Department for Transport

Traffic Advisory Leaflet 7/99

April 1999

The "SCOOT" Urban Traffic Control System

SPLIT CYCLE and OFFSET OPTIMISATION TECHNIQUE

Introduction

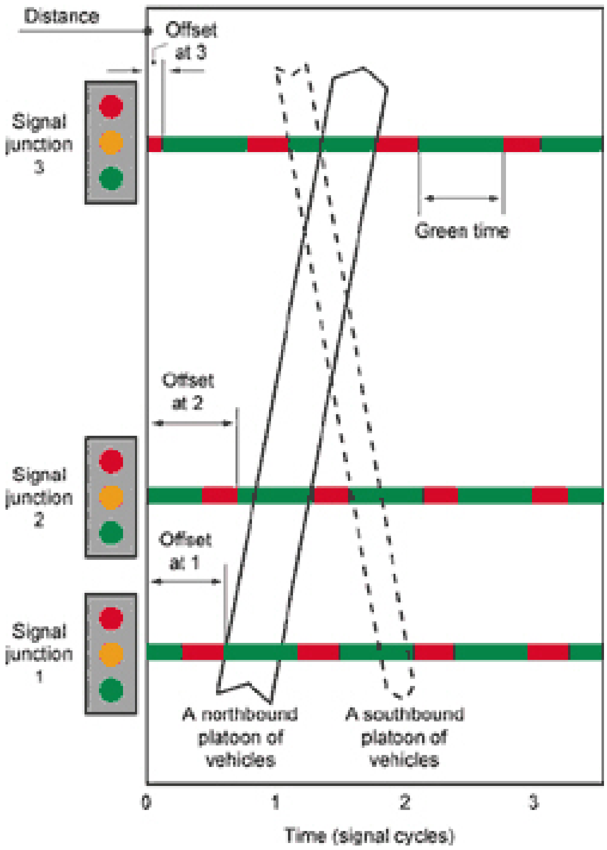
The Transport Research Laboratory (TRL) in collaboration with the UK traffic systems suppliers [1] developed the SCOOT urban traffic control system (UTC). SCOOT is now co-owned by Peek Traffic Ltd, TRL Ltd and Siemens Traffic Controls Ltd. SCOOT (**S**plit **C**ycle **O**ffset **O**ptimisation **T**echnique) is adaptive and responds automatically to traffic fluctuations. It does away with the need for signal plans that 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 170 towns and cities in the UK and overseas.

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 of the Environment, Transport and the Regions (DETR) and the SCOOT suppliers.

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.

Figure 1: An idealised time-distance diagram showing signal co-ordination with a fixed time plan



Off-line software has 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 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.

The first generation of demand responsive systems monitored traffic flows continuously and triggered the most appropriate plan from a library of predetermined plans. Second generation systems used current traffic counts to update historical data and produce new plans. However, the frequent plan-changing in these systems often caused disruption in the traffic networks, and neither method worked as well as simply changing plans by time of day.

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, which has been continuously developed to meet the needs of today's traffic managers.

The 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 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, 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 1993 a SCOOT demonstration project in Toronto [6], 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 Toronto's fixed time plans would require 30 person years of effort. In Sao Paulo [7] in 1997 a survey showed that SCOOT reduced vehicle delays by an average of 20% in one area tested and 38% in another over the existing TRANSYT fixed time plans. It was estimated that financial benefits to Sao Paulo as a result of these delay reductions would amount to approximately $1.5 million a year.


SCOOT in London

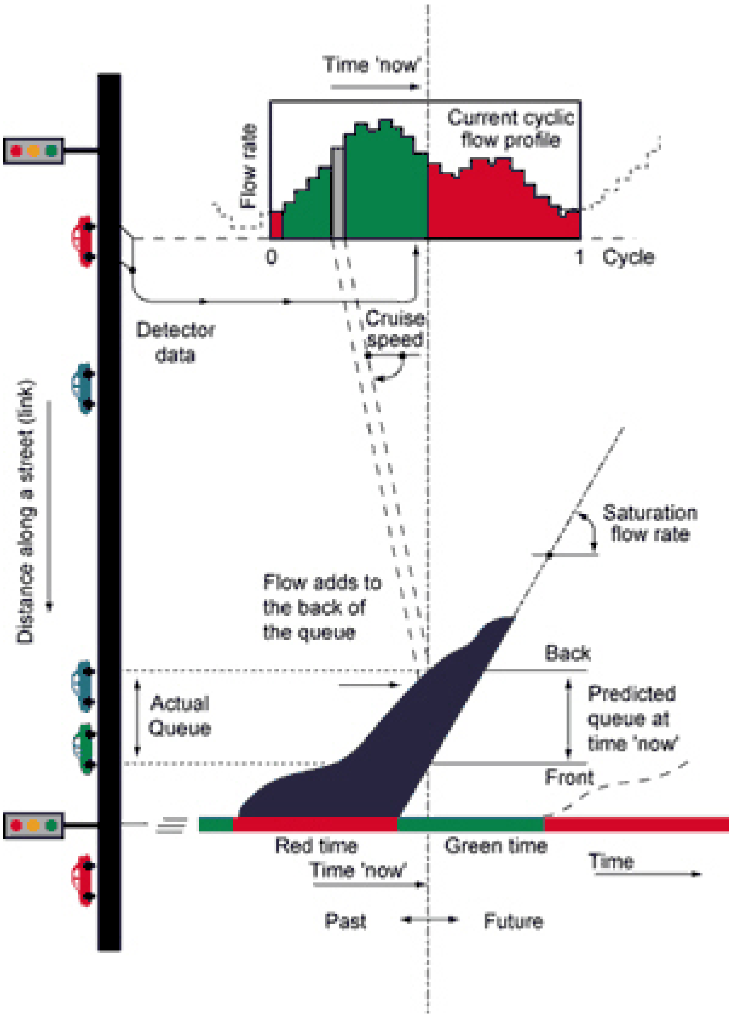
The latest versions of SCOOT include facilities to provide priority to selected vehicles such as buses. Trials in London [8] have shown additional average reductions in delay to buses of 3 to 5 seconds per bus per junction. At particular sites much larger benefits can be found. A trial at one junction in Lances Hill in Southampton has shown reductions in delay of 34 seconds per bus in the PM peak period.

How Scoot Works

The kernel software at the heart of a SCOOT system is standard to all installations [9]. 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.

Figure 2: Principles of the SCOOT traffic models



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 also available.

When a vehicle passes the detector, SCOOT converts the information into a "link profile unit" (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 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 under-saturated 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.

A typical SCOOT based UTC system

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

The SCOOT kernel software is integrated into the supplier specific UTC software that would be accommodated on a computer installed at the control centre. A number of PCs, workstations, and printers may 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 traffic engineers can access the system when away from the control room. This facility is especially useful for setting up the SCOOT system.

Fault Management and Remote Monitoring Systems would further support a typical SCOOT system. 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 sometimes used to monitor traffic on a network controlled by a UTC system

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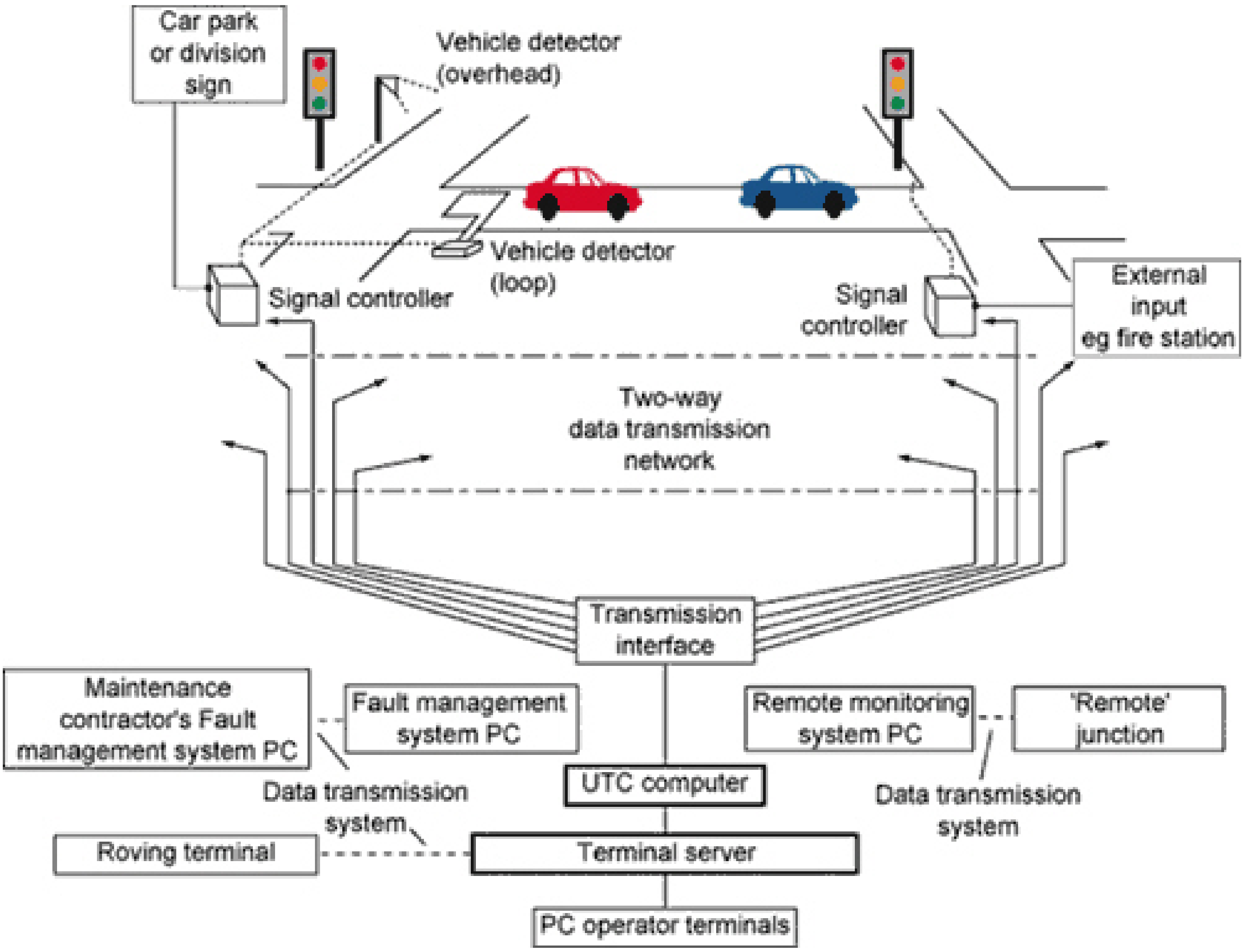
Figure 3: The flow of information in a SCOOT-based Urban Traffic Control system



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, is a significant element in the cost of SCOOT although fewer loops would be required than if all the junctions were isolated VA. 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 actual 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 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.

Linking SCOOT UTC to other systems

VMS sign

UTC 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.

VMS sign

Fleet management systems for buses: the bus priority facilities in the latest versions of SCOOT can use bus positions from the Automatic Vehicle Location (AVL) part of fleet management systems to provide priority to buses.

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 UTC 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 UTC systems can operate fixed time plans where this is required.

Where SCOOT can be used


SCOOT in operation

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 is designed to adapt to variations in traffic flow automatically and so does not need the full time attention of an operator.

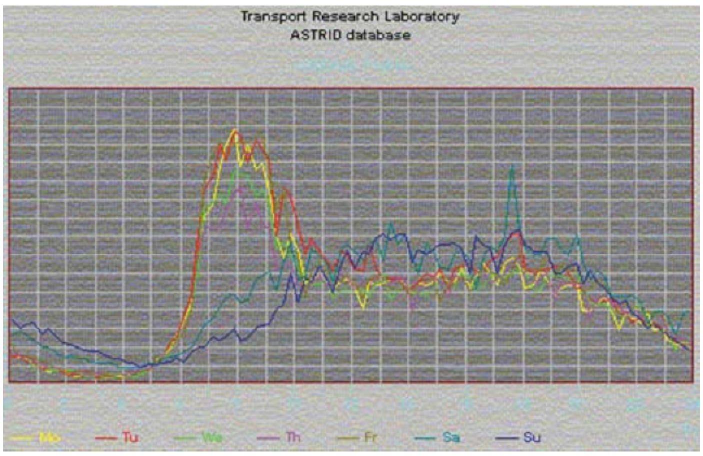
When junctions are some distance apart (more than about 1 km) isolated junction control using a system such as MOVA may be more appropriate. Other site-specific factors would also influence the decision on method of control.

Getting the best out of SCOOT

Bus priority in London

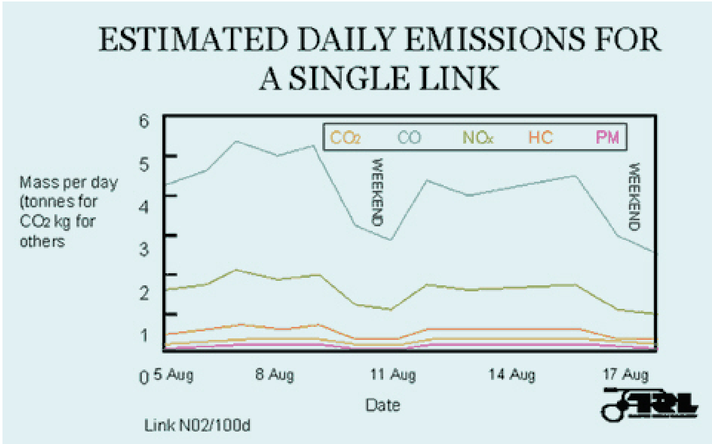
The basic philosophy and algorithms of SCOOT have been retained since its original development. However, important new features have been introduced in response to users' needs, particularly to provide more tools for the active management of traffic [10,11] .

Weightings have been introduced to enable the UTC traffic manager to favour specific links or routes where, for example, buses form a significant proportion of the traffic.



ASTRID

The "gating" facility allows traffic on specific links approaching a sensitive area to be automatically restrained once a specified threshold of saturation has been reached on the critical link. Therefore, the traffic queues are relocated from the sensitive area to links where they do not affect critical junctions, or where a bus lane can be provided to by-pass the queue. Gating has been successfully applied to prevent lock-up of the gyratory system in Kingston town centre and to give priority to buses on Bitterne Road in Southampton.



Emission estimates

Other tools, such as congestion offsets and congestion importance factors, are provided for the traffic manager to tune the response to congestion to minimise its effect in his network.

These features have been added to in the most recent versions of SCOOT.

SCOOT Version 3.1 [12] was introduced in 1996. The main new facilities provided were:

- Bus Priority: A facility has been introduced to integrate active priority to buses or other public transport vehicles. The system is designed to allow buses to be detected either by selective vehicle detectors or by an automatic vehicle location (AVL) system.
- ASTRID [13] (Automatic SCOOT TRaffic Information Database): ASTRID is a database designed to take information from SCOOT and to process and store it for later retrieval and analysis.
- INGRID (INteGRated Incident Detection): INGRID is a system operating in real time that uses information from the SCOOT detectors together with historic data from ASTRID to automatically detect incidents.
- Improved faulty detector logic: SCOOT 3.1 can use the historic data from ASTRID to replace data from faulty detectors.
- Flexible Optimiser Authorities: The amount by which the optimisers can change the signal timings has been made more flexible and can be increased at higher cycle times and under incident conditions.

SCOOT Version 4.0 [14] was released in 1997. Its new features were:

- Estimate of Vehicle Emissions: SCOOT Version 4 will provide estimates of the Carbon Monoxide (CO), Carbon Dioxide (CO_2), Oxides of Nitrogen (NO_x), particulates and Volatile Organic Compounds (VOCs) emitted by vehicles on a link node or region basis.
- Use of historic data in cycle time optimiser: The historic data provided by ASTRID can be used to provide an early warning and therefore allow a quicker response to the onset of peak periods.
- Use of existing non-SCOOT loops: SCOOT normally requires detectors at the upstream end of links. SCOOT Version 4 will be able to utilise information from loops placed at or near the stopline where these exist and SCOOT loops cannot be afforded.
- Enhancements to the cycle time optimiser.

In 1998 Version 4.2 was released with the following new features:

- Improved control of flared approaches.
- Improved recovery logic where SCOOT is overridden e.g. in situations where the controller hurry call facility is used to provide priority to an emergency vehicle or Light Rapid Transit (LRT).
- Inclusion of logic to interpolate data in order to control links where there is no detector.

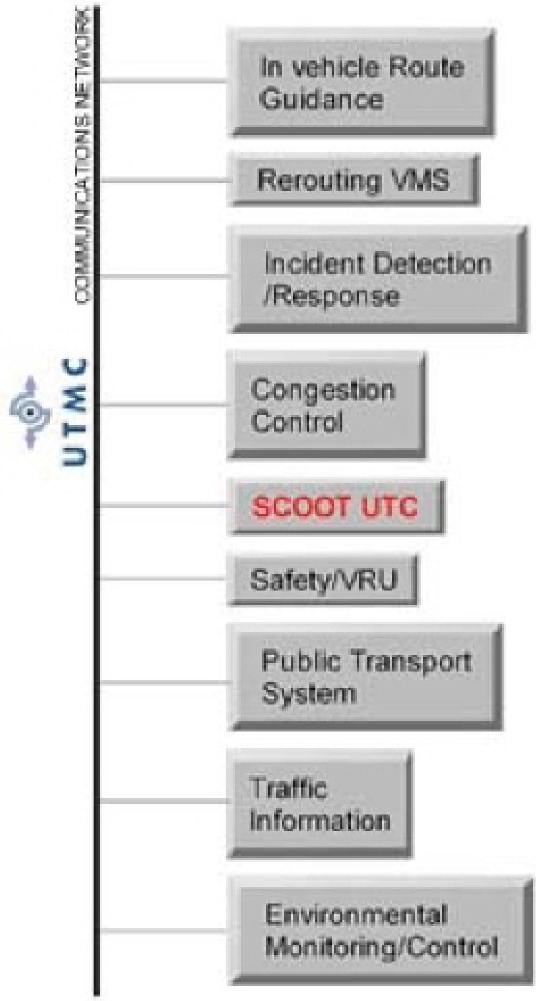
SCOOT Research and Development

The Department is funding a programme of research that will lead to further development of SCOOT. Much of this is being carried out under the European Union research programme on Advanced Transport Telematics. In addition, TRL and the traffic systems companies who supply SCOOT sponsor a programme of improvements to meet user requirements.

Enhancements to the existing incident detection system are being introduced, and additional remedial strategies for responding to incidents and high levels of congestion are being developed.

Further enhancements to the existing selective vehicle priority are being made which will broaden its range of operation.

SCOOT within UTMC



An example UTMC system

UTMC - Urban Traffic Management and Control - is the name given to the new research programme, part funded by DETR, intended to promote the development and implementation of new systems. The UTMC initiative is DETR's response to local authorities' growing needs for cost effective traffic management tools to support a wider range of policies.

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 and its ongoing developments can be integrated into UTMC systems as illustrated in the diagram. UTMC developments are taking account of existing SCOOT based UTC infrastructure and are intended to provide an evolutionary migration path so that investments made in SCOOT UTC systems are utilised to the full in UTMC.

Glossary

Cycle Time is the length of time for all traffic signal stages to run before they are repeated.

MOVA (Microprocessor Vehicle Actuation) is a modern microprocessor technology developed by TRL for isolated intersections to optimise signal timings.

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

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

TRANSYT (TRAffic Network StudY Tool) 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 (Vehicle Actuation) 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.

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