The "SCOOT" Urban Traffic Control System

Contents

Introduction

The SCOOT urban traffic control system was developed by the Transport Research Laboratory (TRL) in collaboration with the UK traffic systems industry[1]. SCOOT is an adaptive system which responds automatically to traffic fluctuations. It does away with the need for signal plans which are expensive to prepare and keep up to date[2]. SCOOT has proved to be an effective and efficient tool for managing traffic on signalised road networks and is now used in over 130 towns and cities in the UK and overseas.

This leaflet is intended to draw the attention of highway authorities (in Scotland, roads authorities) to the advantages of SCOOT. Some authorities may not be aware of the benefits of installing 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 has been improved in recent years, and research currently in hand by TRL and the SCOOT suppliers will deliver further improvements in the near future.

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. Linking traffic signals along a single route so that vehicles get a green signal at each junction in turn is relatively simple. Co-ordinating signals over a network of conflicting routes is much more difficult.

Computer techniques have been developed 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. This is time consuming and expensive, and the resulting plans should be updated regularly as traffic patterns change. To overcome these problems, the concept of a demand responsive UTC system was developed.

The first generation of demand responsive systems monitored traffic flows continuously and triggered the most appropriate plan from the library. Second generation systems used current traffic counts to update historical data and produce new plans. However, this often led to frequent plan changing which caused disruption and often sub-optimal plan changes.

In the late 1970s, TRL developed a methodology to overcome these problems. An on line computer continuously monitored traffic flows over the whole network and made a series of frequent small adjustments to signal timings to reduce delays and improve traffic flow. This was the basis of SCOOT.

Benefits of SCOOT

The benefits of SCOOT compared to alternative methods of control have been well documented[3]. Journey time surveys in Worcester[4] and Southampton[5] found that SCOOT control reduced delays

---

[1] P B Hunt, D I Robertson, R D Bretherton and R I Winton: SCOOT - a traffic responsive method of co-ordinating signals. TRL Laboratory Report 1014. (1981)

[2] M C Bell and R D Bretherton: Ageing of fixed time traffic signal plans. Proceedings IEE Second International Conference of Road Traffic Control, London. (April 1986)

[3] D I Robertson and P B Hunt: Estimating the benefits of signal co-ordination using TRANSYT or SCOOT optimisation. Proceedings 53rd ITE Conference London. (August 1983)

substantially compared with vehicle actuated (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, showed reductions in delays to vehicles of 12% in Glasgow and 27% at Folsehill Road in Coventry. Surveys were taken throughout the day in various locations, including a very dense urban network in the centre of Glasgow and a radial network in Coventry with longer link lengths. In practice, fixed time plans go out of date as traffic patterns change, on average by about 3% a year, 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 and 20% over a typical fixed-time system.

In 1993 a SCOOT demonstration[6] project in Toronto, Canada showed an average reduction in vehicle delays of 14% over the existing fixed time plans. during weekday evenings and Saturdays, vehicle delays were reduced by 21% and 34%. In unusual conditions following a baseball game, delays were reduced by 61%, demonstrating SCOOT's ability to react to unusual events. It was also estimated that updating the Toronto's fixed time plans would require 30 person years of effort.

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

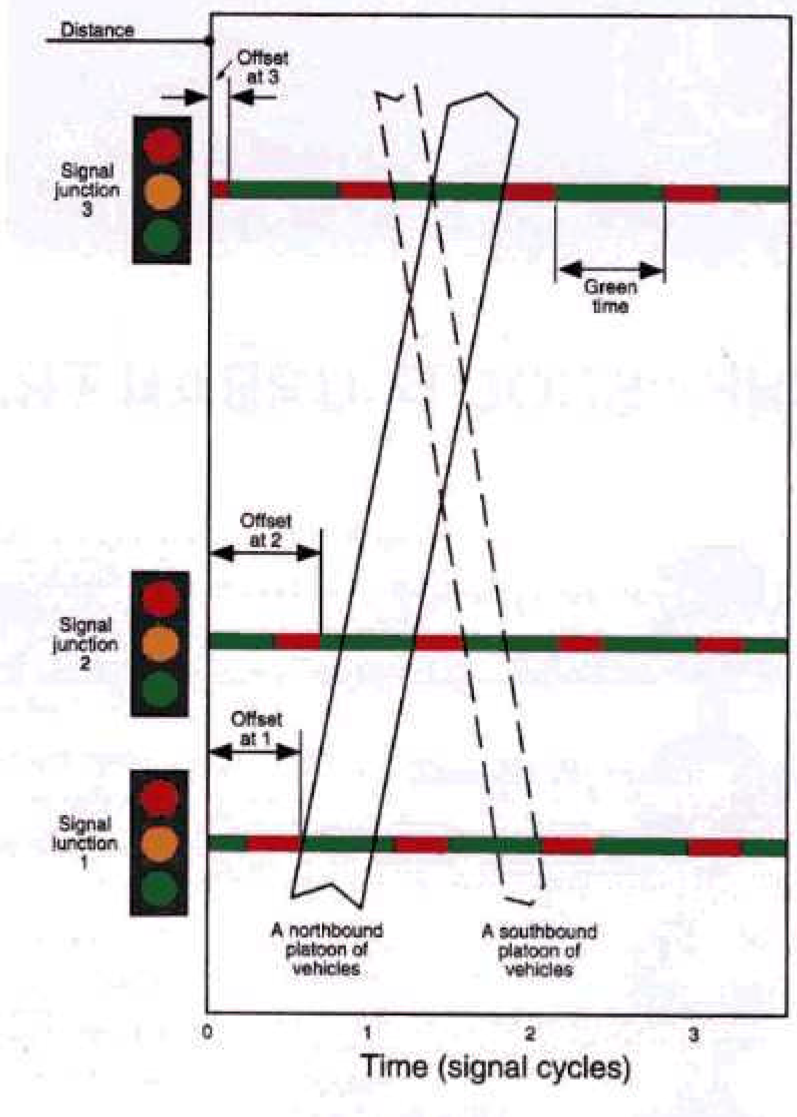
---

[4] J Colyer: SCOOT from Scratch - Experience in Worcester. Proceedings PTRC Summer Annual Meeting, University of Sussex. (July 1985)

[5] R J Powell: SCOOT in Southampton. Proceedings PTRC Summer Annual Meeting, University of Sussex. (July 1985)

[6] SCOOT Demonstration Projects: Report to Transportation Department, Municipality of Metropolitan Toronto, (November 1993)

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



How SCOOT Works

The kernel software at the heart of a SCOOT system is standard to all installations[7]. The additional software (the "knitting" software) which links the SCOOT kernel to on street equipment and which provides the user interface is specific to the supplier.

SCOOT sends out instructions to the "on street" equipment using dedicated telephone lines. These instructions are interpreted and acted upon by traffic signal equipment at the roadside. The equipment replies to the central computer confirming the acceptance of instruction, or detailing a fault condition.

SCOOT obtains information on traffic flows from detectors. As an adaptive system, SCOOT depends on good traffic data so that it can respond to changes in flow. Detectors are normally required on every link. Their location is important and they are usually positioned at the upstream end of the approach link. Inductive loops are normally used, but other methods are being developed.

When vehicles pass the detector, SCOOT converts the information into "link profile units" (lpu), a hybrid of link flow and occupancy. This is the unit used by SCOOT in its calculations. "Cyclic flow profiles" of lpu's over time are constructed for each link.

A SCOOT network is divided into "regions", each containing a number of "nodes" (signalled junctions and pedestrian crossings which are 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 of undersaturated junctions. Region boundaries are located where links are long enough for lack of co-ordination not to matter.

SCOOT has three optimisation procedures by which it adjusts signal timings - the Split Optimiser, the Offset Optimiser, and the Cycle Time Optimiser. These give SCOOT its name - Split Cycle and Offset Optimisation Technique. Each optimiser estimates the effect of a small incremental change in signal timings on the overall performance of the region's traffic signal network. A performance index is used, based on predictions of vehicle delays and stops on each link.

The Split Optimiser works at every change of stage by analysing the current red and green timings to determine whether the stage change time should be advanced, retarded or remain the same. The Split Optimiser works in increments of 1 to 4 seconds.

The Offset Optimiser works once per cycle for each node. It operates by analysing the current situation at each node using the cyclic flow profiles predicted for each of the links with upstream or downstream nodes. It then assesses whether the existing action time should be advanced, retarded or remain the same in 4 second increments.

The Cycle Time Optimiser operates on a region basis once every five minutes, or every two and a half minutes when cycle times are rising rapidly. It identifies the "critical node" within the region and will attempt to adjust the cycle time to maintain this node with a 90% link saturation on each stage. If it calculates that a change in cycle time is required, it can increase or decrease the cycle time in 4, 8 or 16 second increments.

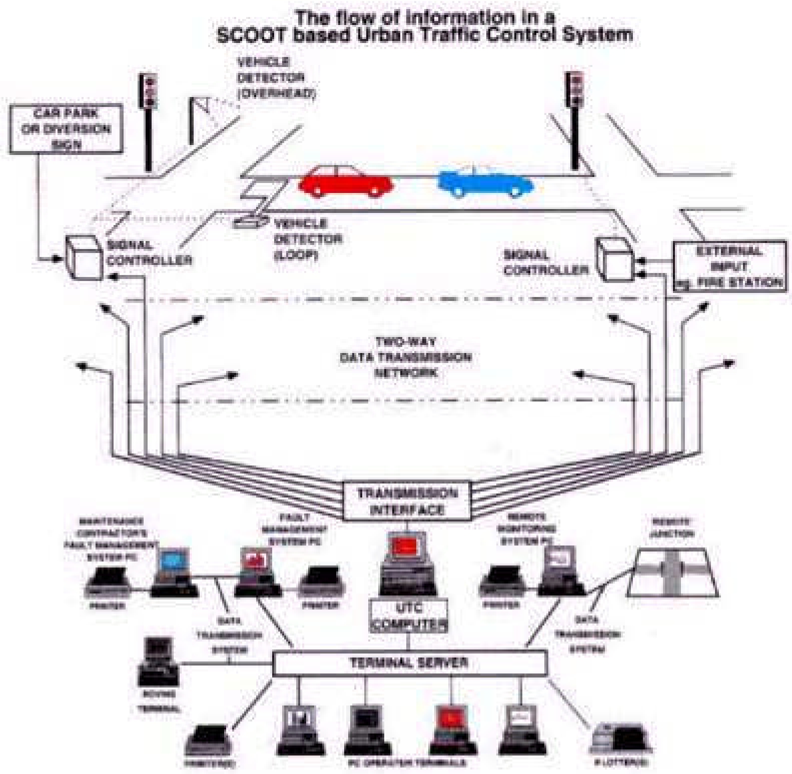
By the combination of relatively small changes to traffic signal timings, SCOOT can respond to short term local peaks in traffic demand, as well as following trends over time and maintaining constant co-ordination of the signal network.

[7] SCOOT Traffic Workshop. TRL, Crowthorne, Berkshire.

A Typical SCOOT System

A typical SCOOT based UTC "instation" would comprise a central processor unit, transmission equipment, PC operator terminals and printers.

Typical SCOOT system



The SCOOT kernel software and the supplier specific "knitting" software would be accommodated on a computer installed at the control centre. The central computer would usually be a VAX, but SCOOT software can be mounted on a variety of other computers.

A number of PCs, work stations, printers and plotters would be linked to the system. The detailed specifications would depend on the requirement of the particular installation.

There is usually a roving terminal so that UTC operators can access the system when away from the control room. This facility is especially useful for setting up the SCOOT system and undertaking database work.

A typical SCOOT system would be further supported by Fault Management and Remote Monitoring Systems. This would provide the operator with integral fault handling facility: a fault detected automatically (or manually) would be relayed to the appropriate maintenance contractor, even during periods when the control room is not manned.

CCTV cameras are extensively used to monitor traffic on a network controlled by UTC systems.

Installing SCOOT

SCOOT depends for successful operation on good traffic data. 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, are a significant element in the cost of a SCOOT system. Overhead detectors have been used successfully in some situations. Validation of SCOOT is the process of calibrating the SCOOT traffic model so that it reflects as accurately as possible the real world events on the street network. This is critical, to ensure effective performance of the system.

Highway authorities wishing to install a SCOOT system or to upgrade an existing one may wish to go straight to one or more of the three 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.

Linking SCOOT to other systems

SCOOT systems can be linked to other traffic management and control systems:-

Variable Message Signs [VMS] systems are widely used to direct drivers to the nearest car park with available space or provide other driver information. Such systems can be linked to SCOOT based UTC systems.

Emergency Green Wave Routes may be specified which can be implemented by remote request from fire stations. This provides a rolling sequence of green signals on successive junctions along a predefined route, to provide the emergency vehicle with maximum priority. The usual method of calling the green wave is by a push button in the fire station, but it is also possible to have a direct link from the fire service or other emergency control room to the UTC computer.

Fault Identification and Management: Scoot based UTC systems can be integrated with Fault Management Systems to enable faults to be automatically recognised and passed directly to the relevant maintenance contractor.

Diversions: SCOOT systems can accept instructions from an external source to implement predetermined diversions, for example in response to a recurrent bridge closure.

Fixed time plan: SCOOT systems can operate fixed time plans where this is required.

Where SCOOT can be used

SCOOT was designed for dense urban road networks such as those in London and other large towns and cities. However the system is also suitable for small networks. It is particularly effective where traffic flows are unpredictable e.g. random changes in traffic patterns such as often occur in popular tourist areas. SCOOT has been very successful in dealing with substantial fluctuations in traffic flows in the Heathrow Airport complex. A four node system has been successfully installed around a retail development in Suffolk, and introduction of SCOOT into the small market town of Dumfries in Scotland is expected to give high economic rate of return on the capital investment.

Full time monitoring of the system may not be practical on a smaller network. However SCOOT systems do not need this as SCOOT is designed to adapt to variations in traffic flow automatically. It may be appropriate to revert to vehicle actuated control late at night when the flows are extremely low.

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

Getting the best out of SCOOT

The basic philosophy and algorithms of SCOOT have been retained since its original development. However, important new features have been introduced in the later versions of SCOOT. These further improve the accuracy of the traffic model and enables SCOOT to be used more flexibly.

SCOOT Version 2.3 enabled the UTC operator to introduce a series of weightings to give priority for specific links or routes. SCOOT could then be instructed to move away from minimising overall delay, to favouring specific links where, for example, buses formed a significant proportion of the traffic. Most SCOOT operators have found instances where the weighting facility has been useful in pursuing particular traffic management policies[8]. Research by TRL has shown the benefits of using the weighting facility to assist bus operation.

SCOOT Version 2.4 was introduced in March 1990, offering further new features[9]. A "green confirm" feedback has been incorporated so that the signal controller informs the central computer when each signal stage is introduced at the signal head. this means that if a demand dependent traffic or pedestrian stage, or an emergency green wave has been operated, SCOOT takes account of this and optimises signal timings accordingly.

A "gating" facility was introduced in Version 2.4[10] which allows traffic entering a specific link or area to be restrained, once a specified threshold of saturation has been reached. This is done by restricting capacity at an appropriate upstream link or links when traffic queues can be accommodated more easily. In effect this facility can be used to "relocate" traffic queues to links where they do not affect critical approaches to junctions. Gating is a potentially powerful traffic management tool which has been successfully applied in Kingston town centre and on Bitterne Road, Southampton where it was used to give priority to buses. Successful introduction of facilities such as "gating" requires detailed knowledge of local traffic conditions.

SCOOT Version 2.5 was released in June 1994 in 'C' programming language. It offered additional facilities such as greater authority of optimisers at higher (>120 sec) cycle times.

The commands controlling the various SCOOT facilities can be compiled into a predefined series of "procedures" designed to invoke particular control strategies. For example, a set of procedures has been designed and used successfully to respond to recurring congestion on the approaches to Trafalgar Square in London. These have provided particularly helpful to buses.

The UTC operator can influence how SCOOT works if congestion builds up. A build up of queues on specific links can be controlled by the use of congestion offsets or the congestion importance factor: the higher the factor, the more SCOOT will attempt to keep that link clear of congestion and the more priority SCOOT will give that link when clearing congestion. The congestion importance factors can be introduced "on-line" by the operator or by timetable to reflect changes in priorities throughout a day.

Upgrading SCOOT systems

A number of new SCOOT facilities have been introduced based on research and requests from users. Existing SCOOT systems can be upgraded by the original system supplier to incorporate new

---

[8] K Wood and R T Baker. Using SCOOT weightings to benefit strategic routes, Traffic Engineering and Control (April 1992)

[9] R D Bretherton and G T Bowen: Recent enhancements to SCOOT - SCOOT Version 2.4 Proceedings 3rd International Conference on Road Traffic Control, IEE, London. (May 1990)

[10] K Wood and R T Baker: User guide to the "gating" method of reducing congestion in traffic networks controlled by SCOOT. (February 1995)

facilities. Upgrading SCOOT to a new version will involve changes to the supplier's "knitting" software.

Providing the central computer has enough processing power, upgrading from SCOOT Version 2.4 to 2.5 can be achieved simply by loading the appropriate software without the need for new hardware.

When upgrading SCOOT, it may be appropriate to upgrade the central computer. However, unless the outstation equipment is very outdated or the user chooses to change manufacturer, the data transmission equipment need not be replaced.

With the conversion of the SCOOT software to the "C" program language, future upgrades should be relatively straightforward.

SCOOT Research and Development

The Department is funding a programme of research to develop SCOOT. Much of this is being carried out under the European Union research programme on Advanced Transport Telematics.

New facilities are being developed to give buses priority by selective detective at signal junctions, and to detect traffic congestion incidents and apply remedial strategies. Ways of using an "expert" supervisory system to invoke recovery strategies are being studied.

A new database, ASTRID, has been developed[11]. ASTRID automatically collects, stores and processes the traffic data used by SCOOT, so that it is available for display or analysis. ASTRID is initially being made available on a separate computer, but the intention is to integrate it with the main SCOOT program in the future.

In addition to the Department's research, the traffic systems companies licensed to supply SCOOT are sponsoring a joint programme of improvements to meet user requirements.

Research is programmed to study ways of reducing the number of detectors required by SCOOT, and to develop alternative forms of detection.

A new version of SCOOT (Version 3.0), incorporating the bus priority facility and other improvements, will be issued in autumn 1995.

[11] N Hounsell and F McLeod: ASTRID: Automatic SCOOT Traffic Information Database. TRL Contractor Report 235.

Glossary

Cycle Time is the length of time for a complete stage sequence to run before it is repeated

Split is the proportion of green time given to a particular link within a cycle.

Offset is the time within the cycle, relative to a common datum, that a green signal is displayed.

MOVA (**M**icroprocessor **O**ptimised **V**ehicle **A**ctuation) is a modern microprocessor technology developed by TRL for isolated intersections to optimise signal timings.

TRANSYT (**TRA**ffic **N**etwork **S**tud**Y** **T**ool) is a program for calculating the 'best' fixed time plans with which to co-ordinate the traffic signals in any network of roads for which the average traffic flows are known.

VA (**V**ehicle **A**ctuation) is a method of Traffic Signal control in which the duration of the green signal is extended, up to a maximum, according to traffic flow.

References

1. P B Hunt, D I Robertson, R D Bretherton and R I Winton: SCOOT - a traffic responsive method of co-ordinating signals. TRL Laboratory Report 1014. (1981)
2. M C Bell and R D Bretherton: Ageing of fixed time traffic signal plans. Proceedings IEE Second International Conference of Road Traffic Control, London. (April 1986)
3. D I Robertson and P B Hunt: Estimating the benefits of signal co-ordination using TRANSYT or SCOOT optimisation. Proceedings 53rd ITE Conference London. (August 1983)
4. J Colyer: SCOOT from Scratch - Experience in Worcester. Proceedings PTRC Summer Annual Meeting, University of Sussex. (July 1985)
5. R J Powell: SCOOT in Southampton. Proceedings PTRC Summer Annual Meeting, University of Sussex. (July 1985)
6. SCOOT Demonstration Projects: Report to Transportation Department, Municipality of Metropolitan Toronto, (November 1993)
7. SCOOT Traffic Workshop. TRL, Crowthorne, Berkshire.
8. K Wood and R T Baker. Using SCOOT weightings to benefit strategic routes, Traffic Engineering and Control (April 1992)
9. R D Bretherton and G T Bowen: Recent enhancements to SCOOT - SCOOT Version 2.4 Proceedings 3rd International Conference on Road Traffic Control, IEE, London. (May 1990)
10. K Wood and R T Baker: User guide to the "gating" method of reducing congestion in traffic networks controlled by SCOOT. (February 1995)
11. N Hounsell and F McLeod: ASTRID: Automatic SCOOT Traffic Information Database. TRL Contractor Report 235.

Contacts for SCOOT systems

Industry

Mr I C Day
Siemens Traffic Controls Ltd
Sopers Lane

Poole
Dorset BH17 7ER
Tel: 01202-782645
Fax: 01202-782331

Mr S Baker
Peek Traffic Ltd
Sovereign House
Stockport Road
Cheadle Cheshire SK8 2EA
Tel: 0161-428-4295
Fax: 0161-428-4926

Research

Other Advice

Mr R D Bretherton
Transport Research Laboratory
Old Wokingham Road
Crowthorne
Berkshire RG11 6AU
Tel: 01344-773131
Fax: 01344-770356

Association of Consulting Engineers
Alliance House
12 Caxton Street
Westminster
London
SW1H OQL
Tel: 0171-222-6557

Mr C Maclennan
Department of Transport
Zone 3/22, Great Minster House
76 Marsham Street
London SW1P 4DR
Tel: 0171-271-5165
Fax: 0171-271-5313

Enquiries

The Traffic Policy/Driver Information and Traffic Management Division of the Department of Transport sponsors a wide range of research into traffic management issues. The results published in Traffic Advisory Leaflets are available to England, Wales and Scotland. Attention is drawn to variation in statutory provisions or administrative practices between the countries.

The Traffic Advisory Unit (TAU) is a multi-disciplinary group working within the Driver Information and Traffic Management Division in the Central Transport Group of the Department of Transport. The TAU seeks to promote the most effective traffic management and parking techniques for the benefits, safety and convenience of all road users.

Enquiries, and requests for unpriced TAU publications, to:
Driver Information and Traffic Management Division, Great Minster House, 76 Marsham Street, London, SW1P 4DR. Telephone: 0171-271 5169. Fax: 0171-271 5313.

Within Scotland, enquiries should be made to:
The Scottish Office, Development Department, Victoria Quay, Edinburgh, EH1 3TA Telephone: 0131-244 0837.