Survey of MOVA and SCOOT operation at M42 Junction 6

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SURVEY OF MOVA AND SCOOT OPERATION AT M42 JUNCTION 6

Version: 1

by K Wood, M Crabtree, A Kirkham, A Maxwell and R Robbins (TRL Limited)

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Executive summary

HA standard TD35/06 requires that MOVA shall be the signal control strategy for all new and refurbished signalised installations on the Agency's All Purpose Trunk Road network, including signalised roundabouts or other closely spaced signalised linked networks. However, little evaluation of the benefits of MOVA control at roundabouts has been undertaken. The pre-evaluation of MOVA project has been commissioned to provide information to help determine the likely benefits of new MOVA installations. A major part of the project has involved a survey of the signal controlled roundabout at Junction 6 of the M42.

Junction 6 is a major intersection with the A45 and the National Exhibition Centre (NEC) entrance. It was refurbished in 2006 and the traffic signal control changed from SCOOT to MOVA, with the SCOOT control still operational. SCOOT was retained with the intention of operating SCOOT when it offered the best control, and MOVA when it offered the best giving the optimum of both systems. A second reason for retaining the SCOOT control was to allow intervention by manual operation for extreme circumstances, motorway closed etc.

The junction, therefore, provided a test site to compare SCOOT and MOVA control of a large roundabout. Such opportunities are rare as the detector requirements for SCOOT and MOVA are different; therefore, it is unusual that both methods of control can be applied at the same site.

The original intention had been to undertake a three-way comparison of MOVA, SCOOT and Fixed-Time control. Unfortunately, the inclusion of Fixed-Time control proved impractical. The traffic conditions at the junction are heavily influenced by events at the NEC. There is not a regular, predictable traffic pattern where volumes and turning movements in the morning peak, inter peak and evening peak are very similar from day to day as is the case at most sites. At junction 6, the timing and number of arrivals and departures at the NEC vary widely from event to event. Therefore, it is not possible to confidently predict which fixed-time plan will be appropriate at a particular time on any day. Hence, the use of fixed-time plans would have required a large supervisory effort to select the appropriate plan and the traffic results obtained would depend on the skill of the supervisor and the availability of suitable plans, as well as on the general effectiveness of fixed-time control.

To evaluate the effectiveness of fixed-time control, it is necessary to ensure that the fixed-time plans are optimal and based on up-to-date information. Therefore, the existing TRANSYT plans would have required updating to current flow levels. In addition, with signalised roundabouts, TRANSYT plans require on-site testing and tuning before use. The preparation of the plans would have required a large effort for the limited benefit in assessing the plans at this unusual site.

Consequently, the objectives of the trial were reduced to the comparison of the effectiveness of MOVA and SCOOT control of the roundabout and to see how any differences vary with the demand on the roundabout.

Preliminary observations at the trial site suggested that the signalised roundabout at junction 6 of the M42 has been successfully converted to MOVA control.

It was also observed that the design of the SCOOT control could have been improved by using a detector on each lane of the signal controlled approaches and modelling each lane as a separate SCOOT link. This approach would more accurately represent the queuing behaviour at such a roundabout where the signing directs drivers to the appropriate lane for their exits. The signing had been improved as part of the modernisation of the control during the installation of MOVA. The queuing behaviour when SCOOT was implemented is not known.

The roundabout has been assessed over a 6 week survey period using the occupancy per vehicle of the MOVA detectors as a proxy for delay. The resulting figures were analysed by the analysis of covariance technique to allow for the effects of different flow levels on different days. The roundabout was also assessed using SCOOT model data. As indicated above, it is believed that the SCOOT model estimates are not as reliable as those from the occupancy of MOVA detectors and so the conclusions are based on the detector occupancy data.

The conclusion from the analysis of the data was that MOVA reduced the delay at the roundabout. Statistically significant reductions of 6% in the weekday inter peak and 10% on Sundays were achieved. Reductions were measured at the other times of day surveyed, but were not statistically significant. Further data collection would be required to obtain statistically significant results. As expected, analysis based on the SCOOT modelled delay was more favourable to SCOOT than those based on the detector occupancy per vehicle measure.

The greater freedom of MOVA control to vary the timings from cycle to cycle and from junction to junction resulted in appreciably shorter green times, particularly away from the peak periods, than did SCOOT control, which was operated under the existing policy of maintaining a fixed 60 seconds cycle time. Under SCOOT control, two of the junctions were operated as a single multi-node with three stages. Therefore, the minimum cycle time would be higher than for two separate two stage junctions. Examination of the SCOOT modelled degrees of saturation showed only limited scope for reducing the cycle time below 60 seconds.

It should be noted that the results quoted here apply just to Junction 6 of the M42, which is an unusually large motorway junction roundabout. Further trials are needed before general conclusions can be drawn. In addition more research and trials, or possibly simulation, is needed on the benefits of operating SCOOT with one loop per lane where lane use is controlled by detailed signing.

1 Introduction

HA standard TD35/06 requires that MOVA shall be the signal control strategy for all new and refurbished signalised installations on the Agency's All Purpose Trunk Road network, including signalised roundabouts or other closely spaced signalised linked networks. However, little evaluation of the benefits of MOVA control at roundabouts has been undertaken. The pre-evaluation of MOVA project has been commissioned to provide information to help determine the likely benefits of new MOVA installations. A major part of the project has involved a survey of the signal controlled roundabout at Junction 6 of the M42.

Junction 6 is a major intersection with the A45 and the National Exhibition Centre (NEC) entrance. It was refurbished in 2006 and the traffic signal control changed from SCOOT to MOVA, with the SCOOT control still operational. SCOOT was retained with the intention of operating SCOOT when it offered the best control, and MOVA when it offered the best giving the optimum of both systems. A second reason for retaining the SCOOT control was to allow intervention by manual operation for extreme circumstances, motorway closed etc.

The junction, therefore, provided a test site to compare SCOOT and MOVA control of a large roundabout. Such opportunities are rare as the detector requirements for SCOOT and MOVA are different; therefore, it is unusual that both methods of control can be applied at the same site.

The original intention had been to undertake a three-way comparison of MOVA, SCOOT and Fixed-Time control. Unfortunately, the inclusion of Fixed-Time control proved impractical. The traffic conditions at the junction are heavily influenced by events at the NEC. There is not a regular, predictable traffic pattern where volumes and turning movements in the morning peak, inter peak and evening peak are very similar from day to day as is the case at most sites. At junction 6, the timing and number of arrivals and departures at the NEC vary widely from event to event. Therefore, it is not possible to confidently predict which fixed-time plan will be appropriate at a particular time on any day. Hence, the use of fixed-time plans would have required a large supervisory effort to select the appropriate plan and the traffic results obtained would depend on the skill of the supervisor and the availability of suitable plans, as well as on the general effectiveness of fixed-time control.

To evaluate the effectiveness of fixed-time control, it is necessary to ensure that the fixed-time plans are optimal and based on up-to-date information. Therefore, the existing TRANSYT plans would have required updating to current flow levels. In addition, with signalised roundabouts, TRANSYT plans require on-site testing and tuning before use. The preparation of the plans would have required a large effort for the limited benefit in assessing the plans at this unusual site.

Consequently, the objectives of the trial were reduced to the comparison of the effectiveness of MOVA and SCOOT control of the roundabout and to see how any differences vary with the demand on the roundabout.

The first stage of the trial was a preliminary survey to check the operation of the signals under both SCOOT and MOVA. Following this check a pilot survey was undertaken to verify the data collection, transfer and analysis methods. The main survey, described in section 5, using automatic data collection was carried out over 6 weeks. Section 6 details the analysis of the data and the method used to allow for the effects of changes in flow levels over the survey period.

1.1 SCOOT

SCOOT (Split, Cycle and Offset Optimisation Technique) was developed at TRL for the coordinated control of networks of signals in conjunction with UK traffic signal companies. It is a traffic responsive coordinated Urban Traffic Control system extensively used in urban areas in the UK and abroad. Because of its ability to both respond to traffic and coordinate multiple sets of traffic signals, it has been used for some time to control signalised roundabouts. SCOOT uses one detector per two lanes on each approach, normally 10 to 15 metres downstream of the previous junction, or 100 to 150m in advance of the stopline for entry links where there is no upstream junction.

The main problem with using a traffic responsive system to control signals on a roundabout is to locate detectors where they will respond to just the required vehicles and not detect those leaving by the exit before the signals. Modern roundabouts with well defined and signed lane allocation make detector siting somewhat easier.

1.2 MOVA

MOVA (Micro-processor Optimised Vehicle Actuation) was also developed at TRL for the control of isolated traffic signals. It optimises the green times using information from inductive loop detectors in each approach lane, normally to minimise delay, but when a junction becomes over saturated it intelligently switches to capacity-maximising mode. Currently (2007), there are at least 1500 installations in the UK with an installation rate approaching 300 sites per year.

MOVA uses two detectors per lane on each approach to the signals. The location of the detectors varies with the approach speed of vehicles. The ones nearer to the stopline (the X-detectors) are around 40m in advance of it and the further, IN detectors at between 100 and 150m.

In 1997, MOVA M4 was released which introduced emergency and priority vehicle facilities. These facilities also found application in the linking of closely spaced MOVA controlled junctions by allowing coordinated control. The linking feature is frequently used when MOVA controls signalised roundabouts. The linking was used between the individual junctions at Junction 6 of the M42.

2 Glossary

Emergency/priority facilities in MOVA	Facilities that allow stages to be truncated and/or skipped in response to the selective detection of emergency or priority (buses usually) vehicles.
IN-detector	The MOVA detector that is furthest from the junction, typically 100 to 150m before the stopline
Link	Signalised approach that is considered separately in the signal control optimisation. Several lanes on an approach may be combined into one link.
NEC	National Exhibition Centre
Node	A signal controlled junction or pedestrian crossing
X-detector	The MOVA detector that is closest to the stopline, typically 40m in advance.

3 Site details

3.1 General

The intersection is a three-level grade separated intersection with through traffic on both the M42 and A45 uninterrupted by the junction. Turning movements are controlled by a large signalised roundabout, approximately 250m internal diameter, except that there is a dedicated slip from the M42 northbound to A45 westbound, that by-passes the roundabout. There are 5 signal controlled entries to the roundabout: the NEC, A45 East and West bound off slip roads and the M42 North and South bound off slips, plus a non-signalised entry from the national motorcycle museum. All the off slip roads have three lanes (A45 Eastbound flares to 4 lanes at the stopline), whilst the NEC exit has two lanes for vehicles going north on the M42 and three lanes for other destinations. The unsignalised museum exit has two lanes.

The roundabout is shown in Figure 3-1, where:

Node 1 = M42 Northbound off slip road

Node 2 = A45 Westbound off slip road

Node 3 = NEC exit

Node 4 = M42 Southbound off slip road

Node 5 = A45 Eastbound off slip road

An aerial photograph is presented in Figure 3-2 (Copyright GeoPerspectives). The SCOOT link diagram is shown in Figure 3-3.

Nodes 2 and 3 are too close together for MOVA IN-detectors to be placed between them, but they do have MOVA X-detectors. They are modelled as a single node under SCOOT control.

Around the roundabout, the MOVA IN-detectors and SCOOT detectors are at a similar distance from the stopline, immediately after the previous exit. MOVA uses a single diamond shaped loop in each lane and SCOOT uses its normal rectangular detectors, one loop over the two left most lanes (lanes 1 and 2) and another loop over lane 3. On the entry links, the SCOOT detectors are somewhat further from the stopline than are the MOVA IN-detectors. The free running journey times from the SCOOT detectors on the slip roads to the stopline are around 11 seconds, which represents a considerable distance at these high-speed sites.

Extensive use is made of signing and marking to maximise good lane choice and minimise weaving movements around the roundabout. Observations of the operation showed good lane discipline in most locations, although at some times vehicles circulating through node 2 to leave northbound on the M42 queued preferentially in the left hand of the two lanes marked for that manoeuvre.

The traffic flows at the roundabout are high; peak hourly flows at all of the junctions (entry plus circulating) exceed 3000 vehicles per hour, with three junctions reaching or exceeding 3500. During major NEC events the flows will increase, particularly when the peak access or egress time coincides with the normal peak period.

3.2 Influence of the NEC

Events at the NEC have a large effect on the traffic demand at the junction. There can be very large movements into and away from the Centre at the start and end of events. Large inflows not only impose a large demand on the roundabout, but the entry to the NEC site is restricted by a mini-roundabout that can cause queues back onto junction 6, compounding the problem of the heavy demand flow.

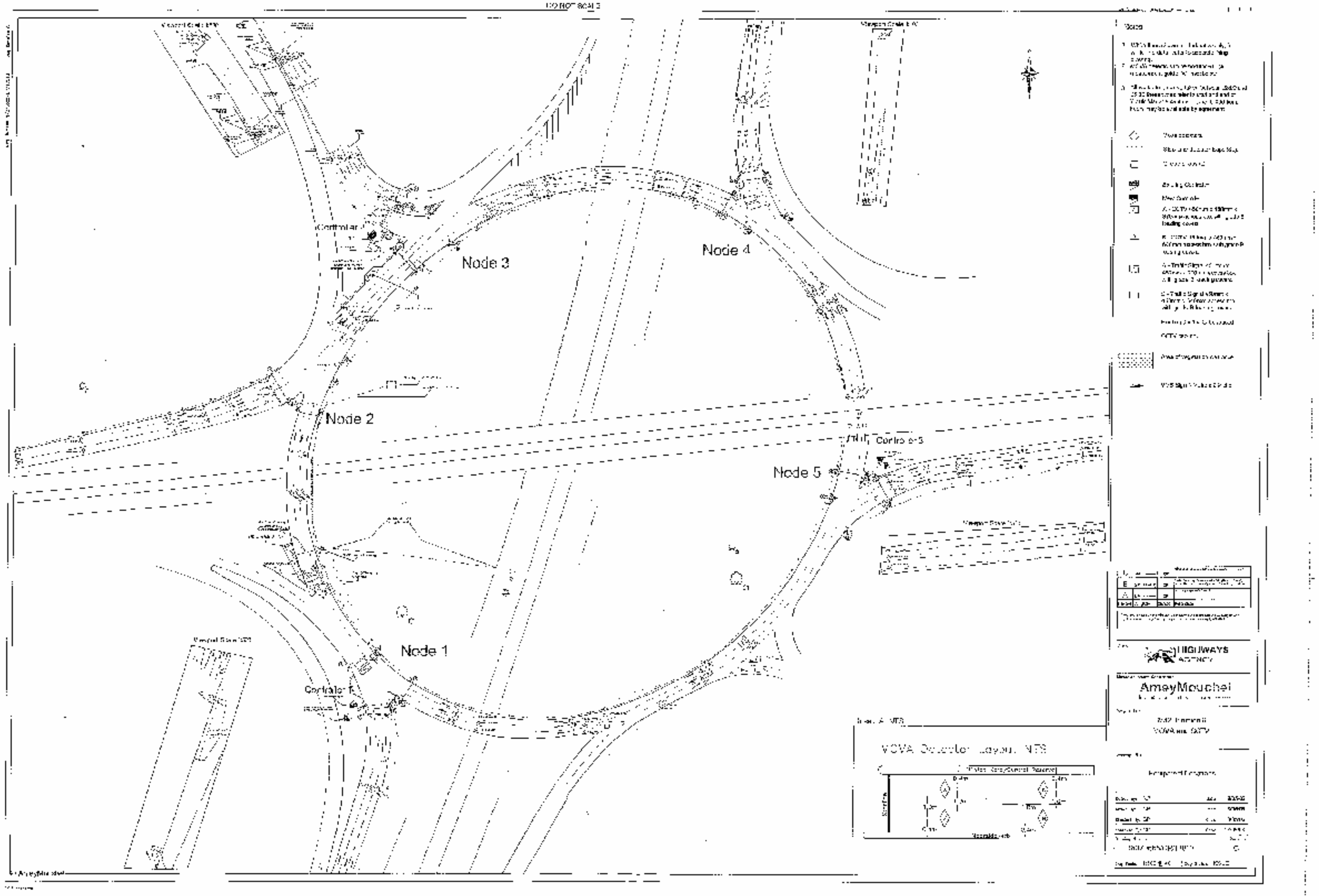

Figure 3-1: M42 junction 6

Figure 3-2: M42 Junction 6

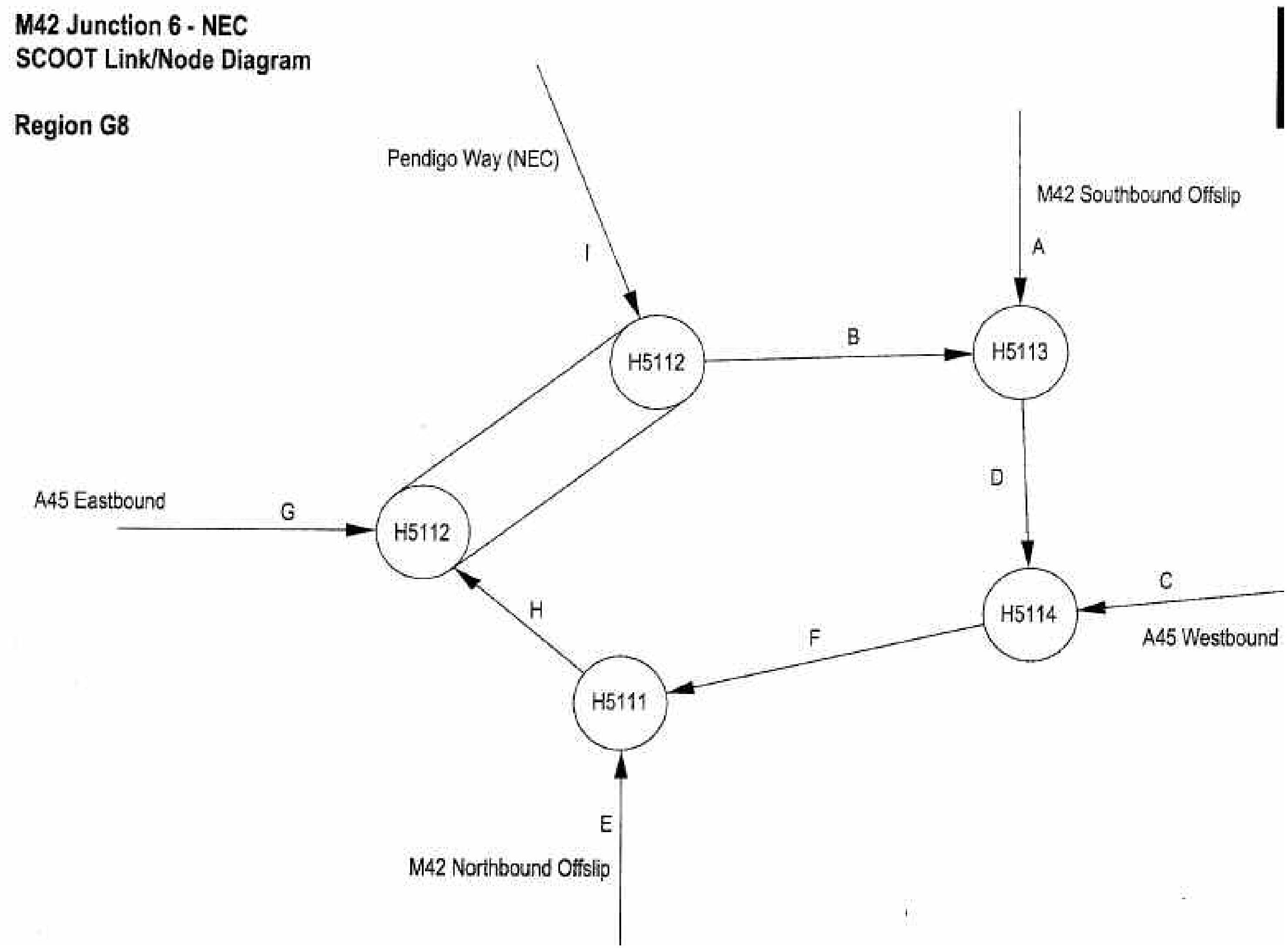

Figure 3-3: SCOOT link Diagram

There are two major car parking areas for the NEC, one with access and egress from the A45 and one from the M42. Any vehicles leaving the NEC car parks that exit onto the A45 wishing to travel on the M42 will be in conflict with all the vehicles leaving the other set of NEC car parks through junction 6.

The largest events at the NEC have more influence on the variability of the traffic movements on the roundabout than do the usual sources: day of the week, time of year or weather. The planning of the survey needed to consider the event programme as a dominating influence on the survey timetable. In particular, the period when the Crufts show was on was excluded from the comparison of different methods of control. The ideal survey scheduling would have each control strategy operating on days when the same events were on at the NEC. Unfortunately, events have varying duration and overlaps; therefore, it is not possible to select a large sample of pairs of days where the same events are scheduled during the pair of days. The general principle adopted was to alternate control strategies as the best way to minimise the traffic flow variation between the days when the different control strategies were operating.

3.3 SCOOT control

Under SCOOT control the signals at the roundabout operated as an independent region of 4 SCOOT nodes. The junctions of the Eastbound A45 off slip and of the NEC exit were operated as a single node, H5112 within SCOOT, as shown in Figure 3-3. The offset for the circulating traffic on the short link between the two junctions was fixed within the UTC system and not variable by SCOOT.

SCOOT detectors were operational on all the links in Figure 3-3. Two detectors were needed on each link as there were more than 2 lanes on each signal controlled link. One loop was cut over the two most left hand lane on each link and a further loop over the remaining one, or in some cases two, lanes. The detector loops on the circulating carriageway were correctly sited just downstream of the previous exit, providing the maximum journey time (advance warning of vehicle arrivals to SCOOT) consistent with not detecting vehicles that are about to leave the roundabout rather than approach the stopline.

Observation of the operation of the roundabout showed that the vast majority of drivers followed the lane markings for their exits. Consequently the lane use was not even at some times. When many drivers wanted the same exit, they would queue in the appropriate lane(s) even though other lanes were underused. At other times, the lane use on the link would be much more even. Due to the use of one detector loop over two lanes, SCOOT is not able to model this variable lane use accurately in individual cycles. Therefore, the control by SCOOT was not expected to be as good as would be achieved by using a detector on each lane of the signal controlled approaches and modelling each lane as a separate SCOOT link.

Because of the nature of signalised roundabouts, traffic on each link at a junction is heading for the same downstream link, the circulatory carriageway downstream of the junction. Therefore, the SCOOT exit blocking logic will not be able to preferentially allocate green to an unblocked link when the circulating carriageway is full. Nevertheless it is important to use the exit blocking logic to model the effect of the blocking so that SCOOT keeps track of the queues caused by the blocking. It would also be possible to set up a congestion offset to favour the circulatory link when the exit is blocked. Each link had the next downstream circulatory link correctly set as its main downstream link. One consequence of the use of the multinode, H5112, is that links H and G both had link H5113 set as their main downstream link, rather than the internal circulatory link, which is their true downstream link and would have been used if the two junctions had been separate nodes within SCOOT.

Congestion importance factors were used to prioritise the response to congestion on the different links. The circulatory links had a congestion importance factor of 6 and the entry links 4, except for the A45 Eastbound off-slip, H5112G, which had a congestion importance factor of 7 and the conflicting circulatory link, H5112H, which had an importance factor of 4. Therefore, at all nodes except H5112, more importance was given by SCOOT to avoiding congestion on the circulatory link, than on the entry link. Such use of the congestion importance factor would be expected to keep the circulating carriageway moving and avoid lock-up.

The journey time, saturation occupancy, and maximum queue clear time had been validated as normal and TRL undertook a small survey to confirm the suitability of the values. No use was made of the SCOOT traffic management features for split weighting or offset biasing, or congestion management other than the congestion importance factor as described above.

3.4 MOVA control

Each of the signal controlled nodes was configured to run MOVA with standard MOVA configuration data. Each junction used one link for each lane and, on this unusually large roundabout, each lane had the standard MOVA detector layout with both IN-detectors and X-detectors, with just one exception: The circulating carriageway at Node 3 of the roundabout was not long enough to accommodate IN-detectors, but did have X-detectors. The positioning of the detectors was determined by the measurement of cruise speeds, in the normal way for MOVA (Crabtree et al 2006 and Crabtree and Henderson 2006).

In addition to the configuration of MOVA as if each node were isolated, much use is made of the emergency/priority facilities in MOVA to allow linking between junctions and to deal with the worst excesses of queuing. Linking works by passing specially conditioned signals between the junctions. These signals activate the emergency/priority facilities, hence allowing, for example, a signal stage running at one junction to ‘hurry-call’ a signal stage at another junction, such that traffic can progress through both junctions with minimum delay.

At the design stage, all the potential linking options are allowed for. For a signalised roundabout having two stages at each node, this involves taking linking signals from each stage confirm at least to the next downstream junction, and sometimes the next upstream junction as well. MOVA takes the signals and converts them either in to a priority call for the required signal stage (if the stage is not running already) or to hold the existing stage (if it is already running).

Queue detection is also employed both from dedicated queue detectors (on the off-slip roads for example) and from using IN or X-detectors as ‘back-stop’ queue detectors. Each of the linking signals is configured to have a delay between the stage running and the signal being passed to the next junction. The delay period can be altered on site.

During validation, armed with all the linking possibilities, the task is both to choose which of the linking signals to use, and to select by how much the signal needs to be delayed. Careful ‘tuning’ of the linking signals continues until progression of the traffic appears optimal. Other aspects of the MOVA configuration data are also validated, including the total green time. It is usual for the total green time to be the same value for all nodes at the roundabout, and in this case the value was set to 65 seconds. (This leads to a cycle time maximum of 77 seconds once the intergreens have been included.) Much effort was put into validation of this strategically important roundabout by the specialist contractor employed by the HA. A TRL engineer visited the site and confirmed that the MOVA operation appeared to be operating satisfactorily.

In addition to the five signal-controlled nodes at this roundabout, there is one minor priority arm, which is the exit from the Motorcycle Museum. The exit includes a queue detector, which when activated, causes the upstream junction to extend its intergreen. The resulting gap in the traffic passing the give-way exit allows traffic to enter the roundabout more easily.

4 Assessment method

4.1 Data collection methods

The main assessment criterion is the difference in delay when the roundabout is operating under the different methods of control. However, the delay at a junction is affected by the demand flow as well as by the effectiveness of the control system. Therefore, the two essential assessment measures are delay and flow. Manual measurement of delay was rejected on grounds of safety and expense. Several observers would be required on each approach to record vehicles in each lane. Having a large number of observers spread round a high-speed roundabout with difficult access and not all observation points protected by crash barriers was considered unacceptable. The cost would also have been prohibitive.

Number plate recognition cameras can provide an efficient method of measuring journey times, but would have been expensive and difficult at this site. Again, because of the large number of lanes, many cameras would have been needed and locating them to observe all lanes would have been very difficult. In addition great care would be required to install them safely in the limited working areas available. It was concluded that a camera based survey was not feasible.

Both SCOOT and MOVA have been used to estimate delays, or changes in delay at traffic signals. The SCOOT model estimates of delay have been found to be good where links are not congested (Carden et. al. 1989), with the accuracy somewhat less in congested conditions

The occupancy of MOVA loops has been shown to provide a proxy for delay at a junction (Young 1988) where queues do not extend beyond the MOVA "IN" detectors. The occupancy per vehicle is linearly related to the delay per vehicle through the junction. Because of the potential problems with congestion and queues extending back beyond detectors, it was decided to collect both MOVA occupancy data and SCOOT model and detector information. Consistent results from the various sources of automatic data would considerably increase the confidence in the assessment.

4.2 Data collected

Having decided to use automatic data collection from SCOOT and MOVA it was necessary to define the information to be collected. The data collected were:

- MOVA error log
- MOVA assessment log
- SCOOT messages
    - M02 – model flow, delay, stops and congestion per link
    - M08 – model degree of saturation per link
    - M29 – detector flow and occupancy each SCOOT region cycle time
    - M37 – stage lengths per node

The MOVA error log is required to determine whether MOVA was operating correctly during those periods when it was controlling the junction. SCOOT fault information is included in the M02 message. The MOVA assessment log provides the information that has been used to assess performance throughout the development of MOVA. It has three main items of interest:

- Junction flow
- Junction detector occupancy
- Stage timing information

Information is available by junction, for the M42 junction 6 roundabout each signalised entry link and conflicting circulating link constitute a junction, 5 in total. The stage timing information is the average stage length and number of times run for each stage in each assessment period.

The M02 data provide the main assessment information. SCOOT processes flow and occupancy data from detectors to produce its internal demand units (Link Profile Units, LPU). The average number of LPU per vehicle may be different for different links, particularly when comparing a link with a loop over one lane with another link where a loop covers two lanes. For SCOOT signal control, the effect of any variation is removed during the validation process, where the saturation flow of the link is calibrated in terms of the LPU measured over the detector(s) on that link. The M02 message outputs flow, delay and stops in “vehicles” where a vehicle is a standard number of LPU, which may not be exactly correct for an individual link. However, the delay is analysed in terms of delay per vehicle. As the same LPU to vehicle conversion factor is used in calculating delay and flow, the delay per vehicle = {*delay / flow*} is independent of the conversion factor and provides an unbiased measure to compare the effects of the different signal control systems.

Congestion information is included in the M02 messages and is used to identify periods where the queues reached back to the SCOOT detector. As described above, the congestion information is used to supplement the delay data when congestion occurs. The M02 data also indicate any period in which there was a detector fault on the link.

More detail is available from the M08 message, which outputs the degree of saturation, percentage congestion and flags to show whether the link was exit blocked or had a maximum queue during the cycle at the end of each green period to each link. The information from the M08 messages is valuable for detailed investigation of particular periods where results appear anomalous.

The SCOOT detector data from the M29 message supplements the MOVA detector data, but is somewhat more limited as many of the SCOOT loops cover two lanes. Information on stage lengths is provided both by the SCOOT M37 message and the MOVA assessment log.

4.3 Analysis periods

Initial examination of the flow data for the junctions round the roundabout showed fairly conventional morning and evening peak periods with some variation between the individual junctions, see Figure 4-1. Junction 3 in the figure is the NEC exit; it is noticeable that the flow there is low in the morning peak, mainly the circulating traffic at the junction with little exiting the NEC. In the evening, the flow was considerably greater as vehicles left the NEC. Patterns at the weekend were different from weekdays and Saturdays different from Sundays.

The analysis periods were defined as:

Weekdays: AM Peak 07:00 to 09:00, inter peak 09:00 to 16:00, PM peak 16:00 to 19:00

Saturdays: 08:00 to 10:00, 10:00 to 12:00 and 12:00 to 19:00

Sundays: 10:00 to 19:00

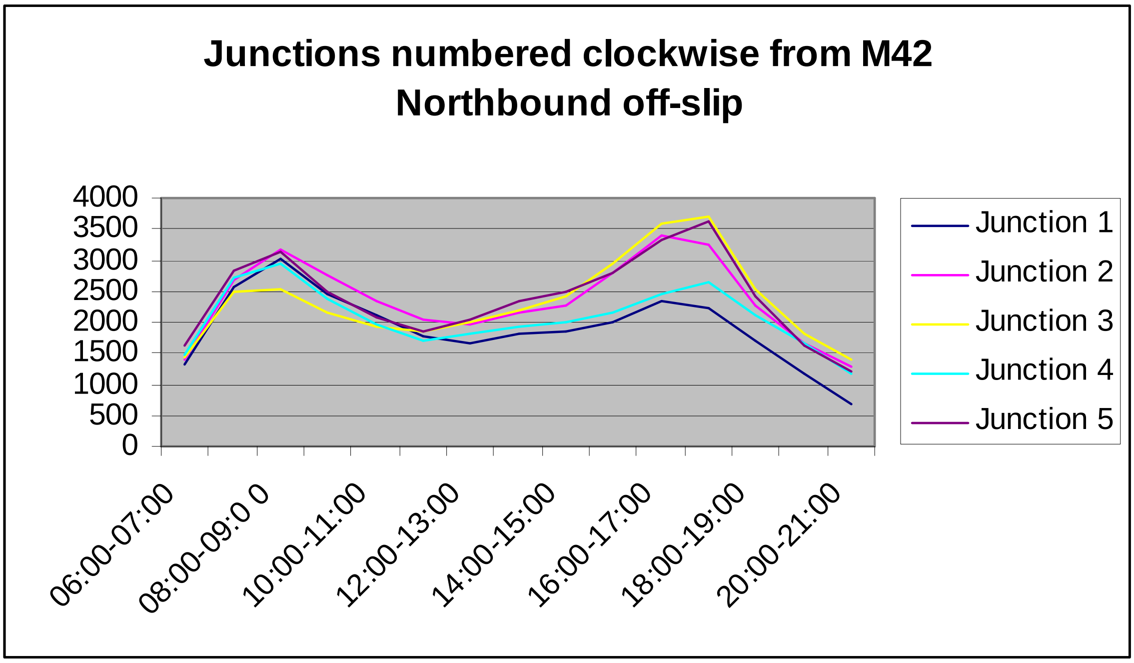

Figure 4-1: Vehicle flow from MOVA X detectors, Thursday 15 March 2007

5 Data collection and survey timetable

5.1 Data collection

The SCOOT messages required for the survey were switched on and directed to the ASTRID database on the Birmingham City Council SCOOT-UTC system. Birmingham CC council staff regularly extracted the data from ASTRID and sent it to TRL for analysis.

Data from the MOVA logs in the three Sentinel traffic signal controllers at the roundabout were periodically downloaded by staff from Amey Mouchel and forwarded to TRL.

5.2 Influence of NEC events

As already noted, the events on at the NEC on any day can significantly influence the flows at the roundabout. To minimise the difference between flows when the two strategies were operating, control was alternated between SCOOT and MOVA daily, with the changeover timetabled from the Birmingham UTC centre at 6 AM. The principle behind alternating control was that it was not possible to reliably predict which events would produce comparable flows, but major events occur over several days. Therefore, alternating control meant that each strategy was operating on at least one day of each significant event. The exception to this rule was during Crufts dog show.

Historically, Crufts has created peak flows (and problems) at junction 6. MOVA had been installed at the roundabout as it was expected to increase capacity. An operational decision was taken that it should be operated under MOVA throughout Crufts. In addition the contract for the installation and adjustment for MOVA included a final validation and adjustment of the MOVA parameters and linking during Crufts.

5.3 Survey period

SCOOT and MOVA control were alternated and data collected from Tuesday 13th March until Friday 27th April. The Easter period was removed from the dataset before it was analysed.

6 Data analysis

The problems for SCOOT modelling and control of using one detector over two lanes were noted in section 3.3. It was decided that because of the potential for inaccuracies in the SCOOT model through assuming equal lane use that the primary analysis would use the MOVA data. The MOVA assessment measures the flow and detector occupancy separately for each lane and then each hour sums the lane values and outputs total flow and average occupancy per vehicle for the junction to the assessment log.

As already described, the average occupancy per vehicle over MOVA detectors is a good proxy for delay per vehicle, provided the queues do not extend beyond the "IN" detectors. Delay at a junction is expected to increase as the flow through the junction increases. Therefore, periods of higher flow are expected to correspond to higher delay and variations in flow will complicate the comparison of the delay under different control strategies. The first stage of the analysis was to plot the occupancy per vehicle against the flow for each junction for each analysis period. Figures for each hour within the analysis period were plotted.

6.1 Allowance for changes in flow

For many years, TRL has used the analysis of covariance technique (Snedecor 1966) to allow for the effect of small changes in flow when comparing the effects of different control systems, see for example Hunt et. al., 1981. The principal assumption is that the delay is approximately linearly related to the flow over the relatively small range of flows observed in one period of the day during a limited survey period. A linear regression line is calculated for delay against flow for each control system and then the best fit parallel lines, assuming the same dependence of delay on flow for the two strategies is fitted. If the slope of the parallel lines is not significantly different from the slopes of the individual lines, then the best estimate the change in delay caused by the change in control strategy is the vertical difference between the lines. An example of the output is shown in Figure 6-1, where the x-axis is the total flow through the junction in vehicles per hour, the y-axis is mean detector occupancy per vehicle and each point represents one hour's data during the week day inter peak period (09:00 to 16:00). The analysis of covariance for this period, at this junction, showed that MOVA reduced occupancy per vehicle, and therefore delay, by 6.6%.

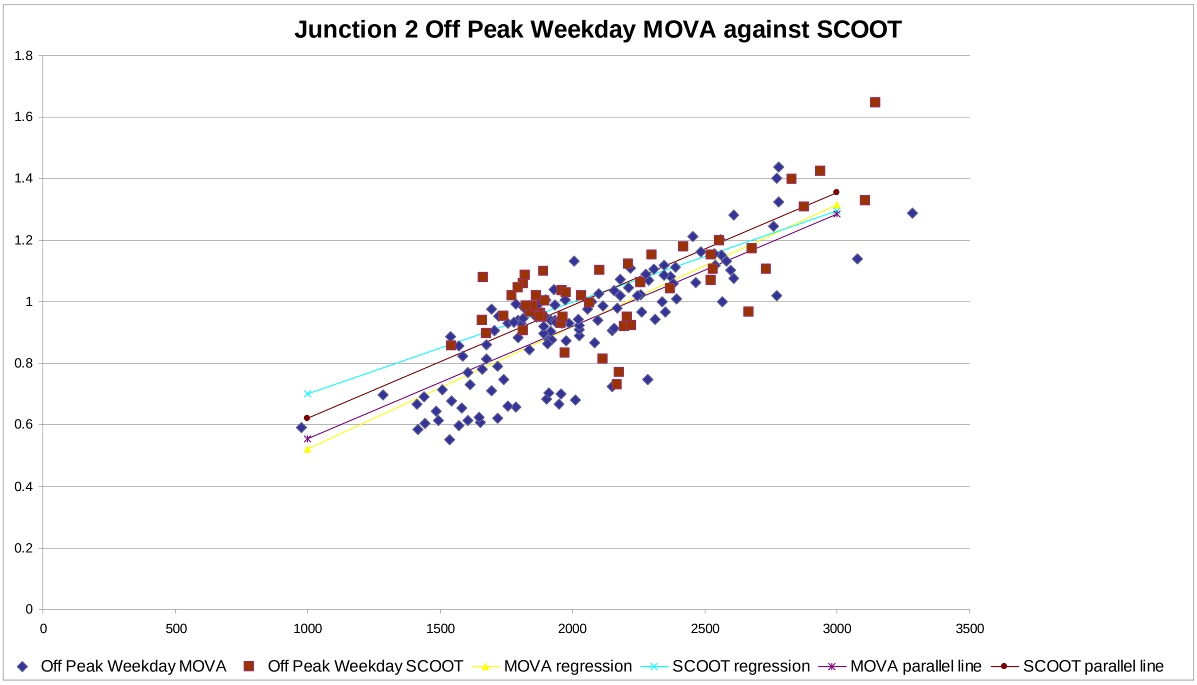

Figure 6-1: Sample analysis of covariance graph

6.2 Total delay

The MOVA assessment logs provided detector occupancy per vehicle for each signalised junction around the roundabout. These were summed to give a proxy for total delay at the roundabout. Similarly the junction flows were summed to give a total flow. Individual vehicles, which do not leave at the first exit, will be counted more than once in the total flow as they progress round the roundabout. However, the resulting figure is the best measure of total demand that the roundabout has to service; each vehicle is counted once for each junction that it passes through.

Because the assessment used detector occupancy per vehicle as a proxy for delay per vehicle, the results in Table 6-1 are percentage reductions only, not absolute values of delay. There was insufficient data available from the morning and inter peak periods on Saturdays, due to gaps in the MOVA logs at one or more junctions and so only results from the afternoon and evening (12:00 to 19:00) are presented.

Table 6-1: Reduction in delay from controlling by MOVA rather than SCOOT

AM Peak	Inter Peak	PM Peak	Saturday afternoon	Sunday
6%	**6%***	1%	7%	**10%***

* Result statistically significant at the 5% level

The weekday results are presented graphically in Figure 6-2 to Figure 6-4. Each point represents the results for one hour. As the inter peak period was considerably longer than either of the peak periods there are more data points in the inter peak. More data results in greater statistical reliability and the results for the inter peak period are the only ones that are statistically significant at the 5% level. In fact those results are significant at the 1% level. The survey was designed to collect sufficient data to provide statistically significant results, but the combination of the variability and size of the measured change in the morning peak meant that those results failed to reach significance.

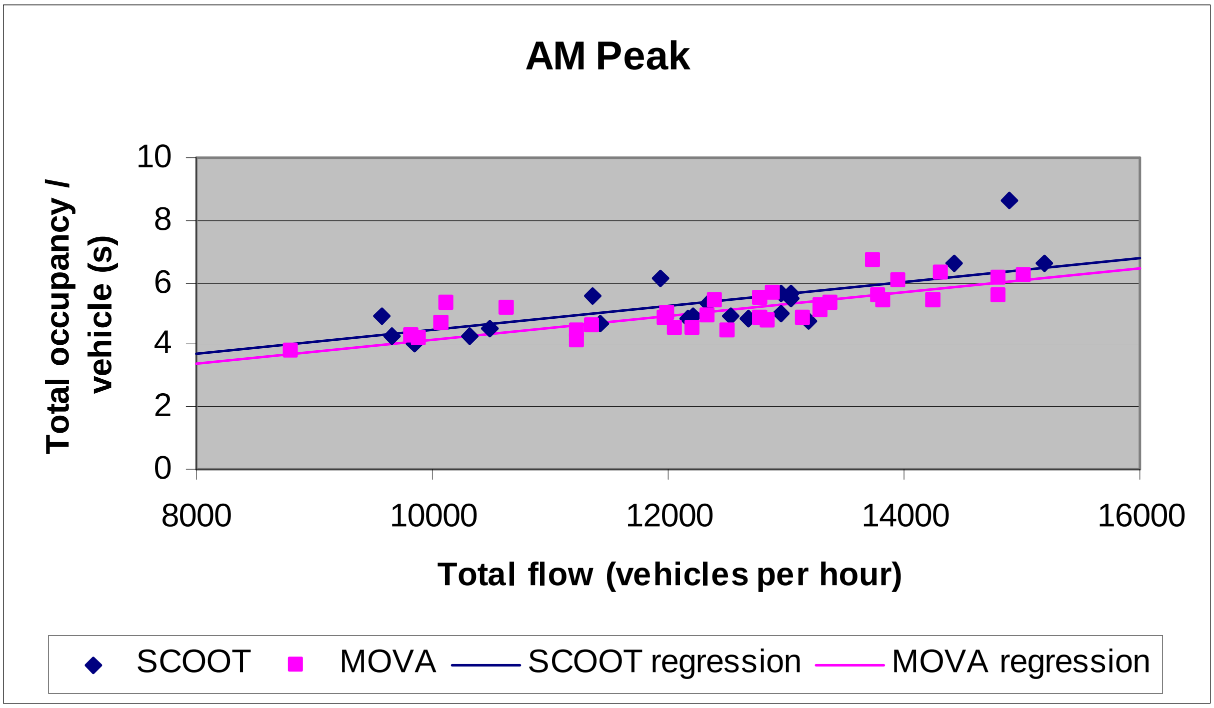

Figure 6-2: AM peak roundabout occupancy per vehicle

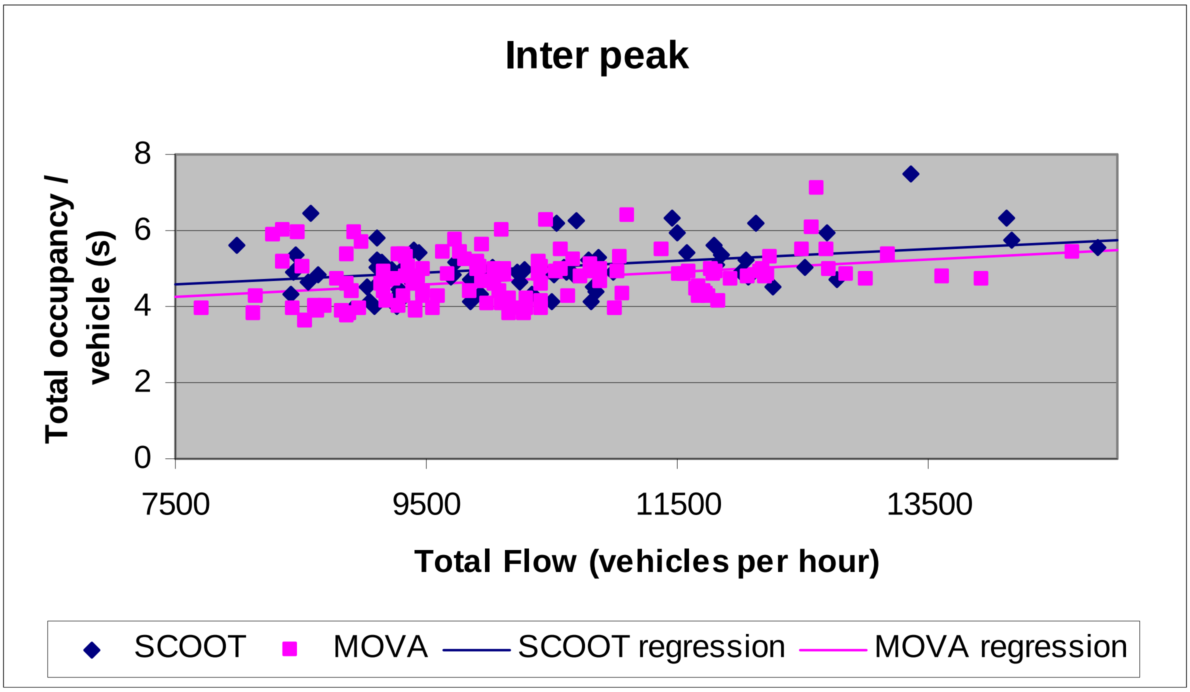

Figure 6-3: Inter peak detector occupancy per vehicle

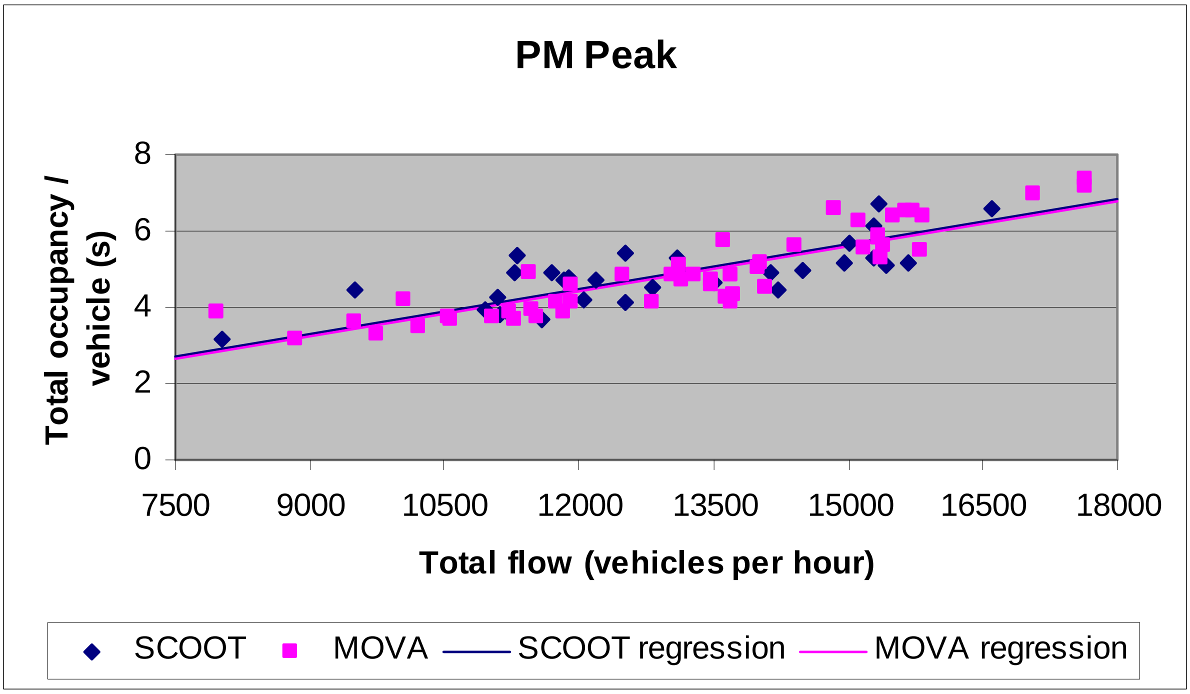

Figure 6-4: PM peak detector occupancy per vehicle

6.3 SCOOT data

The SCOOT delay estimates were subject to error due to the difficulty of modelling the traffic behaviour at this site with one loop over two lanes, but vehicles directed into specific lanes by destination. SCOOT optimises the signal timings based on this potentially inaccurate traffic model. MOVA timings, on the other hand, were optimised based on the traffic in each lane. The result is that when vehicle lane use is unequal on approaches with one SCOOT detector over two lanes, the SCOOT model estimates that SCOOT produces less delay than it does in reality and MOVA produces more delay than it really does.

Consequently, following observation of the roundabout, the decision was taken that the MOVA data should be the primary assessment tool. Analysis of the SCOOT data did, indeed, show that at this site, SCOOT assessed its own performance more favourably than did the raw detector data collected by the MOVA log. Analysis of Covariance was again used to allow for the effects of differences in flow levels (regression against total SCOOT flow for the roundabout). As expected, the results were more favourable to SCOOT than those based on detector occupancy. They are not reported here as it is considered that they are misleading. Because of the deficiencies in the SCOOT modelling of lane use, it is believed that the changes in delay calculated from the unprocessed detector occupancy per vehicle should be used as the best estimate of the change in delay caused by operating under MOVA rather than SCOOT control.

6.4 Signal timings

MOVA has much more freedom to modify the signal timings from cycle to cycle than does SCOOT which is restricted to maintain signals in the same region at the same cycle time and to only make small changes to green splits and offsets in a cycle. The policy that had been adopted for operating the roundabout under SCOOT, was to use a cycle time of 60 seconds throughout the day. This policy was maintained for the survey. Under SCOOT control junction 2, the A45 eastbound off-slip and junction 3, the NEC exit were operated as a single, 3-stage, multi-node because of the short distance between them. The minimum cycle time of a 3-stage node is necessarily considerably higher than that of a 2-stage node because of the extra minimum green and intergreen. Therefore, SCOOT would not be able to run at as short a cycle time as MOVA, which controlled each junction as a 2-stage node. Examination of a selection of the inter-peak SCOOT link degrees of saturation showed only limited scope for reducing the cycle time. However, it would be expected that SCOOT would operate with a maximum cycle time (60 seconds in this case) rather than with a fixed cycle time.

With MOVA timings could vary considerably from cycle to cycle, but the average cycle time by period of the day are shown in Table 6-2 (based on the SCOOT M37 message), where it can be seen that MOVA operated with considerably shorter cycle times, and hence green times to individual approaches, than did SCOOT, particularly during the inter peak period.

Table 6-2: Average MOVA cycle times (s)

	H5111	H5112	H5113	H5114
AM Peak	50.0	46.5	57.5	52.6
Inter Peak	44.7	40.4	42.9	43.2
PM Peak	46.3	53.9	53.1	51.2

The average proportion of green time assigned to each stage showed some small variations with control strategy, but no large differences. On average the control systems agreed on the proportion of green time needed by the entry links and circulatory links as would be expected if both systems were correctly set up. The problem with SCOOT using a loop over two lanes will not affect the average green time to a stage in a correctly validated system, but will affect the accuracy of green allocation in an individual cycle.

6.5 Lock up

Before the refurbishment, the roundabout had a history of occasional severe problems triggered by incidents. It could lock up for significant periods, up to 2 hrs, due to an incident such as a breakdown. MOVA with all of the priority linking has been engineered to keep the circulatory traffic moving. Although MOVA has only been running for about 9 months there have been no instances of roundabout lockup, in the past it has happened perhaps once or twice per annum.

7 Conclusions

The signalised roundabout at junction 6 of the M42 has been successfully converted to MOVA control.

The design of the SCOOT control could have been improved by using a detector on each lane of the signal controlled approaches and modelling each lane as a separate SCOOT link. This approach would more accurately represent the queuing behaviour at such a roundabout where the signing directs drivers to the appropriate lane for their exits. The signing had been improved as part of the modernisation when installing MOVA.

The roundabout has been assessed using the occupancy per vehicle of the MOVA detectors as a proxy for delay. The resulting figures were analysed by the analysis of covariance technique to allow for the effects of different flow levels on different days.

The conclusion from the analysis of the data was that MOVA reduced the delay at the roundabout. Statistically significant reductions of 6% in the weekday inter peak and 10% on Sundays were achieved. Reductions were measured at the other times of day surveyed, but were not statistically significant. Further data collection would be required to obtain statistically significant results. As expected, analysis based on the SCOOT modelled delay was more favourable to SCOOT than that based on the detector occupancy per vehicle measure. They are, however, considered to be unreliable because of the inaccurate modelling due to the use of one loop over two lanes.

The greater freedom of MOVA control to vary the timings from cycle to cycle and from junction to junction resulted in appreciably shorter green times, particularly away from the peak periods, than did SCOOT control, which was operated under the existing policy of a fixed 60 seconds cycle time. If SCOOT had been able to vary the cycle time, there would have been limited scope for operating at a lower cycle time because of the use of a 3-stage multi-node.

It should be noted that the results quoted here apply to just M42 Junction 6, which is an unusually large motorway junction roundabout. Further trials are needed before general conclusions can be drawn. In addition more research and trials, or possibly simulation, is needed on the benefits of operating SCOOT with one loop per lane where lane use is controlled by detailed signing.

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Abstract

This report provides the results of a comparison survey of SCOOT and MOVA traffic signal control at the signalised roundabout of Junction 6 of the M42.

M42 Junction 6 is a major intersection with the A45 and the National Exhibition Centre (NEC) entrance. It was refurbished in 2006 and the traffic signal control changed from SCOOT to MOVA, with the SCOOT control still operational. The junction, therefore, provided a test site to compare SCOOT and MOVA control of a large roundabout.

The roundabout was assessed over a 6 week survey period using MOVA detector data. The conclusion from the analysis of the data was that MOVA reduced vehicular delay. Statistically significant reductions of 6% in the weekday inter peak and 10% on Sundays were achieved. It should be noted, that some recommendations were identified that may have improved the SCOOT control; and these results apply only to this junction, further trials/ simulation at different sites are needed before more general conclusions can be drawn.

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