Fixed Time v Single Stream MOVA Control on a signalled roundabout

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In this case study of the Hobby Horse roundabout in Leicester a comparison, in terms of average delay during AM and PM peaks, is made between full roundabout coordination using Fixed-Time, and adaptive control using single stream MOVA. Microsimulation software (VISSIM) is used as the platform for this comparison whilst LinSig and PCMOVA have been used to configure Fixed-Time and MOVA control, respectively. In this case the microsimulation reveals that Fixed-Time is more effective than single stream MOVA at reducing delays. It is suggested that the increased benefits provided by Fixed-Time originate from the greater proportion of green time available to the approaches than is possible using single stream MOVA. This in turn allows Fixed-Time to offer greater capacity and therefore reduce delays.

INTRODUCTION

It is roughly thirty years since the installation of the first fully signalled roundabout in Nottingham (Davies et al 1980), and signalled roundabouts are now an everyday occurrence in both traffic engineering and British motoring. Roundabouts were conventionally give-way controlled, but part signalisation of larger roundabouts has been used for many years, and full or nearly full signal control is increasingly found at medium as well as large roundabouts. Signalled roundabouts offer benefits in terms of capacity and safety.

One method of control for signalled roundabouts is the use of Fixed-Time plans working either through the UTC (Urban Traffic Control) area or by local CLF. A set of timings for an average cycle would be produced for each flow period, for example, the AM peak, and the controller would repeat the same timings for each cycle in the flow period. Fixed-Time plans will degrade over time as traffic flows vary, one of the reasons why Fixed-Time plans have often been replaced by adaptive control. Adaptive control in the UK is currently dominated by SCOOT (Split Cycle Offset Optimisation Technique) and MOVA (Microprocessor Optimised Vehicle Actuation), both developed by the TRL (Transport Research Laboratory) Ltd.

MOVA can be used at isolated junctions or linked junctions and generates optimised signal timings on a cycle-by-cycle basis depending on volumes of traffic detected on the approaches. Although SCOOT is more common in urban networks, MOVA control is typically found at the more isolated junctions. Whilst adaptive control optimises timings to meet detected demand, it is not documented how and if this form of control can overlap timings at signalled roundabouts or if this is a special characteristic easily implemented using Fixed-Time control. This method of overlapping green times involves starting vehicles further back around the roundabout before the approach green period has ended, in order for them to arrive at the circulating stopline just as it has turned green. Hence, depending on the size of the roundabout, two entries may be green at the same time, achieving improved efficiency.

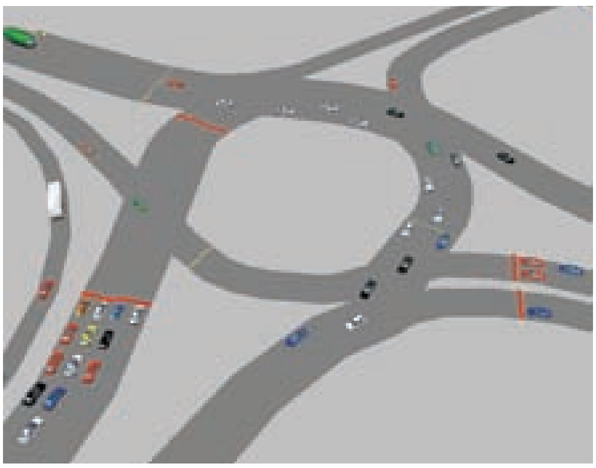
MOVA has been implemented at a variety of junctions and according to TRL Research Report 279 an average 13 % delay reduction is possible with MOVA control. MOVA has now become a popular option for controlling junctions. TD35/06 (DMRB 2006) states

'All new all-purpose trunk road installations shall incorporate MOVA as the standard method of control, if MOVA is not to be used, then a sound case for departure from the standard must be made and approved.'

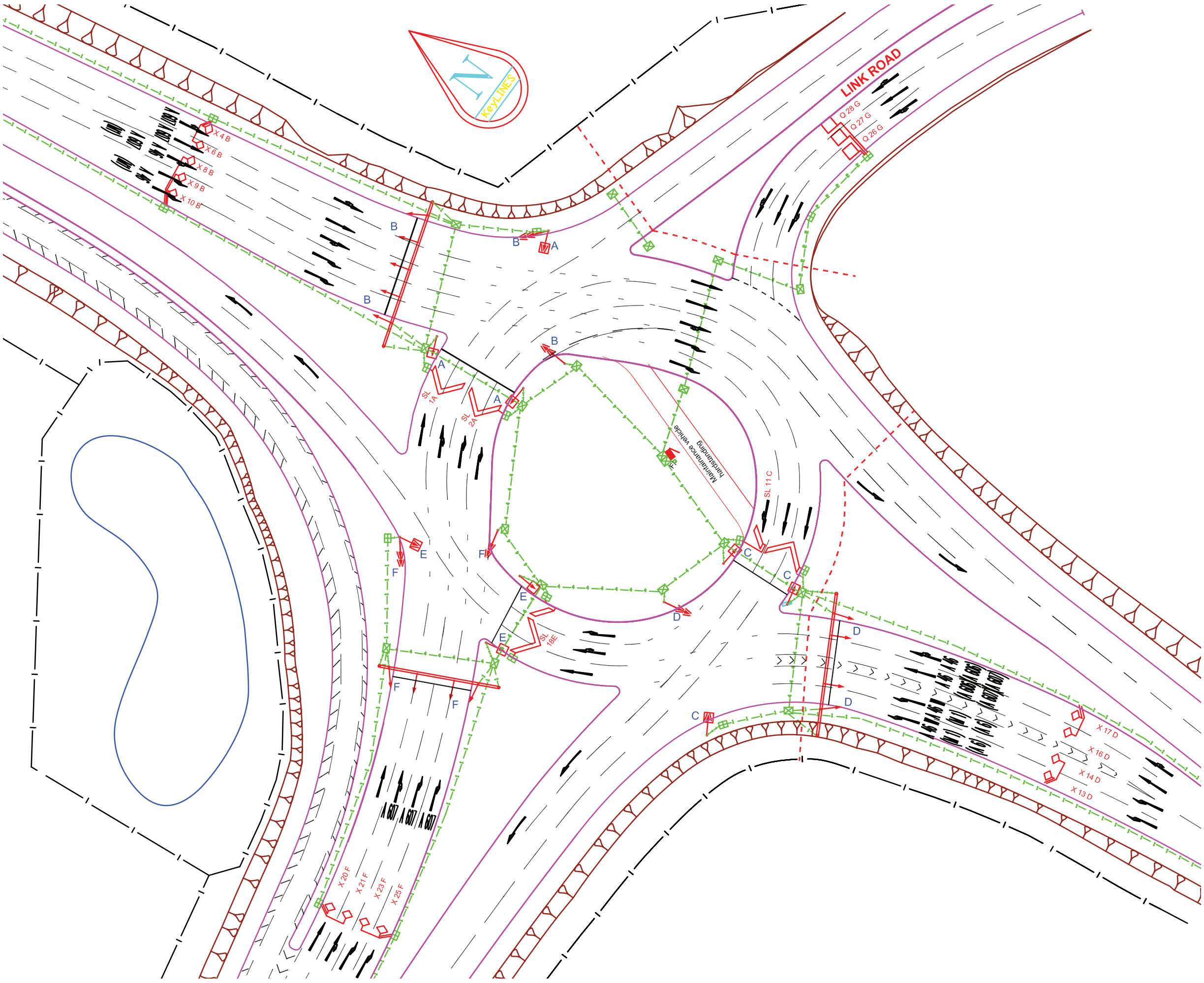
It is not clear whether this standard relates to signalled roundabouts, or if it is prescribed for solely isolated junctions, there being no mention of roundabouts.

The objectives of this study are to measure the differences in terms of delay between Fixed-Time control and single stream MOVA control by obtaining the best possible settings for each mode to enable a fair comparison.

In order to make the research as realistic as possible, a case study approach was chosen. A trunk road signalled roundabout was selected currently operating under MOVA control. The roundabout is situated at the A46/A607, north of Leicester, part of the A46 Leicester Western Bypass, a major route



VISSIM microsimulation model screenshot



Current layout provided by Leicester City Council

for connections to the M1 to the west and links through to the east towards Newark and Lincoln. The junction was upgraded in 2006, adding more lanes, improving alignment and implementing MOVA control at a cost of approximately £3.5 million. The roundabout has four arms, three of which are signalled (the A46 to the north and west, the A607 to the south), and a local access road to the east operates under give way control. The movement from the A46 West to the A46 North has a free flow left turn lane that meets the remainder of the A46 Northbound traffic beyond the junction.

Large variances in the arrival profile of traffic should favour MOVA control as it can vary green times, as opposed to Fixed-Time in which the green times are fixed. To replicate the situation occurring on street, minute-by-minute arrivals were recorded on the three main signalled approaches. In order to include these factors in the modelling process, VISSIM was chosen as the microsimulation tool as it allows flows to be specified in varying time segments including one minute intervals. VISSIM is a microsimulation tool produced by PTV Traffic in Germany.

Roundabouts vary significantly in terms of flows and geometry, and whilst the findings of this study won't necessarily apply to all other roundabouts, it should open discussion for roundabouts with similar properties and geometry.

FIXED-TIME CONTROL

On stand-alone junctions Fixed-Time is a straight-forward and more basic form of traffic signal control, but on a signalled roundabout Fixed-Time control can be used to provide sophisticated linking. A Fixed-Time plan is a timed sequence of stages that satisfy all traffic demands during a single cycle. The length of the stages and the cycle time are normally set using traffic signal calculations based on measured traffic flows through the junction. As traffic flows vary at different times of the day and week, separate Fixed-Time plans can be created to cater for each variation in flows.

Ideally all downstream signals should be co-ordinated with the upstream entry signals, so that no stopping on the gyratory is required (IHT1997). Since signalled roundabouts generally need to cater for traffic movements in all directions, an intricate set of timings are required to facilitate this.

In order to create a set of effective Fixed-Time plans, various procedures must be followed, firstly lane flow diagrams must be produced for each modelled flow period. A lane flow diagram shows the volume of traffic on each lane throughout the junction, distinguishing where it is travelling from and to. The diagrams are created by following the movements vehicles can make using the lane markings on a junction plan. Lane flow diagrams can be produced by hand, using MS Excel or within LinSig.

For this case study the lane flow diagrams were produced using LinSig. An O/D (Origin and Destination) matrix was used to input the flows for each flow group, and the flows were then balanced. This process balances all lane flows on the entry to the network, in this case the approach to the roundabout. Once the model was checked for any inappropriate routes (routes that pass over an arm more than once), the flows were then rebalanced to ensure realistic vehicle behaviour. LinSig can optimise for either Practical Reserve Capacity (PRC) or Delay, although coordinating a very small network such as a roundabout is an iterative process, currently requiring intelligent manual interaction.

The Hobby Horse roundabout conforms to a particular design methodology which has only three signalled nodes. The reason for this is that with three signalled nodes it is possible to achieve front and tail end coordination through the roundabout, such that only the traffic coming from the fourth arm (give way node) will have to stop on the circulatory carriageway. Hallworth (1992) suggested that in order to ensure green efficiency (and hence capacity) with coordination, the optimum cycle time is a direct function of the average travel time to circumnavigate the roundabout (Optimum Cycle Time equals twice the average travel time).

For this roundabout, the cruise times between each pair of nodes has been estimated at about 6 seconds (equates to a speed of approximately 10 meters per second). Hence the total time to navigate the roundabout will be 24 seconds and therefore the optimum cycle time will be around 48 seconds. The optimum cycle time holds true if all approach greens are of similar length. However, where entry green varies, this will have an effect on the optimum cycle time and as a result values around the optimum cycle time should be tested.

In this case the A607 entry turns out to be the critical node, and with a cycle time of 44 seconds, a 7 second green can be given to the approach, which balances the degree of saturation on the entry and circulatory links at this node. If a cycle time any lower than 44 seconds, was employed it would still be necessary to give a 7 second minimum to the approach links which would result in a higher degree of saturation on the circulatory link, and failure to balance the worst degree of saturation. Hence 44 seconds can be considered a sensible minimum cycle time for the AM peak.

A PM peak Fixed-Time plan was created using the same method as the AM peak, although a cycle time of 48 seconds was chosen as the PRC was slightly higher than at other cycle times. In this peak there is a higher proportion of traffic turning right from the A607 into the local access road, hence there are slight queues (approximately 2 or 3 PCUs) at the circulatory stopline crossing the A46 North Approach.

MOVA CONTROL

In order to model the current MOVA design in VISSIM it was necessary to obtain the MOVA Datasets and detector positions for the junction. These were kindly provided along with a plan of the layout by Leicester City Council.

Under MOVA control the junction operates as one stage stream with four main stages. Essentially the main traffic demands are controlled by Stages 1, 3 and 4, each of which runs one of the three signalled approaches to the junction. Stage 2 is linked to the give-way arm and runs to create a larger gap in circulatory traffic if this traffic is queuing.

A VISSIM model was created for this study of the Hobby Horse Roundabout. A total simulation of 5400 seconds (1 1/2 hours) was chosen in order to allow for a 1800 second (30 minute) start up period, where the flows could get started and the control method could settle down, followed by an hour for testing. The VISSIM dynamic assignment tool was used to input flows into the model. Dynamic assignment, as such, wasn't required as there is only one route each vehicle can take to get from zone to zone; but it meant that the flows could be input directly as OD matrices. If the dynamic assignment tool hadn't been chosen, it would mean the flows had to be input separately for each movement for every flow group, and with 61 flow groups required (60 for each minute of the test period and 1 for the start up period) this would have been very time consuming. MS Excel was used to create a text file for each of the 61 flow periods, for both peak periods, these were then imported into the VISSIM model. In order to test that VISSIM was releasing traffic as required, the model was run whilst data was collected on vehicles entering the network. The data was analysed and compared with the flows observed on site, the result of which for the A46 North approach is shown in Figure 1. The first 1800 seconds of the start up period were defined by just one matrix, here the first section of the graph displays how traffic would have been released by VISSIM had just one matrix been used for the entire test period. The results of the test period compared very closely with the flows observed on street, with the slight differences likely to be due to HGV counting. The differences between the start up period and the test period are interesting and show that in order to get a valid comparison, such information should be acquired to build into the model.

Once the model was running, it was checked thoroughly to ensure vehicles were behaving as expected. Allowed routes were altered in order to ensure vehicles used the correct lanes and routes to get to their required destination. Cruise speeds on small roundabouts are generally calculated at about 10m/s, and measurements taken between nodes on the roundabout matched these assumptions. Due to time constraints cruise speeds and saturation flows were not measured on site, but it was considered that as the same model would be used for both methods of control, the fact that it may not exactly match the situation on street, would have limited affect to the outcome of the study. Saturation flows were measured from the VISSIM model in order to validate the MOVA Dataset as discussed in the next section, these compared favourably with typical values you would expect to find in this kind of situation on street, although no parameters that would alter driving behaviour and consequently saturation flows have been altered in the model.

Once the model was calibrated the preferred set of fixed plan timings were set in one copy of the model, and the MOVA dataset was linked to the other model.

Using PCMOVA the dataset was linked to the VISSIM model. PCMOVA required some extra data such as stages, intergreens and phase delays in order to complete the connection. According to the TRL (2008) the two MOVA dataset parameters that have the biggest impact on MOVA operation are the saturation flow value (SATINC) and the cruise speed value (CSPEED), and suggests these two parameters should be measured not guessed. SATINC is the headway time between vehicles discharging at saturation flow and CSPEED is the speed of free-flowing vehicles approaching the junction towards the end of green after the queue has discharged. The current MOVA dataset showed these values to be set at the default program parameters. These parameters were measured based on traffic behaviour in the VISSIM model and then the dataset adjusted to include these values. A slight reduction in average delay was observed with these revised parameters.

The MOVA simulation model was running long cycle times around 90 seconds, this was also observed on street.

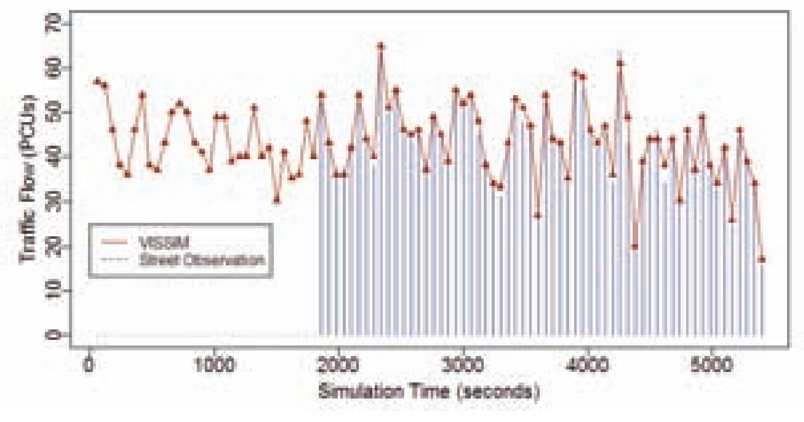
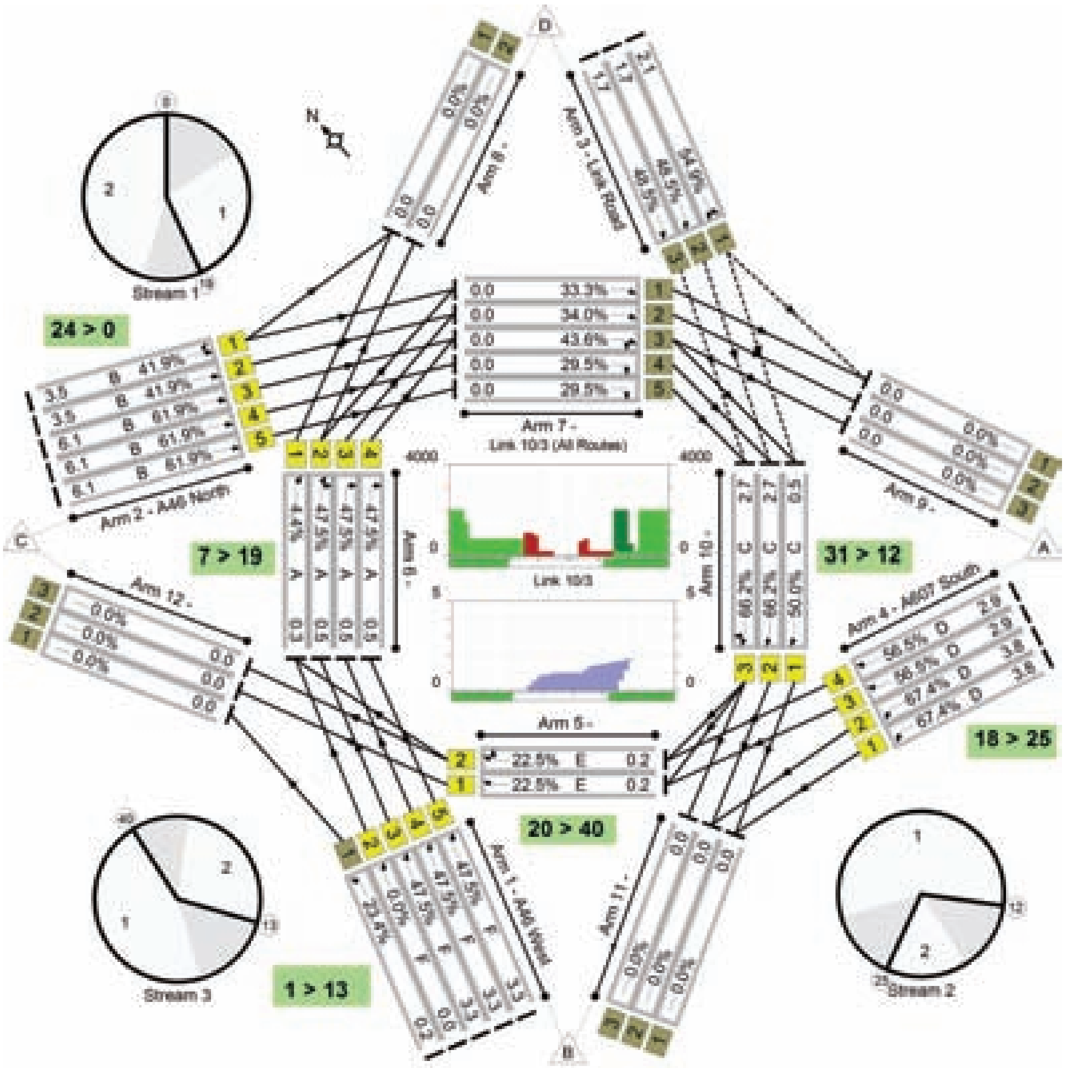


Figure 1: VISSIM Flow arrivals compared with observed arrivals



Junction layout view from LinSig, showing degrees of saturation, timings and timing dials.

Despite this correlation, in order to operate closer to the natural cycle time and in order for MOVA to stand a chance of getting the same performance as the Fixed-Time model, it was decided to alter the MOVA Dataset in order to reduce the cycle times. The MOVA Control manual suggests the TOTALG value (the total green MOVA is allowed to distribute to traffic), is reduced in order to force MOVA to run short cycles. TOTALG was tested at a range of values settling at 36 as the setting with optimum performance. When evaluating MOVA control in VISSIM, the time at which MOVA takes control of the junction varies in every run, which means the results are never exactly the same. This is why the values fluctuate slightly around the optimum value of TOTALG. Tests could have been repeated at these values in order to find the best TOTALG value, but this wasn't the point of the study, and would only have negligible impact on the results. The figure of 36 seconds was chosen for TOTALG which resulted in cycle times reduced to around 56 seconds.

Since SATINC and CSPEED are the parameters that have the biggest impact on MOVA operation, and since the author has no previous experience of measuring these values, a sensitivity test was carried out. Each of the values was altered by +\- 1 second, to see if the results improved. Since the MOVA results altered in every run, due to the time at which MOVA takes control, the results weren't clear cut, but after a reasonable number of runs it was found that the parameters derived by the author produced the best results in terms of delay per vehicle.

VISSIM has the ability to extract all kinds of data from the model, the difficulty comes in analysis. Analysing the data for the Fixed-Time model is fairly straightforward, an added complication is the varying random seeds which cause a stochastic variation of input flow arrival times. However, with MOVA the results change in every MOVA run due to the time at which MOVA took control of the roundabout, before you even consider multiple runs for varying random seeds. For simplicity average delay per vehicle (in seconds) was chosen as the value that would be used to compare the different control methods.

METHOD OF ANALYSIS & RESULTS

Samples of results for the average delay were taken for a variety of scenarios as shown in Table 1. Sample sizes for each scenario are small because of the time required to process each micro simulation and statistical errors are therefore treated according to the student's t test.

Despite the fact the roundabout had been set-up using normal Highways Agency approved procedures, improvements to the MOVA dataset altering the value for TOTALG resulted in a reduction of the cycle time and improved average delays per vehicle of 16.4% (from 28.1 to 23.5 seconds).

MOVA delays were then much closer to those of Fixed-Time in the AM peak period, but the Fixed-Time method offered a further 14% reduction in delay (23.5 to 20.2 seconds) over MOVA control.

The comparison between MOVA and Fixed-Time control methods was also compared for the PM peak, with a reduc-

Scenario	Mean Average Delay per Vehicle (secs)	Error (secs)
Original MOVA model (AM Peak)	28.1	1.0
Optimised MOVA model (AM Peak)	23.5	0.3
Fixed-Time Model (AM Peak)	20.2	0.2
Optimised MOVA model (PM Peak)	21.5	0.2
Fixed-Time Model (PM Peak)	19.7	0.3
Optimised MOVA model (AM Peak + 25%)	36.2	0.9
Fixed-Time Model (AM Peak + 25%)	30.7	2.1

Table 1: Summary of results

tion in flow which saw Fixed-Time reduce delays by 8.4% more than MOVA control (21.5 to 19.7 seconds).

The flows were increased by 25% on all approaches for the AM Peak period in order to test the flexibility of the Fixed-Time timings. In this situation Fixed-Time still offered a reduction in delays of 15.2% over the MOVA method of control (36.2 to 30.7 seconds). Given that Fixed-Time performed better than MOVA even with this increase of traffic, the capability of a Fixed-Time plan to cater for varying demands is highlighted. In this test, the traffic flows were increased at the same level across the whole junction. For optimum performance the green splits would be expected to stay at the same proportions, although a different cycle time may improve capacity. As MOVA has the opportunity to change cycle time, it may have been expected that MOVA would have performed better under this test. The Fixed-Time model was constrained with a cycle time of 44 seconds, and MOVA was only constrained by TOTALG. MOVA could have been struggling due to the constraint implemented by TOTALG, so a test was carried out with TOTALG increased from 36 to 50 seconds, and no change in the result was found. This lead to the conclusion that TOTALG was not constraining MOVA and that its performance was optimal.

The main difference in Fixed-Time and MOVA control, under a single stream, is that the MOVA method cannot overlap green times or intergreens, as it is effectively being controlled as a T-junction with each approach running in a separate stage and the intergreens associated with this. Under Fixed-Time control with a carefully coordinated set of timings, the entry greens are fixed so that lost time is kept to a minimum.

The results from the VISSIM testing show that Fixed-Time control would reduce average delays with the flow scenarios tested, how relevant these flows are to the variability found on street is not known and requires further investigation.

GREEN EFFICIENCY

To establish the reason for the improvement in performance of the junction under Fixed-Time control as opposed to MOVA, the lost time under each method of control was compared for the AM Peak models. The cycle time for the Fixed-Time AM peak model was 44 seconds and the average MOVA cycle time was 56 seconds. The sum of all the entry green time periods for the Fixed Time model was 40 seconds, out of a possible 44 second cycle time, leaving a lost time of 4 seconds, where none of the approaches are green. However under the MOVA method of control the sum of all the entry green time periods is 40 seconds, out of a possible 56 second cycle time, leaving a lost time of 16 seconds in every cycle. To take into account the differences in cycle time a method similar to that used by Hallworth (1992) was implemented. The total green time was multiplied by the number of cycles in the hour for each method of control and then divided by the number of seconds in the hour to give a green efficiency ratio. A ratio of 1 would mean that there was no lost time at all. It would be possible to have a ratio of greater than 1 if green periods overlapped. In this Fixed-Time example, the A46 North approach and the A607 approach are green at the same time for a couple of seconds, however there is small element of lost time between other movements. The green efficiency for the Fixed-Time method was 0.89, and 0.71 for the MOVA method. This is a considerable difference and explains why the Fixed-Time method, so effortlessly improves upon the MOVA method of control due to the fact that for every cycle a higher percentage of green time is available to traffic than under MOVA control.

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CONCLUSIONS

The objective of this study was to assess whether the benefits gained from adaptive signal control outweigh the special properties of Fixed-Time signalled roundabouts associated with the overlapping of entry greens. This study has found that adaptive control in this situation controlled by a single stage stream, couldn't reach the benefits attained by Fixed-Time control and its ability to provide a higher proportion of green time for every cycle.

As a result of this study improvements can be made to the Hobby Horse roundabout through method of control. Although these results are only for a single roundabout, they still arguably raise serious questions for the industry. It has been suggested, but not documented, that MOVA experts are now able to replicate Fixed-Time coordination using Linked MOVA. Unfortunately a scarcity of expert knowledge at this point in time, is likely to result in MOVA installations that don't rise to their true potential. At this point of flux in the industry it seems irrational to prescribe MOVA for all trunk road roundabouts, without any documentation on how MOVA can be linked successfully, when a Fixed-Time plan could be a worthy competitor.

Brian and Helen Simmonite are investigating linked MOVA possibilities at this roundabout and will report back to *Traffic Engineering and Control* with their findings.

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FURTHER INFORMATION

This paper is based on Helen's master thesis, please email helen.simmonite@jctconsultancy.co.uk or telephone 01522 751010 for further information or a copy.

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