A REVIEW OF SCATS OPERATION AND DEPLOYMENT IN DUBLIN

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ABSTRACT

This paper introduces the real-time coordinated adaptive traffic system SCATS and gives an overview of its basic operation. The system takes as input detector data as a real-time measurement of traffic flow, and seeks to optimally control the flow of traffic throughout the network. Commencing with a brief introduction to the general principles underlying the SCATS architecture and operation, the remainder of the paper will analyse SCATS operation from a traffic control perspective at different levels of implementation, introduce the SCATS user interface and additional features, and explore how third-party systems can be used with SCATS. In addition, the way in which SCATS optimises junction flow and synchronises inter-junction flow will be discussed with reference to the Dublin network. Throughout the paper, specific emphasis will be placed on the adaptive aspects of the system such as self-calibration and autonomous decision-making.

INTRODUCTION

The Sydney Coordinated Adaptive Traffic System (SCATS) is an adaptive urban traffic management system that synchronises traffic signals to optimise traffic flow across a network. It operates in real-time, communicating with local traffic signal controllers every second, and automatically calculates the appropriate signal timings in response to variations in traffic demand and system capacity. Developed in the early 1970's by the Department of Main Roads (now the Roads and Maritime Services), New South Wales, Australia, SCATS has been continually refined and updated and is now recognised as one of the most advanced traffic control platforms available. It is currently used in more than 250 cities in 27 countries and is licensed to operate at more than 37,000 intersections worldwide.

Originally installed in Dublin in 1989, SCATS was selected as part of a traffic management tender to replace an older Plessey UTC system from the late 1970s. The initial project was for 32 intersections within the city centre rising to 300 by year 10 and included a link to the Plessey UTC system for alarm notification. Over the following twenty five years, the SCATS installation in Dublin has been continually upgraded and the area of operation has been expanded up to and beyond the city boundary. Currently, there are over 750 intersections connected in the Greater Dublin Area (GDA) and the SCATS network has even been extended to a number of nearby towns and cities by means of a hosting service.

The SCATS software is available in various packages with options to suit different needs and budgets. The core client software package includes the graphical user interface - *SCATS Access*; the software utility to create graphics for intersections, subsystems, and regions - *SCATS Picture*; and a tool providing direct access to data on intersection alarms and events – *SCATS Log*. In addition to these basics, there are many extra software packages available. In Dublin, we have a number of additional products including the following:

- *Traffic Reporter*
  This utility provides reports for detector volumes and traffic performance in graphical or tabular form. Actual cycle times are compared with SCATS cycle time requirements, giving the operator an understanding of how well SCATS is coordinating roads in the subsystem.

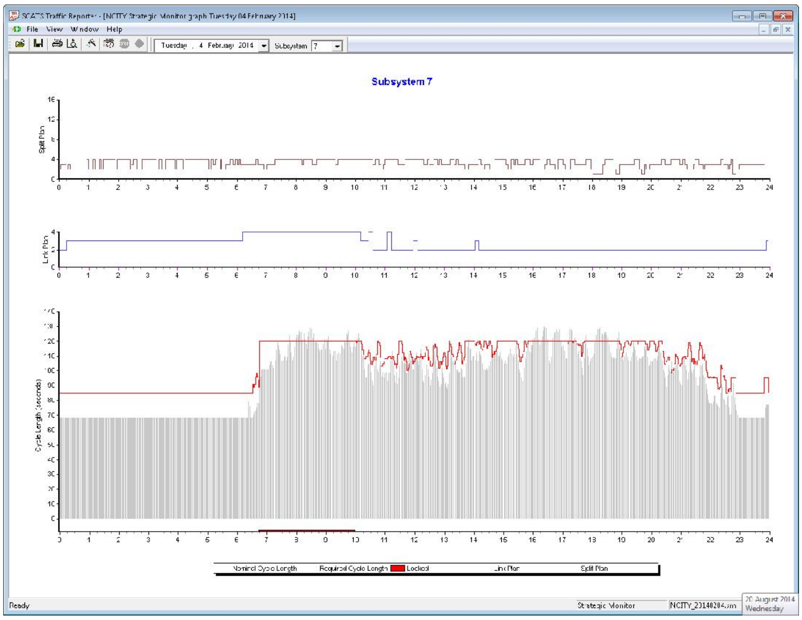


Figure 1: SCATS Traffic Reporter

- *SCATS History Reader*
  History Reader reads and displays historical data collected and saved by SCATS. It allows a user to view the phase sequence and phase time at any intersection after the event.

- *SCATS Simulator (SCATSSIM)*
  A suite of software that allows SCATS to be linked to a traffic micro-simulation. This provides an accurate simulation of a network of SCATS-controlled intersections. In Dublin, SCATSSIM is linked to a city centre Q-Paramics model which allows new junction arrangements to be tested with actual, historical SCATS data.

In addition to the software components described above, an important feature of the SCATS system that has been utilised to great effect in Dublin is the ITS port. The ITS port is a method allowing information exchange between SCATS Central Manager and an ITS Application. Using TCP/IP communication, external software systems can access data as well as interact with the SCATS system. In Dublin, this method has been used to support the operation of many systems, from a Fault Management System (FMS), to a Real-Time Journey Time System (TRIPS), and also a Bus Priority system (DPTIM). It should be noted that all of these systems are third-party software packages, designed either as commercial products or as part of a Dublin City Council tender. The TRIPS software was developed by Advantech Design. The FMS software was developed by Nicander, a software company based in the UK. The DPTIM system was also developed by Advantech Design. The design specifications for both of these systems were created by Dublin City Council.

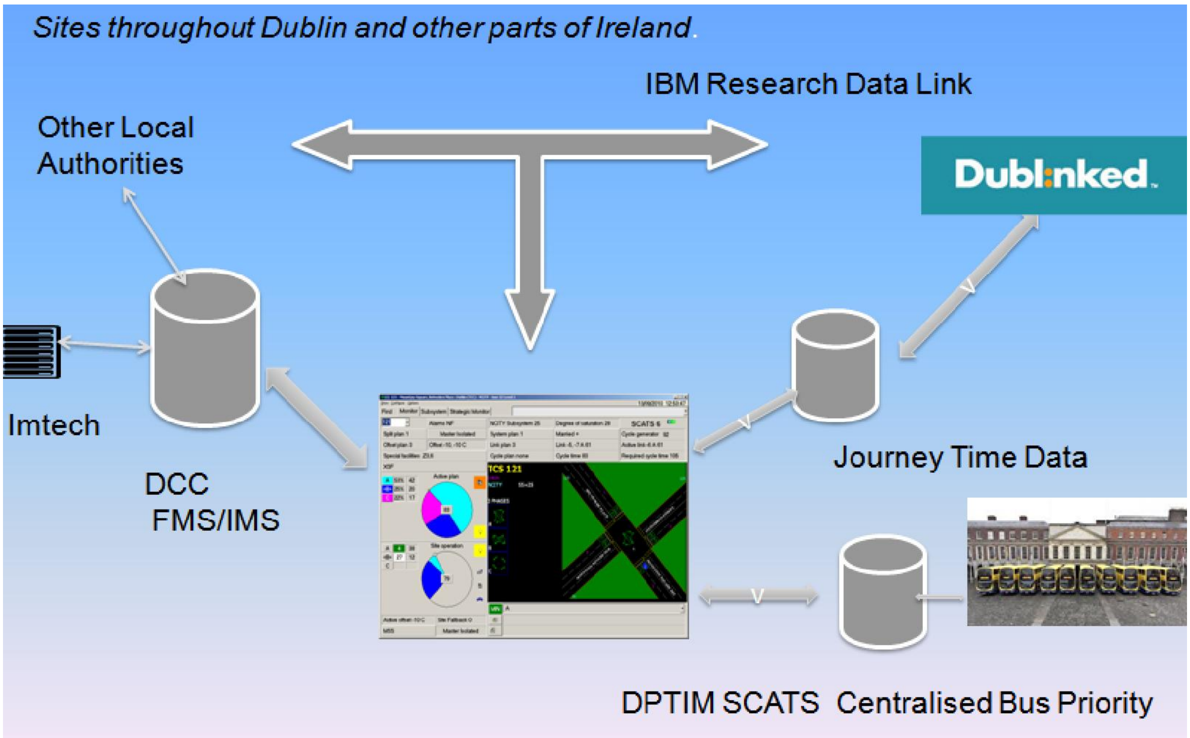


Figure 2: SCATS data used in ITS Systems and Research

Beyond the obvious roles in traffic management and supporting transport applications via the ITS port, SCATS plays an important role in Dublin as a provider of data for research and analysis. In recent years, Dublin City Council have, in association with the other Regional Local Authorities and the National University of Ireland (NUI) Maynooth, taken part in the Dublinked scheme, an initiative designed to make data more accessible to external agencies and facilitate data-driven innovation in the urban environment. This platform makes huge amounts of data available to the public, and the SCATS traffic data is part of this data stream. In addition, SCATS traffic data is central to an ongoing partnership between Dublin City Council and the IBM Smarter Cities Research Centre. IBM has made Dublin their research testbed and in exchange for access to the city's data on traffic patterns, Dublin City Council receive the benefits of expert analyses.

Another research project involving the use of SCATS data is the EU-funded INSIGHT programme. The vision of this project is to use streams of heterogeneous data as a means of detecting unusual events on the road network with a high degree of certainty. SCATS data is one of the streams of data being analysed as part of this process. Dublin city is to be the test environment for application of this new type of Incident Management System (IMS). This initiative will be reviewed in more detail later in the paper.

SCATS ARCHITECTURE & OPERATION

Designed in a modular way to promote scalability, SCATS is structured as a distributed system with junctions being divided into geographical areas, known as regions. Traffic control in each SCATS region is implemented by the Regional Computer, each one capable of controlling up to 250 intersections. It should be noted that the Regional Computers are hardware platforms only and not specifically designated to a particular region. A Central Management Computer, which serves primarily as a repository for traffic volume data, networks all the regional computers together into one system, making all junctions accessible through the SCATS user interface. Expansion of the system is achieved by installing additional regional computers. At present, Dublin has eight regions in operation.

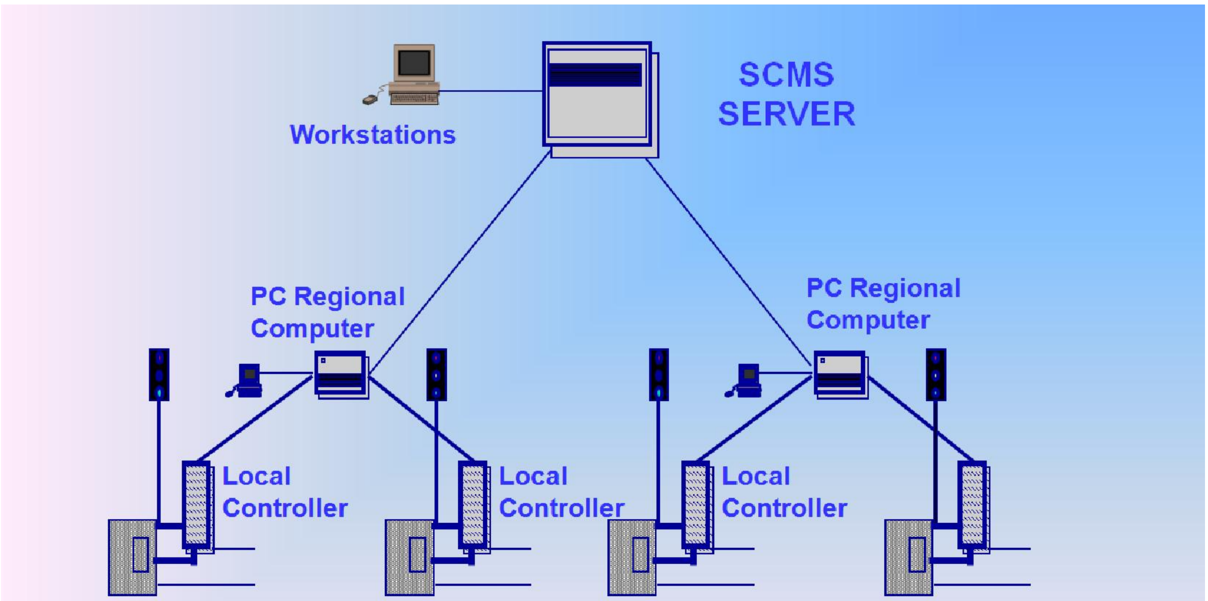


Figure 3: SCATS Central Manager

Within each SCATS region, the network is further subdivided into links and nodes. Junctions can be grouped together into nodes, referred to as subsystems, and these subsystems can then be connected by links designed to synchronise the flow between them. Links between subsystems can be specified as conditional, meaning they are invoked subject to particular traffic conditions. As such, the resulting inter-connected units can be viewed as dynamic systems in their own right.

From a traffic management point of view, the control functions implemented by SCATS can be divided into three categories (see figure 4):

Intersection	*those functions which mainly affect local operation such as VA parameters and safety clearances (Tactical Control)*
Subsystems	*traffic entities where the cycle time, splits and offsets for small groups of intersections are constantly monitored and adjusted (Strategic Control)*
Systems	*groups of subsystems which may be linked according to traffic conditions to provide progression along a road*

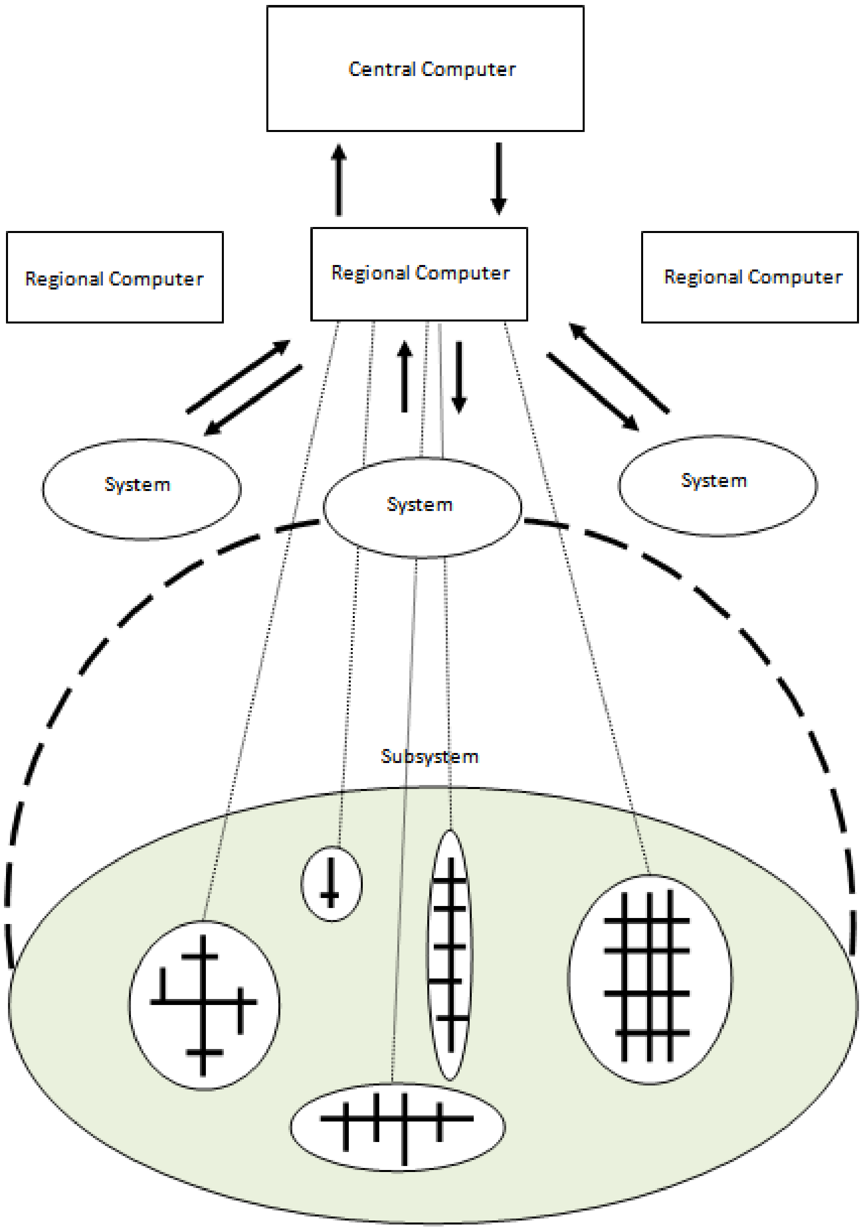


Figure 4: Hierarchy of traffic control in SCATS

In terms of operation, SCATS is known for its effective use of feedback control, achieved through a process of continuous and autonomous measurement and self-calibration. In order to balance local site optimisation with inter-site coordination, SCATS has a hierarchical structure, featuring two distinct levels or layers of control: strategic and tactical. At the tactical level, control is undertaken by the local controller, allowing green phases to be terminated early and omitting phases for which there is no demand. Decisions are made based on information from vehicle detectors at the junction. At the strategic level, the regional computers use flow and occupancy data collected from vehicle detectors to give coordination between groups of junctions. Optimum cycle length, phase splits, and offsets are determined on an area basis, and not just for one junction. Strategic control adjustments are based on a traffic demand measurement known as 'Degree of Saturation' (DS), a value representing how effectively the road is being used.

SCATS DEPLOYMENT IN DUBLIN

The following sections will provide a brief overview of how SCATS operates in general and also how it is used in Dublin. The hierarchy of operation outlined in the previous section – intersection, subsystem, system – is a useful approach to understanding SCATS control and will structure the following sections of the paper.

INTERSECTION OPERATION

At the tactical level of control, SCATS functions as a junction optimiser. The local controller undertakes the management of traffic flow, changing signals in response to demand, terminating phases early if traffic is light and implementing safety timings such as pedestrian clearances and inter-greens. Decisions are based on information from vehicle detectors at the intersection. The preferred primary location for SCATS detectors is at the stop line in each lane; in Dublin, detection is mainly carried out by "figure of eight" loops, typically 4.5m long and set back from the stop line about 1.5m – 2m. However, video detection, radar, traffic-cams and thermi-cams are also used at many sites. The data collected by the detectors is used by the local controller and also sent back to the regional computer.

In terms of traffic controllers, there are many different types that can operate under SCATS. From the old Phillips PTFs to the American Eagle controllers and, in Poland, Siemens 800s via a SOTU (SCATS Outstation Transmission Unit) interface. However, it is important to draw a distinction between being approved to connect to a SCATS system and being a type-approved SCATS controller. A requirement of a type-approved controllers is that they must be compatible not only with SCATS but with each other. All the traffic controllers used in Dublin are type-approved so, although supplied by four different manufacturers, the modules and programs for all traffic controllers are completely inter-changeable. The most common is the Phillips/Tyco controller PSC Mk1 and 2 and the Eclipse controllers. Each traffic controller is connected to its regional computer via a communications network. In Dublin, this connection is achieved using a range of methods including telecom leased lines, our own fibre and copper network, and IP over GPRS using a dedicated APN.

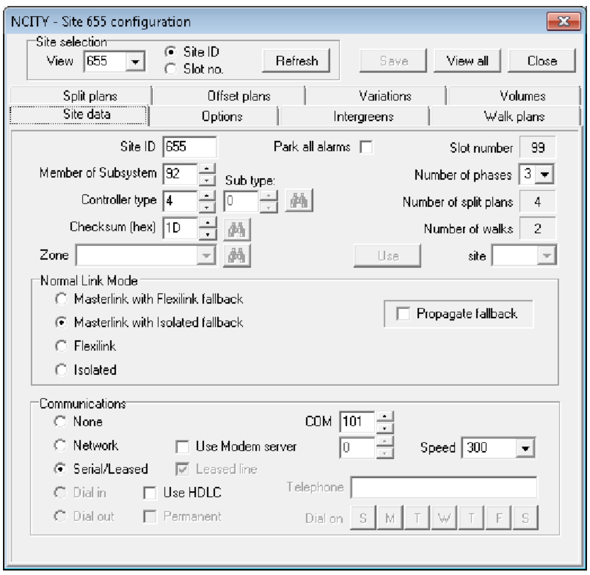


Figure 5: SCATS Site Configuration

Figure 5 shows some of the data required in order to connect a new intersection to SCATS. In order to communicate with the local controller, SCATS must know the physical location of the communications processor in the computer. This is called the slot number.

The operator must also specify the intersection number, the number of the subsystem to which the intersection belongs, the local controller type and the checksum. A checksum is the sum of all numbers in the controller's memory and should correspond with the number stored in the SCATS regional computer.

This comparison guards against errors due to faulty or incorrect memory in the controller or cross-connection of communication links.

Once configured correctly and connected to the network, SCATS is now operational. There are five main modes of operation as shown below. In Dublin, traffic signals are generally set to run in Masterlink with a fallback mode of either Isolated or Flexilink mode, used if communications fail.

1. **Masterlink** – SCATS master provides the timings to the site and a site must request to terminate a phase. All timings except safety timings are set by the SCATS master. This is the standard network operation mode. The SCATS system processes the data from each site and uses its algorithms to set phase splits, cycle time and linking.

2. **Master-Isolated** – In this mode all the SCATS algorithms for junction optimisation are used and the junction is under full SCATS master control. However, there is no requirement to keep coordination and the pivot phase (a prioritised main road phase) can gap and the cycle length is not fixed in a cycle.

3. **Fixed Time Plans** – FTPs can be defined via the Time of day scheduler (Action Lists) and will allow split linking and cycle length to be set, no adaptive operation is allowed. Normally is used where sites have no detection i.e. just being commissioned or where the detection is faulty.

4. **Isolated** - The junction operates on its junction timings i.e. its min/maxes and is monitored with the information displayed by SCATS to an operator but it is not operating under SCATS master control.

5. **Flexilink** - This is the cable-less linking means of operating a site. While the plans and schedules are initially programmed in the controller, these plans and schedules can be altered and set up as required by a SCATS operator.

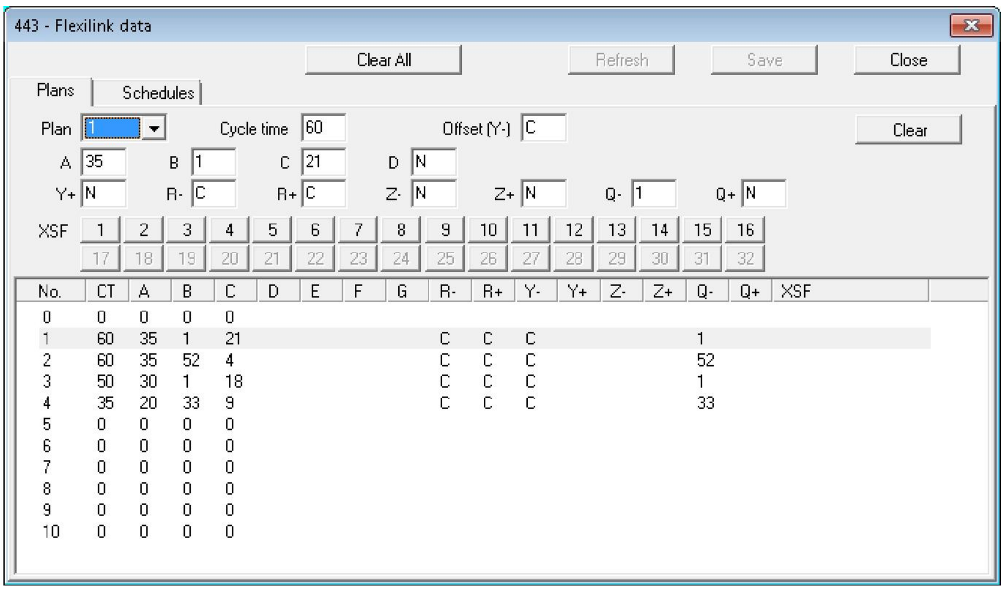


Figure 6: Flexilink Data

Strategic control at an intersection is managed by the regional computer. In contrast with tactical control, decisions at the strategic level are based on Degree of Saturation (DS). Although a familiar term in traffic flow theory, this DS is actually a SCATS-derived figure, representing how effectively the road is being used. An important feature of SCATS is that it uses the number of spaces and the total space-time between vehicles to determine DS rather than the volumes and occupancy. At each detector, the space between vehicles (recorded in terms of time and referred to as space-time) is monitored. As data is collected, the max-flow per detector is determined and the average space-time at which this max-flow occurred is also recorded. SCATS uses this max-flow value to compare data from each cycle per lane and determine if the roadway is being used as efficiently as possible a and if a lane in an approach is over or under-saturated. The calculation of the max-flow value is an example of self-calibration in SCATS. On setup of the site, no initial values need to be entered; SCATS begins monitoring the detector actuations immediately and quickly determines a value for the max-flow. This value is continually monitored and updated if a new max-flow is recorded. The system will also flag an alarm if the highest flow value on a day does not come within a defined percentage of the max-flow figure.

The formula for DS is shown below:

$$DS = \frac{g - (T - t.n)}{g}$$

where n = number of vehicles, T = total phase space-time, t = optimum space-time, and g= green-time. The value of n is calculated by counting the number of spaces, rather than the number of vehicles, and adding one. Also, the optimum space-time, t, is calculated as the average space-time measured at max-flow.

The formula above works as follows: the space-time for the previous cycle is being compared to the cycle at max-flow to determine if it is under or over-saturated. This is achieved by taking the average space-time at max-flow (t) and multiplying it by the number of vehicles (n), to give a value of T for the measured cycle as if it was at max-flow; this is then compared to the actual T recorded for the measured cycle.

1. If $T = (t.n)$, then DS = 100% i.e. Optimum
2. If $T > (t.n)$, then DS < 100% i.e. Under-saturated
3. If $T < (t.n)$, then DS > 100% i.e. Over-saturated

DS calculations form the basis for strategic control. Volume and Space-Time data are collected at each site by Strategic Inputs (SI) with a separate SI being used for each movement. This information can then be used by a Strategic Approach (SA) which determines how SCATS will use the data that has been collected. The objective of the SCATS algorithm for degree of saturation is to achieve an equilibrium point between the competing approaches, known in SCATS jargon as EQUISAT.

SUBSYSTEM OPERATION

A SCATS subsystem comprises at least one main junction (known as the critical junction) and may also contain adjacent minor junctions or pedestrian crossings. Every junction in a subsystem will share a common cycle time and operate the same split plan number. It is at the subsystem level that Strategic Control is implemented through the use of Strategic Inputs (SI) and Strategic Approaches (SA). Strategic Inputs gather the detector DS data and the Strategic Approaches vote for changes to cycle time and split plans. Strategic Approaches can be used to represent a particular traffic movement so that, at an intersection, most phases will have an associated Strategic Approach which votes for a more favourable phase split and/or an increase in the cycle time.

As can be seen from figure 7 below, SI 38 is a Strategic Input for site 55 and it records detector actuations on detectors 1 and 2. The DS values calculated for both lanes are displayed on the left as 71% and 65% respectively. A Strategic Approach (SA38) for site 55, shown on the right, takes the highest DS value from the SI data and uses it, possibly along with data from other Strategic Inputs, to vote for Split Plan and Cycle Time changes that would benefit the approach.

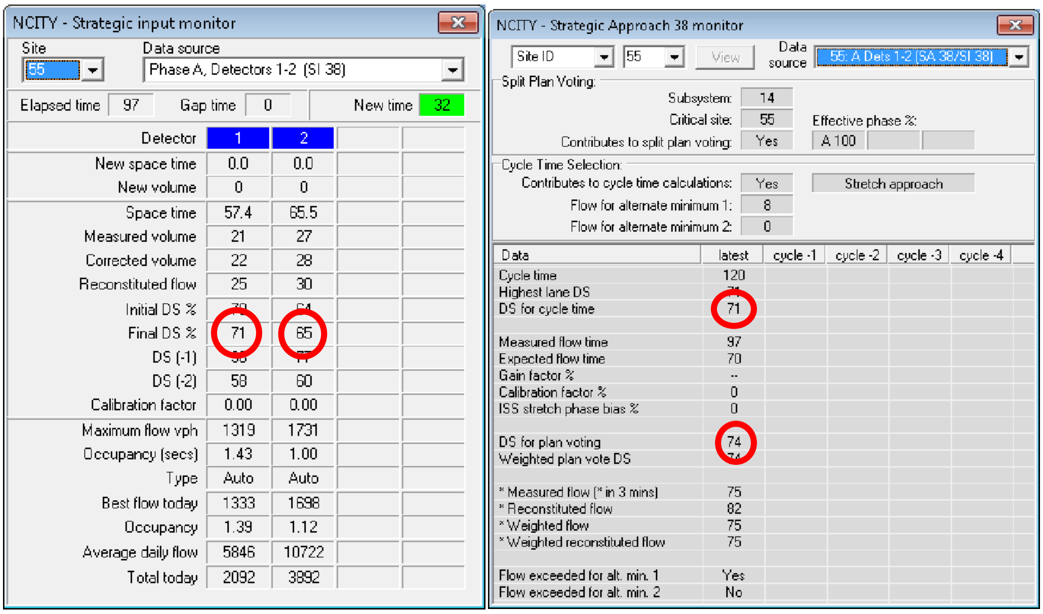


Figure 7: Strategic Inputs & Strategic Approaches

As can be seen from the figure above, the DS value taken from SI 38 for Cycle Time voting is the higher of the two, 71%. However, the DS value taken for Split Plan voting is 74%. The reason for this is that, in general, only main road approaches are permitted to vote for increases in Cycle Time. In this case, the DS value of 74% comes from a side-road and is included in the voting for Split Plan changes but not for Cycle Time voting. A Calibration Factor value can also be added to manually modify the DS values obtained at the detectors.

Strategic Control involves the optimisation of the following parameters for each subsystem:

- Cycle time
- Split Plans
- Offset Plans

Cycle Time

The control of the Cycle Time of a subsystem is based both on volume and Degree of Saturation. User-defined minimum and maximum values are specified for each subsystem. Usually, the minimum is set at 40 seconds and the maximum at 120 seconds. In addition, a user-defined Stretch cycle time is specified. In SCATS, a Stretch (or Pivot) phase is nominated at each intersection; the main feature of this phase is that it receives all spare time from other phases when the cycle time is above the Stretch Threshold. For example, for a subsystem with Maximum Cycle Time of 120 seconds and a Stretch Cycle Time of 100 seconds, any increase in Cycle Time above 100 seconds will be given directly to the Stretch phase. This is known in SCATS jargon as *the Stretch Effect.*

At low volumes, the subsystem will run the minimum Cycle Time until a user-specified volume threshold is reached. At this point, the subsystem will jump directly to an Alt Min cycle time (two Alt Min cycle times may be specified).

In Dublin, the volume threshold for elevation to the Alt Min Cycle Time is generally 8 vehicles per cycle. Beyond this, the Cycle Time of a subsystem is determined by the highest value of the Degree of Saturation of all Strategic Approaches in the subsystem; although, only certain Strategic Approaches are permitted to vote for Cycle Time. In Dublin, only main-road Strategic Approaches are given this facility.

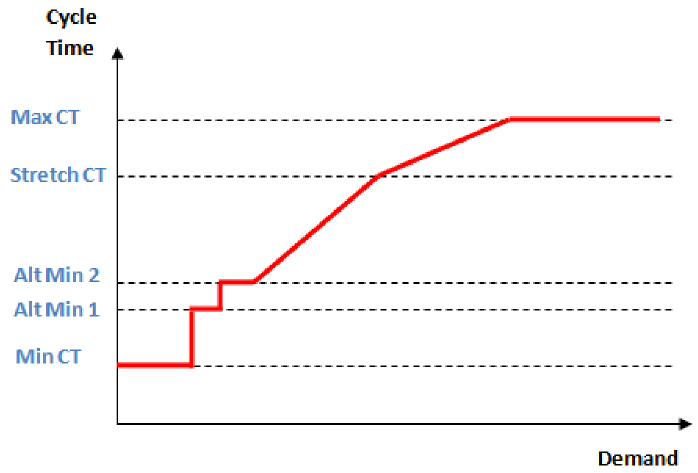


Figure 8: Cycle Time Reference Values

The relationship between DS and Cycle Time is based on two user-specified cycle time calibration factors; these values, the required DS for Stretch Cycle Time and the required DS for Maximum Cycle Time, are provided to control the sensitivity of the cycle time to changes in the DS value. The Stretch Cycle Time will be reached if the DS is not less than the user-specified value. The subsystem will use the votes of all Strategic Approaches permitted to vote for Cycle Time. However, only Stretch Phase Strategic Approaches can elevate the Cycle Time beyond the Stretch Cycle Time threshold. In the figure to the left, only a DS value of 92% on a Stretch Phase Strategic Approach will elevate the Cycle Time to 120 seconds.

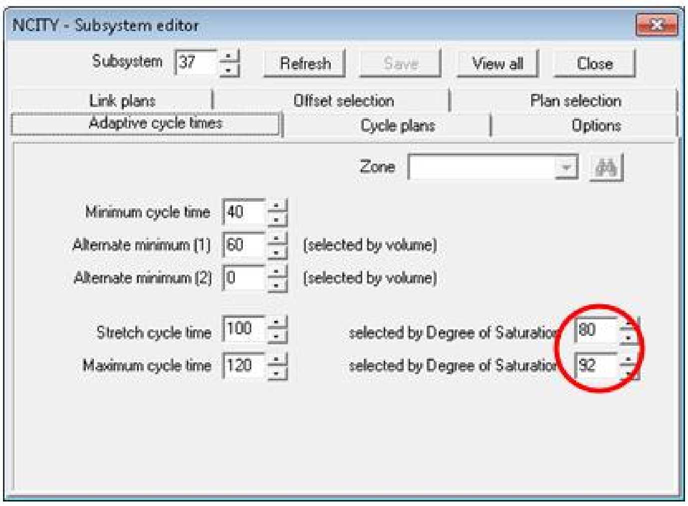
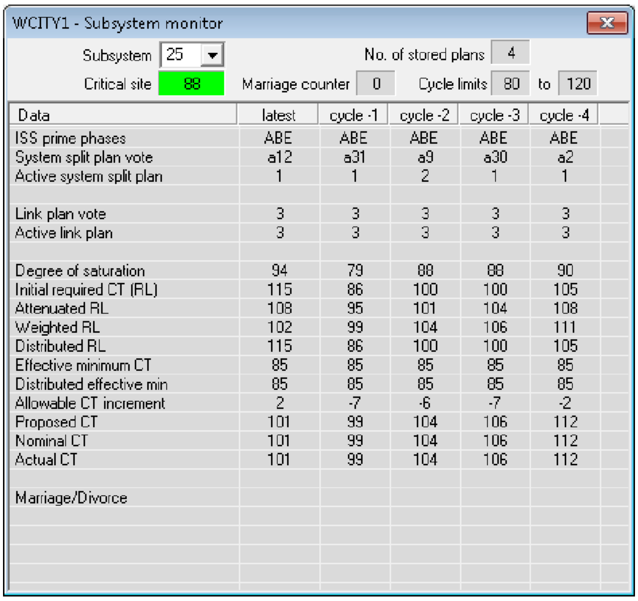


Figure 9: Subsystem sensitivity to changes in DS

For DS values between the two user-defined thresholds, the Cycle Time is an interpolated calculation of the Stretch Cycle Time and the Maximum Cycle Time. The figure below is taken from a subsystem that has a Stretch Cycle Time of 100 seconds for a DS of 88% and a Maximum Cycle Time of 120 seconds for a DS of 96%. As can be seen from the column on the right (occurring 4 cycles previous), a DS of 90% generates a Required Cycle Length (RL) of 105 seconds. Further SCATS calculations, based on previous intersection demand, produce the proposed Cycle Time of 112 seconds, two seconds less than the Cycle Time of the previous cycle.

The figure also shows that for two cycles the DS was 88%. This relates to the occasions when a side-road SA was high but the main-road (Stretch Phase) Strategic Approaches were low. Thus, the highest possible Cycle Time available to the side-roads was selected, matching with a DS of 88%.



Data	latest	cycle -1	cycle -2	cycle -3	cycle -4
ISS prime phases	ABE	ABE	ABE	ABE	ABE
System split plan vote	a12	a31	a9	a30	a2
Active system split plan	1	1	2	1	1
Link plan vote	3	3	3	3	3
Active link plan	3	3	3	3	3
Degree of saturation	94	79	88	88	90
Initial required CT (RL)	115	86	100	100	105
Attenuated RL	108	95	101	104	108
Weighted RL	102	99	104	106	111
Distributed RL	115	86	100	100	105
Effective minimum CT	85	85	85	85	85
Distributed effective min	85	85	85	85	85
Allowable CT increment	2	-7	-6	-7	-2
Proposed CT	101	99	104	106	112
Nominal CT	101	99	104	106	112
Actual CT	101	99	104	106	112
Marriage/Divorce					

Figure 10: Subsystem Monitor View

In order to weight the DS values of a particular Strategic Input, SCATS provides the option of a Calibration Factor. This user-defined variable can by assigned to any Strategic Input and will give the specified weighting to votes for changes to Cycle Time or Split Plan. The weighting can have a positive or negative impact; values less than 100 reduce the DS value and, likewise, values greater than 100 increase the DS value. The range is from 0 to 255. For example, a value of 80 will reduce the DS value to 80% of its actual value.

Split Plans

SCATS can select the best set of splits for each subsystem by using one of two different methods:

- Discrete Split Selection (DSS)
- Incremental Split Selection (ISS)

In DSS operation, SCATS automatically selects, cycle-by-cycle, the most appropriate plan for the prevailing traffic conditions from a table of pre-entered plans. The selection process is performed by Strategic Approach voting. Each Strategic Approach identifies which phases are of use to its traffic movements and can vote for a plan which gives more time to that particular phase. As can be seen below, SA38 is permitted to vote for a split plan change and it specifies that A phase is 100% useful to it.

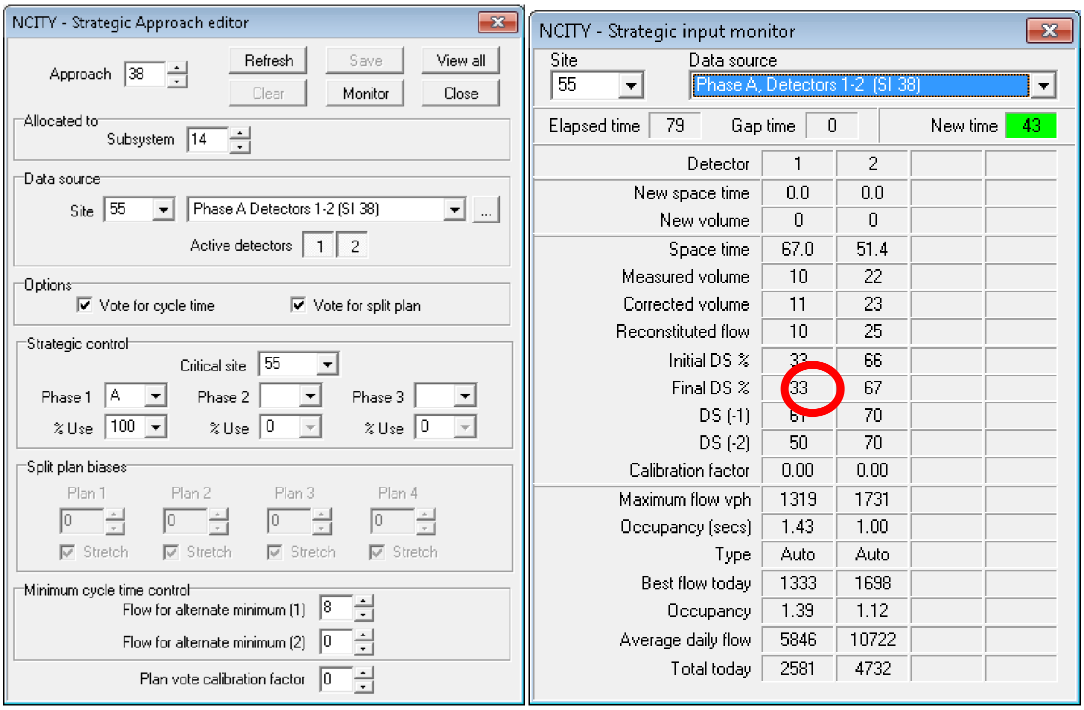


Figure 11: Strategic Approach Voting

SCATS uses this information, together with the degree of saturation on the busiest lane of the approach, to predict how a split plan change would affect the traffic flow. In the figure above, we can see that SA 38 uses data from SI 38, which consists of detectors 1 and 2. The busiest lane between the two is detector 2 with a degree of saturation of 67%. If phase A is currently given 50% of the time under Split Plan 1, the predicted degree of saturation for phase A under Split Plan 2 which gives 55% of the time would be:

Projected DS = 67 * 50/55 = 61%

So, in this case, selecting Split Plan 2 would result in a lower DS for SA 38. This procedure is carried out by SCATS for each Strategic Approach and the Split Plan chosen is the one which gives the lowest maximum Degree of Saturation.

Incremental Split Selection (ISS) operates in a similar way to the discrete method outlined above, except that selection is not made from pre-entered plans. Instead, the phase splits are incremented and decremented by small amounts each cycle in order to find the lowest Degree of Saturation possible for the busiest lane. SCATS has stored in its software tables of possible split variations for 2, 3, & 4 incremental phase junctions. A two phase incremental table is shown below:

Change Type	0	1	2	3	4	5	6
Phase A	0	+1	-1	+2	-2	+3	-3
Phase B	0	-1	+1	-2	+2	-3	+3

If we assume that the current phase splits are A = 56% and B = 44%, then in the next cycle the available choice of splits will be:

Change Type	0	1	2	3	4	5	6
Phase A	56	57	55	58	54	59	52
Phase B	44	43	45	42	46	41	47

The decision on which split to select is made by comparing the respective DS values that each prospective split timing would produce. Assuming that the A phase currently has a DS of 82% and B phase has a DS of 70%, the predicted DS values associated with each of the splits above can be calculated as shown:

Change Type	0	1	2	3	4	5	6
Phase A	82	81	83	79	85	**78**	87
Phase B	70	72	68	73	67	**75**	66

Change Type 5 produces the most 'EQUISAT' result and these split values are adopted for the next cycle. Phase A is increased by 3% and Phase B is decreased by 3%. ISS can incrementally control as many as four phases on the critical intersection of a SCATS subsystem.

Offsets

Coordination between the junctions within a subsystem is achieved by specifying a time offset between junctions. The time offset between two junctions in a subsystem can be specified in four different plans. The offset is a positive or negative value with reference to a phase of the critical junction in the subsystem; if there is only one junction in the subsystem the offset references itself. Offsets are specified for both low and high Cycle Times. The Cycle Times at which a low or a high offset should be used are manually entered by the operator. For Cycle Times in between these values, SCATS interpolates the offset, meaning that SCATS automatically calculates the appropriate offset based on a proportion of the threshold values.

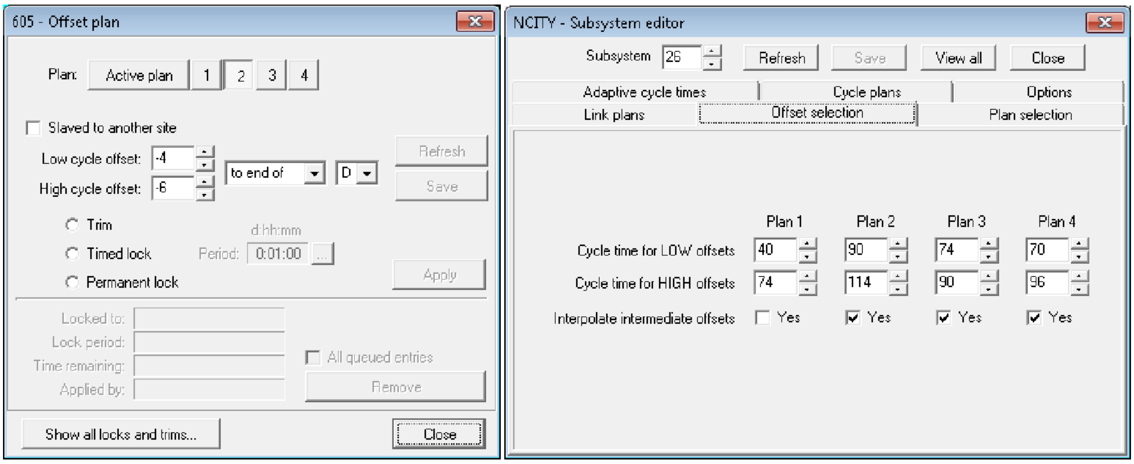


Figure 12: Offsets within a Subsystem

For example, using the data above for site 605, the values for Offset Plan 2 are -4 and -6 seconds. The 4 second value is used when the cycle time is 90 seconds and the 6 second offset is used when the cycle time is 114 seconds. Both of the junctions are in subsystem 26. Junction 179 is the critical intersection. As the cycle time is 120 seconds, the high cycle offset value will be used. The starting position of the cycle generator for junction 605 will begin its count 6 seconds before the end of phase D of junction 179, the critical intersection. As can be seen in the figure below, the end of phase D of site 605 corresponds with a position exactly 6 seconds before the end of phase D in junction 179.

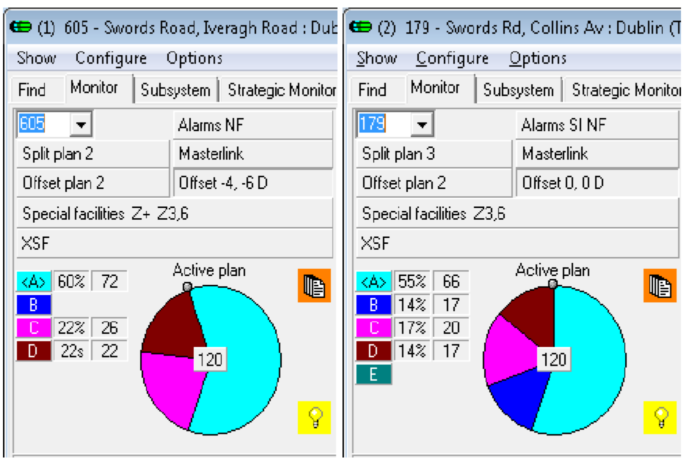


Figure 13: Active Offsets in a Subsystem

SYSTEM OPERATION

As explained in the previous section, within a subsystem, all junctions operate at the same cycle time and will have offset values designed to provide synchronisation between the junctions at all times of day. At the System Level, coordination between subsystems is achieved through the use of links. A link is the time-based relationship between two junctions in two different subsystems - basically an external offset. In SCATS jargon, a link is sometimes called a marriage. A marriage can only occur between two subsystems, as junctions within a subsystem are not regarded as being married since they are tied to each other permanently by definition.

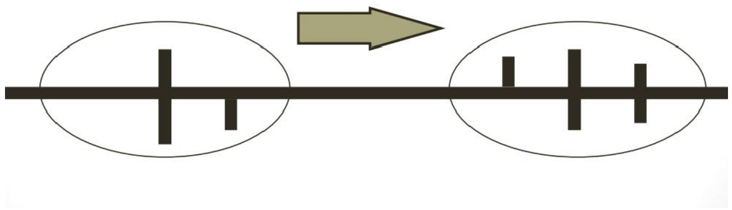


Figure 14: Linking in SCATS

Links can be specified to be permanent connections between two subsystems or they can be conditional, invoked only under certain traffic conditions. Each cycle, SCATS checks the conditions for the link and, if the conditions are met, the subsystem marries. Likewise, when conditions are not met, the linkage is disconnected and the two subsystems divorce. Subsystems can have links to more than one subsystem, and can marry and divorce at different times according to the traffic conditions. As such, Systems in SCATS are dynamic, characterised by casual membership and a constant change of connections between subsystems.

All subsystems within a married group (the System) will operate at the same cycle time. By convention, a subsystem is only considered to be married if it is married to another subsystem; being the target of a marriage does not constitute marriage in SCATS. Consequently, in any group of married subsystems, there will be one (and only one) subsystem that is not married to any other subsystem in the marriage chain. This subsystem is referred to as the 'master' subsystem, and it is usually geographically in the middle of the marriage chain of subsystems.

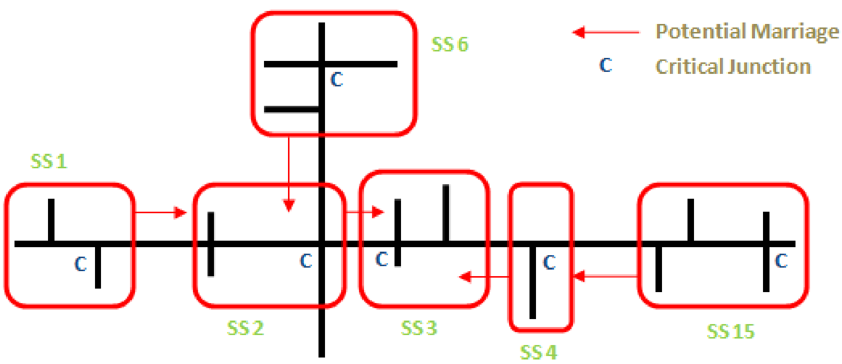


Figure 15: A marriage chain in SCATS

The conditions under which a subsystem will marry are described by the link itself. A subsystem will vote to marry another subsystem if:

- There exists valid link (external offset) data to another junction in another subsystem AND
- A permanent or forced marriage is specified, or
- The volume of traffic travelling over specified detectors is greater than an operator-entered threshold
- The respective cycle lengths of the two subsystems are within +/- 10 seconds.

As can be seen below, there are a number of different types of linking control available. Links can be based on cycle time, volume, or can be permanent. Usually, links are specified for main roads only, one for AM peak flow (inbound) and one for PM peak flow (outbound).

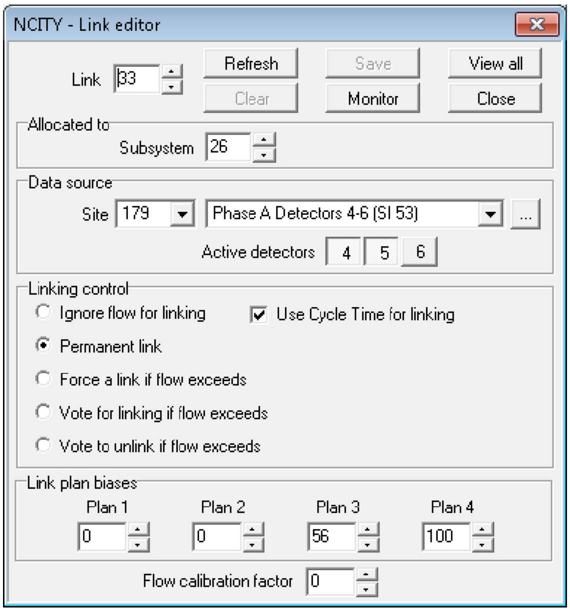


Figure 16: Links and Link Plans

Once a link is established between two subsystems (either forced or voted), suitable offset values need to be selected. Link Plans containing manually-entered offset values, chosen to meet flow requirements throughout the day, are voted for by the links. There are four Link Plans available and in Dublin the convention is as follows:

- Link Plan 1 - Light/Night time traffic flow (low cycle time)
- Link Plan 2 - PM peak
- Link Plan 3 - Balanced flow between both directions
- Link Plan 4 - AM peak

A Link Plan is selected by comparing the product of volumes and Link Biases for each link. Link Plan Biases are user-entered values which indicate the degree of preference a link has for a particular Link Plan. So an inbound Link will have a low preference for Link Plan 2 as it favours the outbound flow.

For example, consider the junction in the figure below with links for the outbound direction (north) and a link for the inbound direction (south).

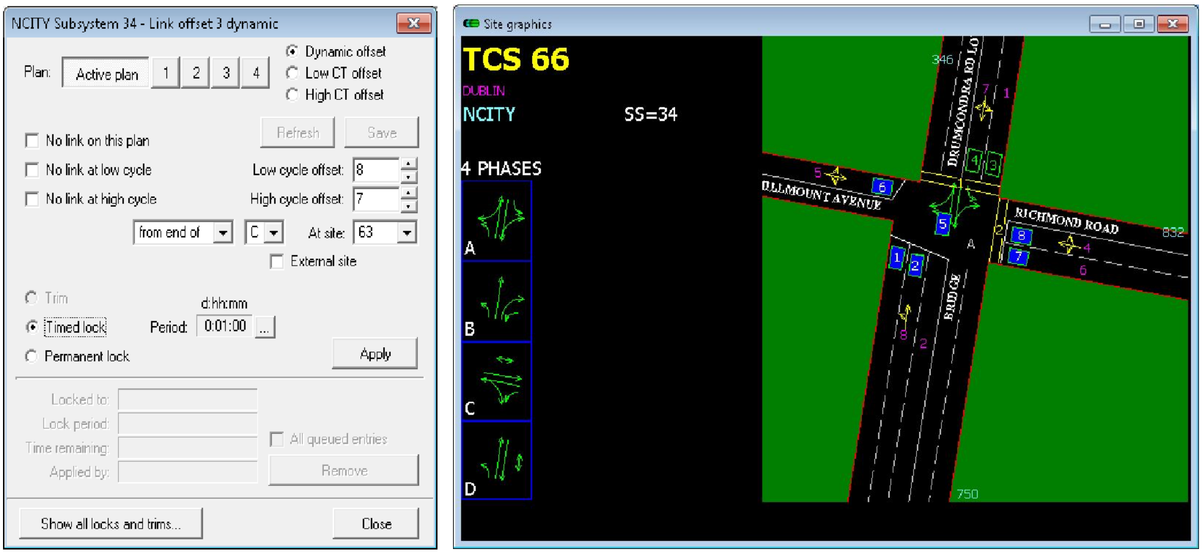


Figure 17: Link Plan Offset Values

The data source for the links is the Strategic Input (SI 86), associated with the subsystem for both the inbound and outbound directions. The inbound link uses detectors 3/4 of SI 86 while the outbound link uses detectors 1/2. Traffic volume counts from the detectors are multiplied by the 'degree of preference' that each link has for the particular Link Plans. From the sample values in the table below, we can see that 1250 vph were recorded by detectors 3/4 while only 810 vph were recorded by detectors 1/2. The result is that Link Plan 4 is selected. This plan will have offset values that provide linking for the inbound direction.

	LP1	LP2	LP3	LP4
SI86 biases (Dets 3/4)	0	0	56	100
Votes (1250 vph)	0	0*1250 = 0	56*1250 = 70000	100*1250 = 125000
SI86 biases (Dets 1/2)	0	100	56	0
Votes (810 vph)	0	100*810 = 81000	56*810 = 45360	0*810 = 0
TOTAL VOTES	**0**	**81000**	**115360**	**125000**

Figure 18: Link Plan Voting

For each Link Plan, two offset values are specified, one for High Cycle Time and one for Low Cycle Time. As explained in the previous section on offsets, SCATS will select the appropriate offset based on the Cycle Time thresholds entered. If the cycle time is between the two thresholds, SCATS will automatically calculate the correct offset by interpolating between the two offset values.

SCATS USER INTERFACE

SCATS provides a colourful and informative User-Interface as shown in the figure below. As can be seen, a full understanding of the junction operation, including subsystem information and link status, can be gained from this one screen. For example, we can see that the intersection number is 64, the subsystem number is 26, and the Region is NCITY. The operating mode is Masterlink, the degree of saturation is 101, the cycle time is 120 seconds, and the cycle generator is at point 0 of its revolution. The junction is running Split Plan 3, Offset Plan 3, and there are no active links.

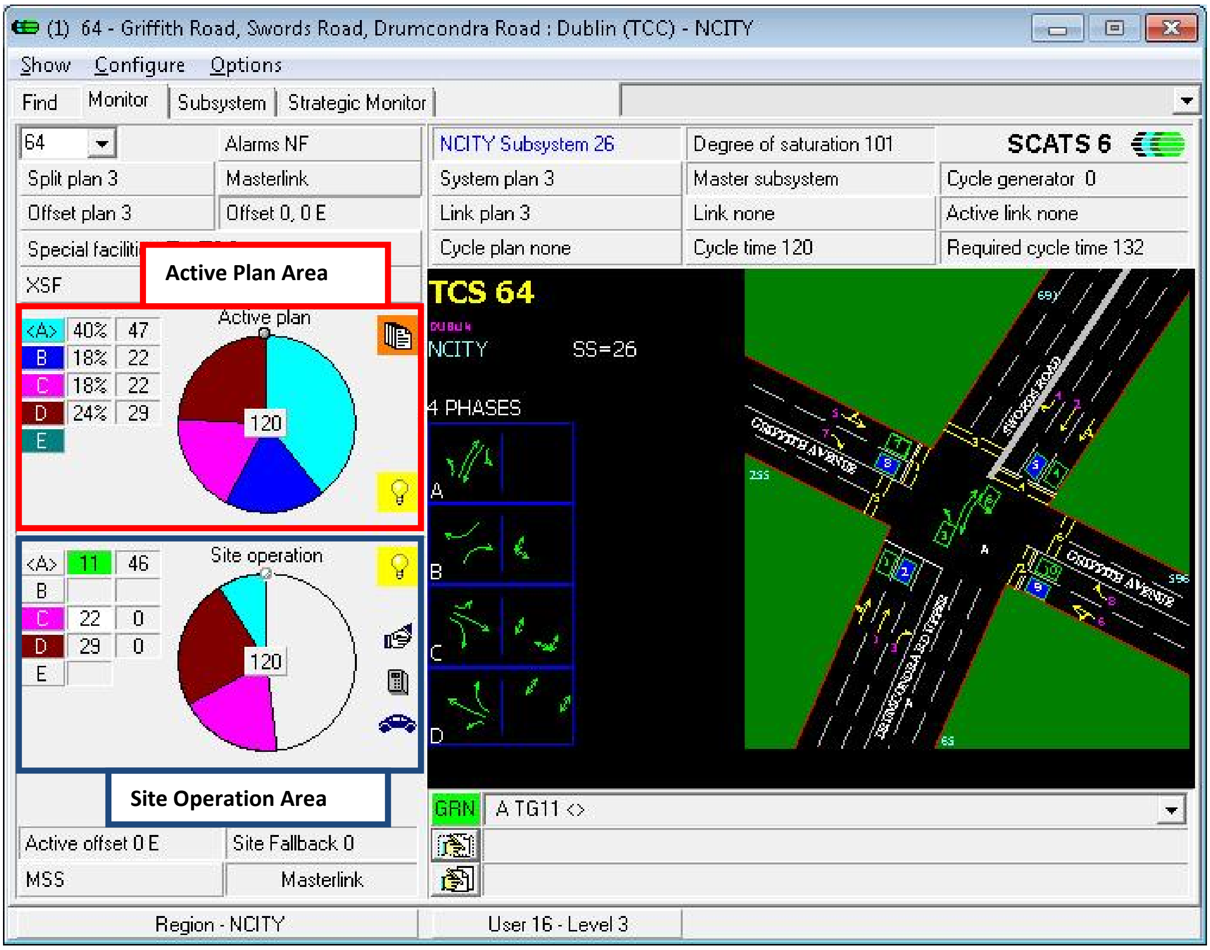


Figure 19: SCATS Access User Interface

The graphical components of the SCATS Access screen show the junction layout on the right and two views of the cycle generator on the left. The top view is the Active Plan Area – this displays the split plan timings that have been selected; the lower view is the Site Operation Area – this displays the actual real-time phase splits. Tactical control at the junction will terminate phases early in light traffic or omit un-demanded phases altogether.

ADDITIONAL FEATURES & SYSTEMS

In the previous sections of this paper, an overview of the basic operations and algorithms in SCATS was presented. Of course, there are many more operational features available and in an actual setup, all possible tools are utilised in order to optimise traffic flow in a network. This is the case in Dublin. In addition to the tools already discussed, other SCATS features such as Variation Routines, and Action Lists are used in Dublin. These will be introduced below.

VARIATION ROUTINES

Variation Routines are used to modify the default behaviour of an intersection or subsystem, typically by testing one or more conditions, then applying one or more actions to override the normal operation. Common routines used in Dublin are applying ISS at an intersection and running an intersection in Master-Isolated mode below a certain Cycle Time threshold. The figure below shows that at site 64, the junction will change to Master-Isolated mode below 100 seconds. This has the effect of reducing the priority of the main-road approaches. Also, an ISS variation routine has been created but has been skipped at this time.

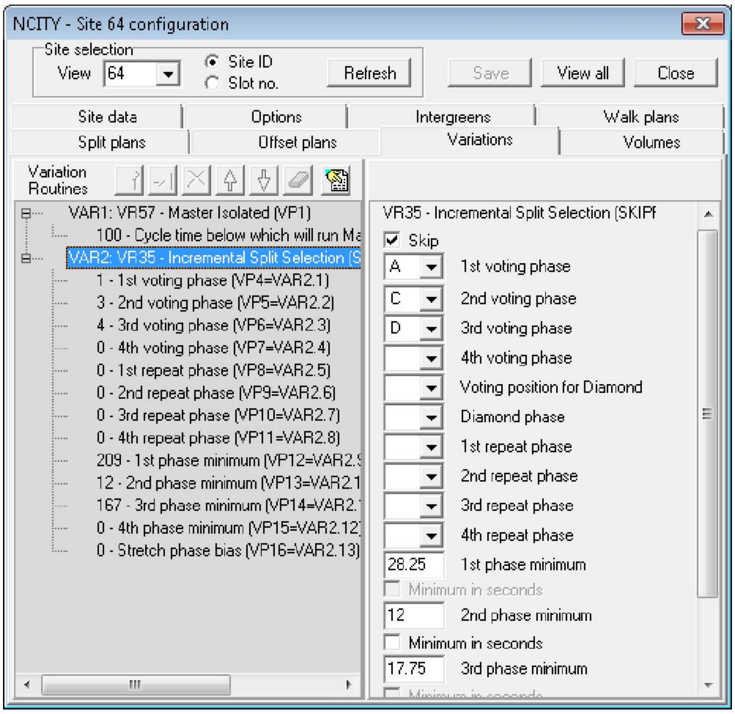


Figure 20: Variation Routines

ACTION LISTS

The Action List facility allows the user to store a SCATS command (the action) for automatic application at some time. In practice, the time at which the action should be applied is specified through the use of a scheduler. Actions can contain a number of SCATS commands or instructions which will all occur simultaneously. For example, during peak times it is common policy in Dublin for junctions along a main route to have fixed cycle times applied through the use of an Action List. Split Plan modifications such as Locks and Trims (a type of lock removed automatically by SCATS) are also commonly called through the use of Action Lists.

ITS SYSTEMS

In Dublin, SCATS has proved indispensable not only as a traffic flow optimisation tool but also as a platform for supporting the data requirements of third party software through the ITS port. This facility has provided the opportunity for Dublin City Council to layer external software products on top of SCATS. The following software systems are used in Dublin and their operation is made possible through access to SCATS data.

The journey time estimation tool, TRIPS (Travel Time Reporting and Integrated Performance System), is a facility that accurately predicts Travel Times by interfacing directly with SCATS. TRIPS actively collects and processes travel time data every 60 seconds, ensuring that the output is always consistent with current road demands. The data can be collected directly from SCATS Strategic Monitor files or from the TRIPS ITS Server, via a Local Area Network. One of the outputs from TRIPS is a Travel Time graph which allows users to instantly view and evaluate road performance.

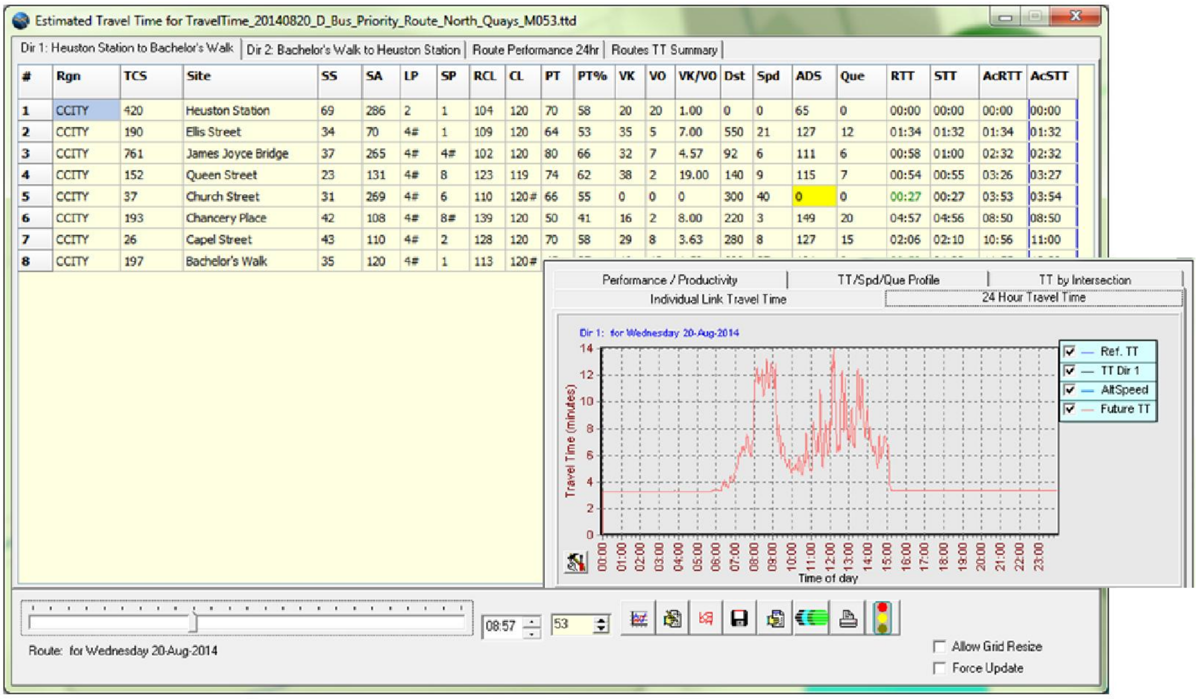


Figure 21: TRIPS User Interface

Other systems operating in this way include a fault management system and a Bus Priority System that communicates directly with SCATS through the ITS port to invoke operational changes to assist buses in real-time. The FMS software was developed as part of a traffic signal maintenance contract. Imtech are the current maintenance contractor and the FMS plays a vital role in the service provided through the identification and repair of faults, and the restoration of normal operation. Faults can be raised manually by an operator on foot of a direct observation or report from a member of the public, or they can be raised automatically, through the interface with SCATS. The FMS software monitors alarms generated in SCATS and will automatically raise a fault if the alarm meets pre-defined criteria.

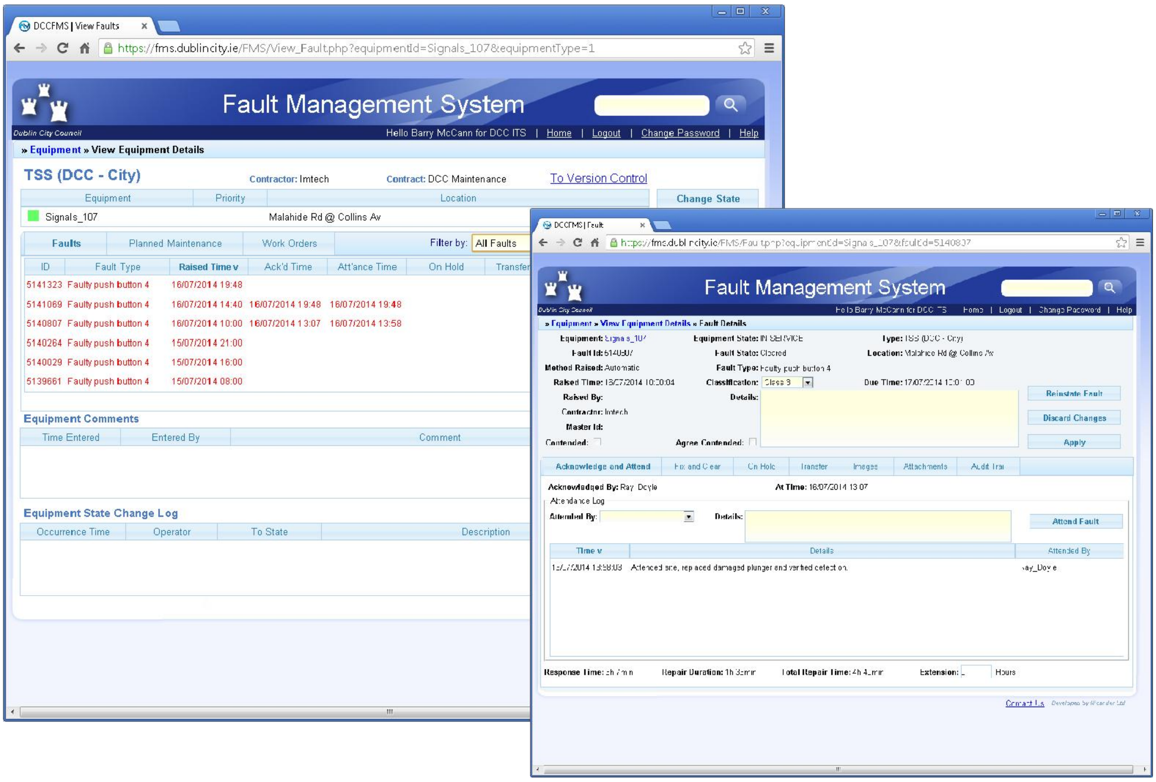


Figure 22: FMS User Interface

Finally, the most recent addition to the SCATS family of third-party software systems is a Bus Priority System, the Dublin Public Transport Interface Module (DPTIM). The purpose of this software is to integrate data received from the GPS modules fitted in Dublin buses with SCATS and enable the implementation of public transport priority measures. The GPS data supports an Automatic Vehicle Location (AVL) System which provides Dublin Bus with accurate bus location information every 30 seconds in a system tracking around 1300 buses in real time.

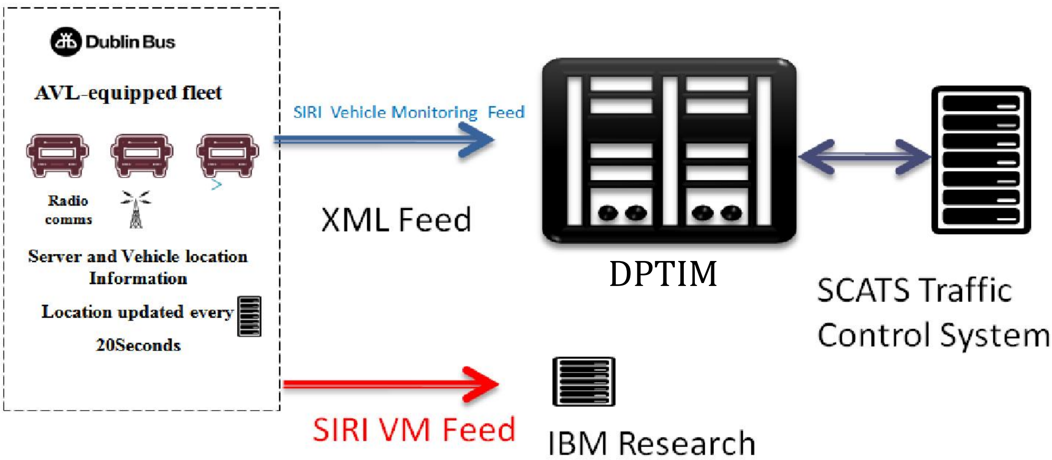


Figure 23: DPTIM and SCATS interaction with AVL system

A high-speed fibre optic network link between CIE computer centre and DCC offices has recently been installed and is now operational. With access to bus location information, and with an interface to SCATS through the ITS port, the DPTIM software invokes specified traffic signal interventions when particular trigger conditions are met. At various areas of interest throughout the city, DPTIM virtual detectors can be configured. Each time an updated location message is received, the software will determine if a bus is located within the area of the virtual detector. This operation allows the estimation of bus journey times through or between virtual detectors, as well as other variables such as the number of buses queuing in a particular zone. Variations in aggregated variables over time can be used to identify congestion in an area; appropriate and specific SCATS commands can then be automatically applied to militate against further delays.

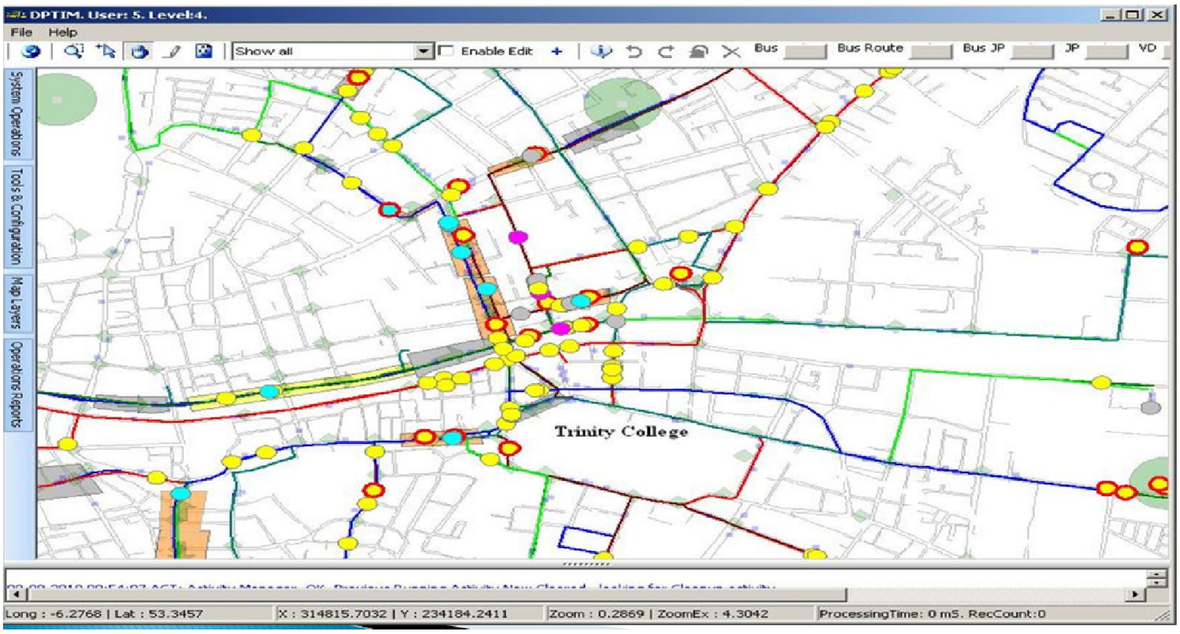


Figure 24: DPTIM Map User Interface

There are two types of virtual detector – journey time and queuing. Journey time detectors require a start and end detector to be configured along the route, and are used to estimate the travel time between detectors. A deviation from scheduled position is calculated and can be used as a trigger for a SCATS intervention. Queuing detectors are used to determine the queuing time at a particular location. The interventions are specified through the DPTIM Activity Editor and can include modifications such as Split Plan changes, Phase Dwells, or Phase demands. The DPTIM activity is applied to SCATS through an Action List via the ITS port. A clean-up activity can also be specified in order to reduce the impact of any intervention on normal junction operation.

CONCLUSION

The objective of this paper was to provide an introduction to the basic structure and operation of SCATS and to give an overview of how SCATS is used in Dublin. The SCATS software system operation was discussed at three levels of implementation – intersection, subsystem, system – in order to highlight the distinction between the two control layers (tactical and strategic). Throughout, an attempt was made to highlight the autonomous and self-calibrating nature of the SCATS software. Following the review SCATS basic operation, the User Interface was introduced in order to illustrate the graphical capabilities of SCATS.

It was also the intention of this paper to convey how SCATS is currently deployed in Dublin and in what capacities. The importance of SCATS as a provider of data to support traffic software and as a key component in research and analysis were presented. The use of the ITS port as a means of facilitating external software such as the FMS, TRIPS and DPTIM was highlighted. In addition, the role of SCATS in the Dublinked scheme and the Dublin City Council partnership with IBM were discussed.

With regard to SCATS operation and deployment into the future, new services through system upgrades will undoubtedly feature prominently in the way SCATS is used in Dublin in the coming years. For example, there are plans to separately package the SCATS controller software, TRAFF, which would allow it to be sold as an add-on to any controller. This would significantly increase the types of controllers available for use in Dublin. Also, one particular feature being rolled out as part of version 6.9.2 is the facility to import latitude and longitude coordinates into SCATS and display the network over a Google Earth display.

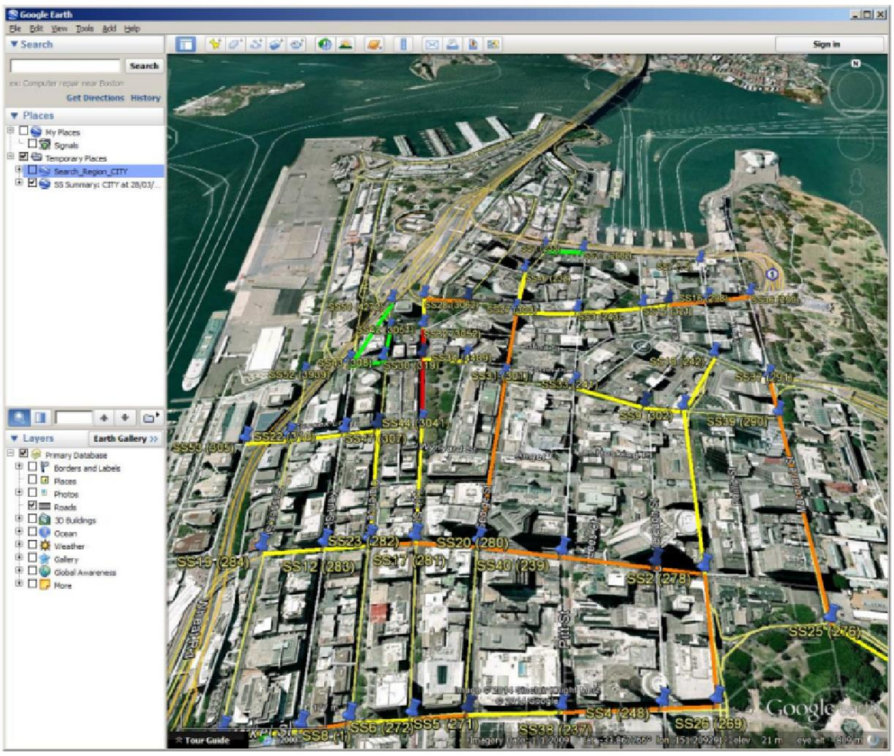


Figure 25: SCATS Display in Google Earth

The future of SCATS in Dublin will certainly expand on its existing role supporting new technologies. As ITS research and technology progresses, SCATS outputs will be an invaluable data source for testing new innovations. An example of this is a current research project that was briefly mentioned earlier, and which shows how Dublin and SCATS are playing central roles in the development of new technologies, is the INSIGHT project. Dublin is to be the testbed for this new application, an Incident Mangement Service (IMS) for urban traffic management. INSIGHT stands for Intelligent Synthesis and Real-time Response using Massive Streaming of Heterogeneous Data. The system utilises large heterogeneous data streams including SCATS data and crowd-sourcing data to support intelligent urban traffic management by identifying unusual events or incidents with a high level of accuracy.

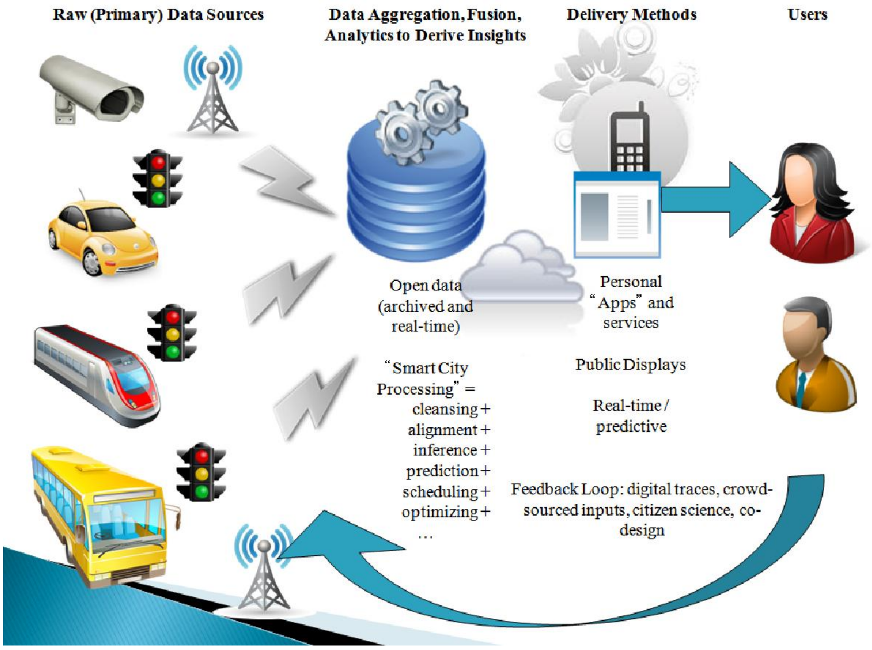


Figure 26: INSIGHT Feedback Loop

As can be seen from this review of operation and deployment of SCATS in Dublin, it is integral to traffic management in the city and will be for many years to come. The service provided is multi-faceted: from a junction optimiser, to a data repository for traffic analyses, to a platform for additional software systems. It is this functional flexibility that has allowed the part played by SCATS to grow over the years and which has resulted in its central position in Dublin's traffic control and management operation.

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