trigger links, the green time is reduced at each of the three entries to the gyratory, labelled 'Gate' in Figure 2. The degree of restraint increases with the number of trigger links that exceed their critical values. Queues build up on the gated links as the traffic is metered onto the gyratory, reducing the flow there. The resulting lower flow on the gyratory and fewer vehicles leaving towards the bridge keep the gyratory free-flowing and prevent lock up.

The trial showed that by avoiding lock up the network delay inside the gates reduced by 22%. In addition there was no increase in delay on the gated links. The delay imposed on the gated links by SCOOT gating was no greater than that previously caused on those links by lock up of the gyratory. It should be noted that such large reductions in delay are only likely when gating is used to impose the minimum delay at the gate needed to prevent the lock up of a gyratory. Using gating to relocate queues on a radial route will normally increase rather than reduce overall delay.

Gating on the Bitterne Road, Southampton

Another reason for using gating is as part of a bus priority system. In some circumstances the congested links where buses are delayed in queues are too narrow to accommodate bus lanes to allow the buses to avoid the queues. It may be possible to use gating to relocate the queues to an area on the approach to the congested links where bus lanes or other priority measures can be installed.

The technique is not new and easily predates the development of the SCOOT gating facility; a queue relocation system using queue detectors and fixed time plans had operated for many years on the Bitterne Road in Southampton. The aim of that scheme was to move queues away from the approach to a narrow railway bridge to locations where buses could be provided with special facilities to avoid the queues.

Side roads joining the main roads were gated with long queues on the side roads, but buses were given separate access points onto the main road, avoiding the queues. On the Bursledon Road signals were installed at the end of a bus lane. The signals were used to relocate queues to where the buses could bypass the queues using the bus lane. With the advent of SCOOT gating the system was converted to operate under SCOOT control giving more flexible control than was possible using fixed-time plans. The results of the fixed-time scheme were that non-bus journey times were about the same with and without the scheme, but with queuing in different places. Bus journey times were dramatically improved.

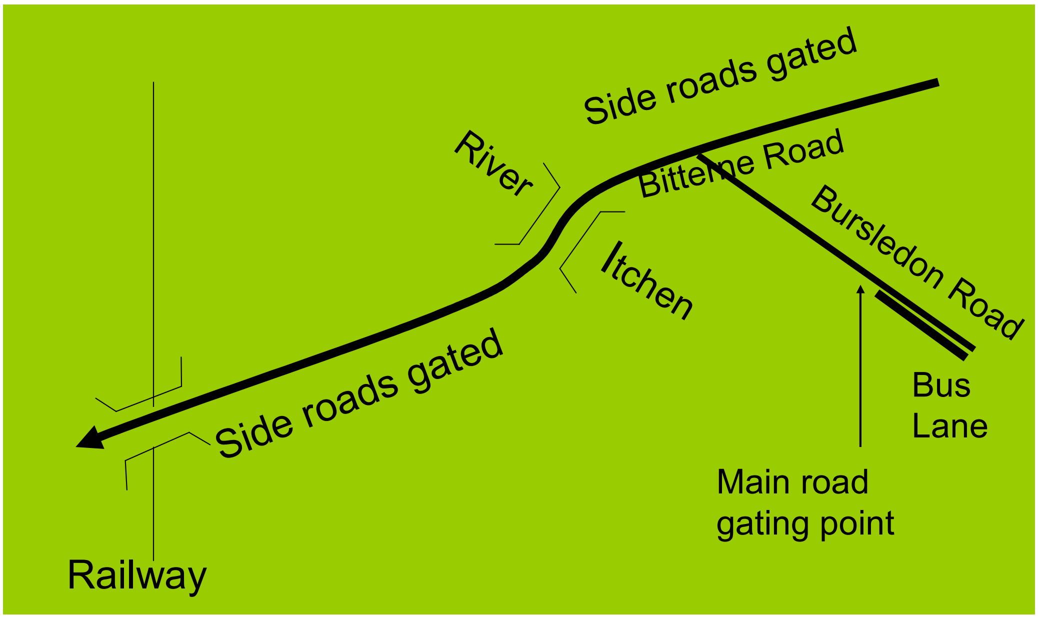

Figure 3: Bitterne Road scheme, Southampton

Operation through SCOOT gating was compared with the fixed-time plans and delay to non-bus traffic was found to be reduced because of the more responsive control. It was not possible to switch off such a well established scheme to measure the effect of SCOOT gating against no restraint. However, gating would not be expected to reduce overall delays in such a queue relocation scheme. The scheme is shown schematically in Figure 3.

Gating to manage vehicle emissions in Birmingham

A further example of the use of gating comes from the DfT UTMC03 project on managing vehicle emissions. In that project SCOOT gating was used to relocate queues to reduce the emissions from vehicles in sensitive areas. The trial in Birmingham was in Handsworth on the A41 Soho Road, a local centre with a lot of kerbside activity, see Figure 4.

Figure 4: Handsworth

The objective of the trial was to relocate queues and their associated vehicle emissions to locations where considerably fewer people would be exposed to the reduced air quality. Inbound traffic in the morning peak was held at traffic signals near the M5. The chosen area had little housing or other activity near the road and few pedestrians walking along the road (see Figure 5).

In the evening peak the major movement was outbound from the centre of Birmingham, through Handsworth towards the M5. This traffic was restrained at signals at the end of a flyover over the ring road. A location dominated by roads and traffic with little other activity. Few non-travellers would be exposed to increased vehicle emissions in this location.

Figure 5: AM gating point, A41 Birmingham

Some tuning of the control parameters was required in the morning peak because of complaints of the size of queues at the gate. It was not possible within the resources of the project to fully quantify the changes at the gating point, but reduction of emissions in the protected area were estimated to be about 3 to 4% for most pollutants. A drop in flow was also measured, resulting in a further 4% reduction in emissions, but the reduction in flow may have been due to drivers diverting and emitting pollutants elsewhere.

The results in the evening peak were not as good with only very small reductions. Further examination of the results showed that there was a considerable volume of traffic travelling towards Birmingham in the evening peak and the effect of gating at a 2-stage junction was to delay that traffic in the protected area. The results demonstrate the importance of careful scheme design and ensuring that significant extra delay is only imposed on the vehicles that it is intended to gate.

Full details on the use of gating are provided in the documentation provided with each system.

Congestion supervisor

SCOOT is a flexible traffic management tool for experienced engineers. However, to provide such a good level of flexibility and control inevitability means that the system may appear complicated to use with many parameters to understand and set. In SCOOT MC3 a congestion supervisor has been provided to assist users.

The supervisor runs continuously in the background searching for and analysing congestion problems. It reports its results to help the engineer make optimal use of all the facilities that are available in SCOOT to manage congestion.

The congestion supervisor has been developed based on the information already available within the SCOOT system. The aim of the supervisor is to continuously monitor congestion throughout the SCOOT controlled network, to identify links causing serious problems and to diagnose the probable reason for congestion emanating from those links. The congestion problem and the recommended action to take will then be reported to the users.

Analysis of congestion problems in the supervisor is based on the use of 'Wasted Capacity,' a quantitative measure of the loss of effective throughput caused by exit blocking of a link. Tracing Wasted Capacity from link to link allows the supervisor to locate the source of the problem and to quantify the size of the problem and the importance to assign to it when reporting to the user.

Overall the aim of the congestion supervisor is to target regularly recurring congestion rather than congestion caused through incidents. Objectives of the SCOOT MC3 supervisor include:

- Identify nodes that are the cause of the congestion problem
- Calculate congestion offsets on 'short' links
- Identify possible changes to congestion importance factor
- Diagnose problems when there are faulty links
- Report/diagnose problems where the degree of saturation is low

- Diagnose and report where a junction is overloaded

In a particular implementation, the results from the congestion supervisor may be directly provided to the engineer, or may be further refined through a UTMC system supervisor. A UTMC common database can include rules to enable the database to act as a UTMC supervisor. It will also include mechanisms for users to set the rules and hence define the supervisory functions and actions. Using such a UTMC supervisor allows the information provided by SCOOT to be combined with further inputs to the UTMC common database, such as car park occupancy and discharge rates. The supervisor will consider this extra information before reporting to the user or taking other action.

References

1. K Wood et. al. Improved traffic management and bus priority with SCOOT, ITS World congress, Chicago, USA, October 2002

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