Advice Leaflet 1: The "SCOOT" Urban Traffic Control System

SPLIT
CYCLE and
OFFSET
OPTIMISATION
TECHNIQUE

Introduction

Traffic congestion is an ever increasing problem in towns and cities around the world and local government authorities must continually work to maximise the efficiency of their highway networks whilst minimising any disruptions caused by incidents and events. The traffic adaptive urban traffic control (UTC) system SCOOT[1] (Split, Cycle and Offset Optimisation Technique) has been developed by TRL to help authorities manage and control traffic on their networks.

This leaflet is intended to draw the attention of traffic authorities, consultants and researchers to the advantages of SCOOT. Some authorities may not be aware of the benefits of installing the latest version of SCOOT. Others which already have SCOOT systems may not be getting the best out of them or appreciate the benefits of extending or updating them. SCOOT is continually being improved through research by TRL funded by the Department for Transport (DfT) and the SCOOT suppliers.

Overview

Modern traffic signal control provides an important tool in the traffic manager's toolbox for managing the highway network and SCOOT is the world leading adaptive signal control system. It coordinates the operation of all the traffic signals in an area to give good progression to vehicles through the network. Whilst coordinating all the signals, it responds intelligently and continuously as traffic flow changes and fluctuates throughout the day. It removes the dependence of less sophisticated systems on signal plans, which have to be expensively updated.

Many benefits are obtained from the installation of an effective Urban Traffic Control system utilising SCOOT, both reducing congestion and maximising efficiency which in turn is beneficial to the local environment and economy.

- World leading adaptive control system
- Customised congestion management
- Reductions in delay of over 20%
- Maximise network efficiency
- Flexible communications architecture
- Public transport priority
- Traffic management
- Incident detection
- Vehicle emissions estimation
- Comprehensive traffic information

Modern traffic management and control systems must account for all methods of transport in our urban areas and SCOOT provides effective priority for public transport without disadvantaging the normal traffic, allowing public transport vehicles to adhere to their schedule and hence provide a credible alternative mode of travel.

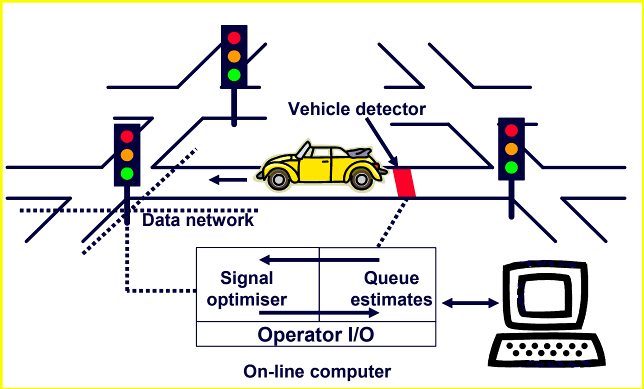
SCOOT has been demonstrated in over 200 towns and cities in over 14 countries around the world given proven benefits in reduced congestion and delay. These have been demonstrated several times with detailed studies highlighting the effectives of SCOOT urban traffic control as a tool for management of traffic and congestion.

The development of SCOOT

In urban areas where traffic signals are close together, the co-ordination of adjacent signals is important and gives great benefits to road users. Co-ordinating signals over a network of conflicting routes is much more difficult than co-ordinating along a route.

Early work developed off-line software to calculate optimum signal settings for a signal network. TRANSYT, developed by TRL, is probably the best known example. TRANSYT can be used to compile a series of fixed time signal plans for different times of day or for special recurring traffic conditions.

Preparing such signal plans requires traffic data to be collected and analysed for each situation and time of day for which a plan is required. This is time consuming and expensive and unless plans are updated regularly as traffic patterns change they become less and less efficient. To overcome these problems, the concept of a demand responsive UTC system was developed. Initial efforts were not successful, mainly because of a continuing reliance on plans, either pre-prepared or dynamically developed.



TRL developed a methodology to overcome these problems. An on line computer continuously monitored traffic flows over the whole network, fed the flows into an on-line model, similar to that used in TRANSYT, and used the output from the model as input to its signal timing optimisers. These optimisers made a series of frequent small adjustments to signal timings to minimise the modelled vehicle delays throughout the network. This was the basis of SCOOT, which, has been continuously developed to meet the needs of today's traffic managers.

New features have been added as SCOOT has been developed. Traffic management features have been added and refined in each version. Major enhancements include:

Version 3.1[2] included bus priority, database facilities and incident detection.

Version 4.2[3] added estimates of the emission of pollutants.

Version 4.5 enabled the bus priority to differentiate between different buses, e.g. to give more priority to late buses, enhanced the technique to "gate" traffic into sensitive areas and provided extra help to engineers setting up a system.

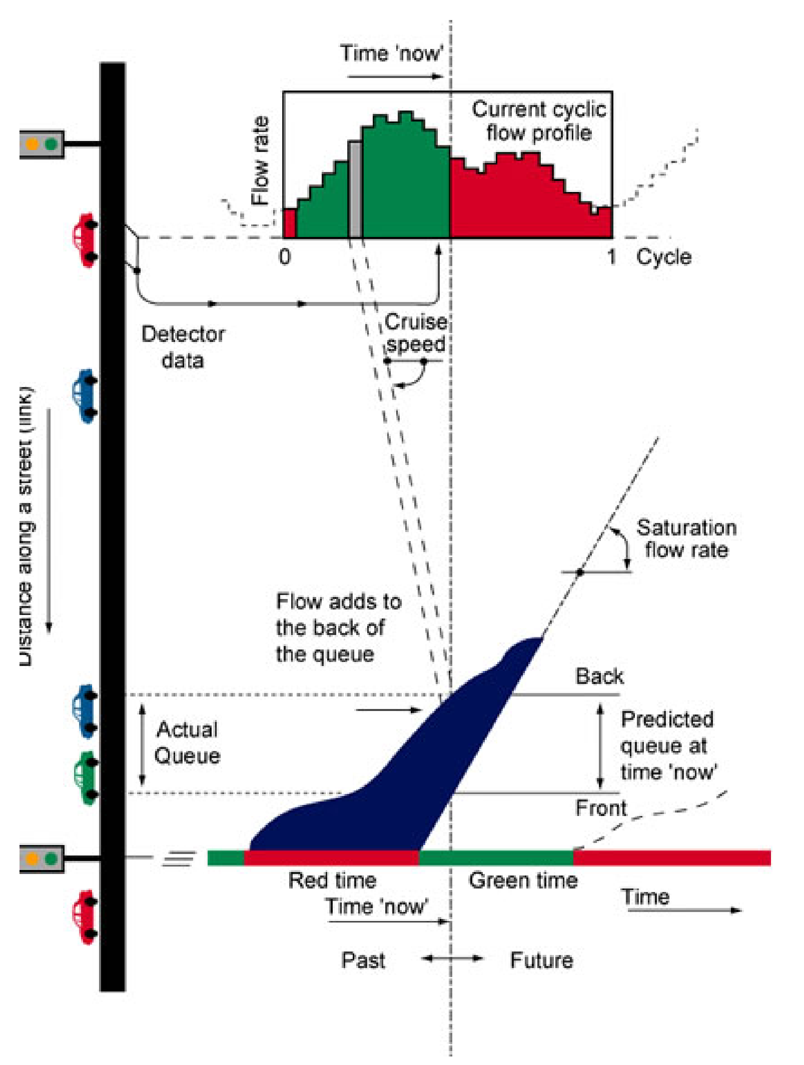
SCOOT MC3[4], the latest version, has enabled the Kernel software to safely use data supplied by packet switched communications systems, provided a congestion supervisor and increased the priority available to buses by allowing stage skipping where it is appropriate.

How SCOOT works

The Kernel software at the heart of a SCOOT system is standard to all installations. The additional software (the “knitting” or UTC software) which links the SCOOT Kernel to on-street equipment and which provides the user interface is specific to the supplier. The user interface includes the data input to store information on the detector locations, physical layout of the road network and how the traffic signals control the individual traffic streams in the SCOOT database.

Any adaptive traffic control system relies upon good detection of the current conditions in real-time to allow a quick and effective response to any changes in the current traffic situation. Detectors are normally required on every link. Their location is important. To provide good information in advance of the vehicles’ arrival at the stopline SCOOT detectors are usually positioned at the upstream end of the approach link. Inductive loops are normally used, but other methods are also available.

Information from the detectors is input to the SCOOT model, which models the progression of the traffic from the detector through the stopline. It takes due account of the state of the signals and any consequent queues. The operation of the model is summarised in the diagram and described below.



When vehicles pass the detector, SCOOT receives the information and converts the data into its internal units and uses them to construct "Cyclic flow profiles" for each link. The sample profile shown in the diagram is colour coded green and red according to the state of the traffic signals when the vehicles will arrive at the stopline at normal cruise speed. Vehicles are modelled down the link at cruise speed and join the back of the queue (if present). During the green, vehicles discharge from the stopline at the validated saturation flow rate.

The data from the model is then used by SCOOT in three optimisers which are continuously adapting three key traffic control parameters – the amount of green for each approach at each junction (Split), the time between adjacent signals (Offset) and the time allowed for all approaches to a signalled intersection (Cycle time). These three optimisers are used to continuously adapt these parameters for all intersections in the SCOOT controlled area, minimising wasted green time at intersections and reducing stops and delays by synchronising adjacent sets of signals.

The operation of the optimisers provides the necessary combination of responsiveness to traffic fluctuations and the stability to maintain coordination. The split optimiser optimises every stage change, the offset is optimised each signal cycle for every node and the cycle time for each region is optimised once every five minutes or once every two and a half minutes when required to respond to rapid flow changes.

SCOOT signal timings evolve as the traffic situation changes without any of the harmful disruption caused by changing fixed time plans on more traditional urban traffic control systems. By the combination of relatively small changes to traffic signal timings, SCOOT responds to short term local peaks in traffic demand, as well as following trends over time and maintaining constant co-ordination of the signal network.

The traffic engineer can use the traffic management facilities of SCOOT to manage traffic in line with the local policy as described overleaf

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Benefits of SCOOT

The benefits of SCOOT compared to alternative methods of control have been well documented. Journey time surveys in Worcester[5] and Southampton[6] found that SCOOT control reduced delays substantially compared with Vehicle Actuation (VA) (i.e. non co-ordinated) signal operation. Typical delay reductions were 23% in Worcester and 30% in Southampton.

Comparisons of the benefits of SCOOT, with good fixed time plans[1], showed reductions in delays to vehicles of 27% at Foleshill Road in Coventry - a radial network in Coventry with longer link lengths. In practice, fixed time plans go out of date as traffic patterns change, by about 3% a year on average, so the benefits of SCOOT over an older fixed time plan would be even greater. On average, it is estimated that SCOOT would reduce delays by approximately 12% against up-to-date signal settings and 20% over a typical fixed-time system.

In unusual conditions in Toronto[7] following a baseball game, delays were reduced by 61%, demonstrating SCOOT's ability to react to unusual events. Trials of the bus priority features in London have shown additional average reductions in delay to buses of 3 to 5 seconds per bus per junction. At particular sites much larger benefits can be found. A trial at one junction in Lances Hill in Southampton has shown reductions in delay of 34 seconds per bus in the PM peak period. Using stage skipping in SCOOT MC3 has been shown to give a typical extra benefit of 4 seconds per bus.

Traffic Management

In addition to the efficient control of traffic, SCOOT provides a wide range of traffic management facilities. Further details of the bus priority and gating techniques are provided in separate leaflets in this series.

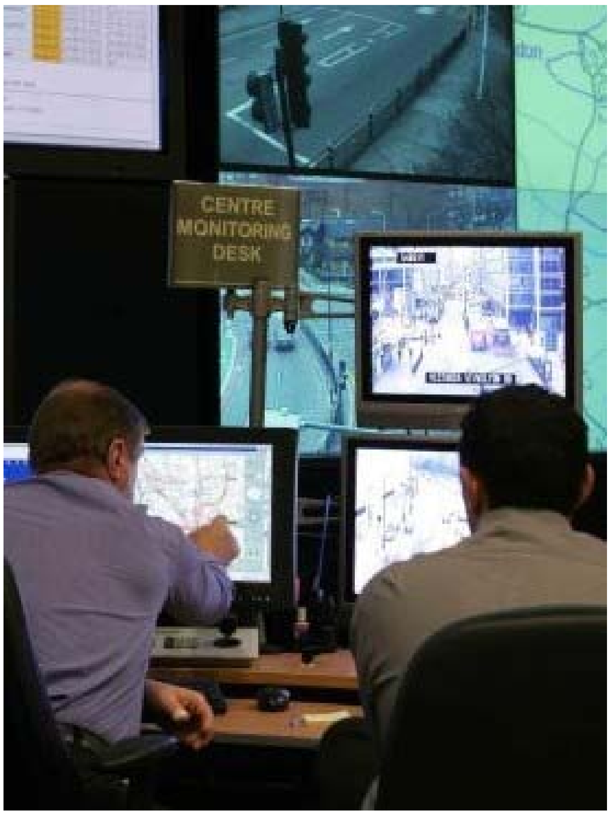
Throughout its life SCOOT has been enhanced, particularly to offer an ever wider range of traffic management tools. The traffic manager has many tools available within SCOOT to manage traffic and meet local policy objectives such as: favouring particular routes or movements, minimising network delay, delaying rat runs and gating traffic in certain areas of the city. Because of its efficient control and modelling of current conditions, SCOOT has much more scope to manage traffic than less efficient systems. For instance, buses can be given extra priority without unacceptable disruption to other traffic.

SCOOT detectors are positioned where they will detect queues that are in danger of blocking upstream junctions and causing congestion to spread through the network. Within SCOOT, the traffic manager is able to prioritise where such problems should be minimised and SCOOT then automatically adjusts timings to manage the congestion.

Where local action is insufficient, the engineer can specify holding areas where queues should be relocated to in critical conditions, gating traffic entering the urban area to ensure efficient operation of critical, bottleneck links. SCOOT will continuously monitor the sensitive area and smoothly impose restraint to hold traffic in the specified areas when necessary.

SCOOT naturally reduces vehicle emissions by reducing delays and congestion within the network. In addition it can be set to adjust the optimisation of the signal timings to minimise emissions and also provide estimations of harmful emissions within the controlled area.

SCOOT MC3 includes a congestion supervisor to help apply the congestion management facilities most effectively to meet local conditions.



A typical SCOOT system

SCOOT systems are designed to meet the user's requirements. There will be a central processor hosting the SCOOT Kernel integrated with the company specific UTC software that controls communications to the on-street equipment and provides the operator interface. This processor and associated networked terminals may be installed in a control room. Alternatively for smaller systems, the processor may be installed in the authority's server room and engineers control the system through client software on their desk top computers. In larger systems there may be a control room staffed by operators, with selected engineers also having system access from their desk tops. This access may extend to viewing and controlling CCTV to compare on-street conditions with the SCOOT model.

Access to the system when on-street is provided by roving terminals. These are typically used for initial system validation, tuning and maintenance.

SCOOT can be integrated into a fault monitoring system to provide integral fault management and, if required, automatic fault reporting to the maintenance contractor 24 hours a day.

System basics

Good traffic data is a prerequisite for successful operation and the detectors are an essential part of the SCOOT system. Inductive loops are most common, though other types of detector can be used. For best results, detectors are required on each link. Installing inductive loops, and maintaining them subsequently, is a significant element in the cost of SCOOT, although less than would be required if all the junctions were operated by isolated VA. Overhead detectors have been used successfully in some situations.

A SCOOT network is divided into "regions", each containing a number of "nodes" (signalled junctions and pedestrian crossings) that all run at the same cycle time to allow co-ordination. Nodes may be "double cycled" (i.e. operate at half of the regional cycle time) at pedestrian crossings or undersaturated junctions. Region boundaries are located across links where co-ordination is least critical, e.g. long links. Data on the regions, nodes, stages, links and detectors will need to be stored in the SCOOT database.

When all the equipment has been installed and the network data input into the database, the system will need to be validated. Validation of SCOOT is the process of calibrating the SCOOT traffic model so that it reflects as accurately as possible the actual events on the street network. This is critical, to ensure effective performance of the system. Those parts of the system that have been validated can be operated under SCOOT control whilst further nodes are being validated. Once the system has been validated, the traffic management parameters can be set to manage traffic in line with the authority's strategy.

Highway authorities wishing to install a SCOOT system or to upgrade an existing one may wish to go straight to one or both of the two traffic system companies licensed to supply SCOOT. However, prospective users with limited experience of UTC systems may find it useful to seek advice from a consultant with experience in the field.

Where can SCOOT be used?

SCOOT was originally designed to control dense urban networks, such as large towns and cities. It is also successful in small networks, especially for areas where traffic patterns are unpredictable. With over 200 systems worldwide SCOOT is working effectively in a wide range of conditions in places as diverse as big congested cities: Beijing, Bangkok and London, to small towns or networks such as:

Heathrow airport and systems localised round individual junctions of the M25.

When junctions are some distance apart (more than about 1km) isolated junction control using a system such as MOVA[9] may be more appropriate. Other site-specific factors may influence the decision on method of control.

Many cities have well defined main radial routes with many signalised junctions and few, if any, traffic signals between the outer areas of the radials. SCOOT has been successfully used in such cities.

UTMC

UTMC - Urban Traffic Management and Control has been developed through a large programme funded by the Department for Transport. The primary goal of UTMC is to deliver better tools which support the pro-active management of the urban traffic mix, essential if wide ranging local transport objectives are to be met. Such policy aims now include public transport priority, improved conditions for vulnerable road users, reducing traffic impact on air quality, improving safety, restraining traffic in sensitive areas and managing congestion.

SCOOT has been at the heart of the demonstration stage of UTMC and has been enhanced to maintain that position. The use of time-stamped data in SCOOT MC3 enables suppliers to produce systems that can exploit both modern packet switched communications systems and the UTMC data transmission protocols.

Traffic information

The primary purpose of SCOOT is to control traffic signals in urban networks to optimise overall traffic performance in accordance with the traffic management policies of the local authority. However, in the process of optimisation, the traffic model within SCOOT generates a large quantity of on-line traffic data, such as flow, delay and congestion. Use of the data has been facilitated by the development of ASTRID[8], which automatically collects, stores and processes traffic information for display or analysis.

Data are available at an individual link level on all signal controlled links.

Information available and data storage

ASTRID is the database used to store information derived from SCOOT systems. A standard setup will store the following data directly from SCOOT:

- Flow: flow in vehicles per hour as modelled by SCOOT
- Flow: flow in vehicles per hour derived from detectors (best for links with one detector per lane)
- Delay: total delay in vehicles per hour
- Congestion: percentage of 4 second intervals when a detector is occupied by traffic. (This value is independent of the SCOOT model)
- Emissions estimates (version 4.0 onwards only)

Other information can be derived from these basic data, e.g. speed by combining delay, cruise time and link length. The data is available at the level of link, node, region, area or route ('route' is any pre-defined set of links). Both current and historic data is available.

SCOOT MC3

SCOOT MC3 (Managing Congestion, Communications and Control), the latest version of SCOOT, enhances how SCOOT operates in four key areas: communications, congestion control, bus priority and puffin pedestrian facilities. In addition to the facilities available in previous versions, SCOOT MC3 has the following new developments:

Time stamping of data

Communication systems are continually developing and analogue dedicated lines, which currently most SCOOT systems depend on, are likely to become increasingly expensive and ultimately not supported at all. A major new development has enabled SCOOT to make flexible use of new communication systems and remove the reliance on second-by-second communication. SCOOT has been modified to use time-stamped data to allow for inconsistencies and delays in data packet delivery. To accompany the time stamping development, the resolution at which SCOOT stores some of the flow data has been reduced from 4 seconds to 1 second. It is predicted that as long as any delays are of the order of only a few seconds the move away from guaranteed second-by-second communication will have a negligible operational effect.

Congestion supervisor

From the outset the optimisers in SCOOT have acted to help to control congestion. Over the years a number of additional facilities have been provided. These congestion management features have been enhanced in SCOOT MC3 by the addition of a congestion supervisor. The supervisor runs continuously in the background searching for and analysing congestion problems. It will report its results and help the engineer to make optimal use of all the facilities that are available in SCOOT to manage congestion. 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.

Stage skipping for bus priority

Enhanced bus priority in the form of stage skipping is now included in SCOOT MC3. If a bus arrives at such a time in the signal cycle that it would have to wait for a side road to be serviced, the existing bus priority would curtail the length of that side road. With stage skipping the side road can be completely omitted during this cycle, reducing delays to the bus waiting at the signals. Comprehensive guidance is included within the system on when stage skipping is appropriate and when it may be inadvisable - for instance, skipping pedestrian stages is *not* recommended and the system provides complete flexibility to configure the most appropriate solution for each situation.

Extensive tests in London during the development programme showed typical average benefits of 4 seconds per bus through each junction with stage skipping. As with all SCOOT bus priority features, stage skipping has flexible input requirements. The approach of a bus can be indicated by on-vehicle transponders activating special detectors, or the location can be provided by a bus management system using any automatic vehicle location system.

Puffin pedestrian facilities

Puffin crossings introduced a variable intergreen as a means to provide a red period to vehicles that could be extended by on-crossing pedestrian detectors without extending the invitation to cross period to pedestrians approaching the crossing. This variable intergreen period, at Puffins and junctions with on-crossing detectors is modelled accurately in SCOOT MC3. The improved modelling reduces delay, particularly at junctions with Puffin facilities.

References

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