Responsive Linking for MOVA at A64/ A1079 Grimston Bar

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1. Background/ Concept

Having designed and validated a number of Linked MOVA installations at signalised roundabouts, I found one aspect often to be problematic. This is the priority linking between streams at the roundabouts.

Intersections at a signalised roundabout can be contained within the same stream (in which case the stop-lines are rigidly linked via phase delays in the controller), or they can be configured in separate streams. Configuring intersections in separate streams allows a greater degree of flexibility, as they can be linked or un-linked (useful in low-flow, off-peak conditions) as required.

Linked operation between streams is desirable when traffic demand is high enough and a large percentage of traffic travels directly to the downstream circulatory stop-line.

Un-linked operation is generally desirable at time of lower traffic flow, and particularly on high speed entry approaches where vehicles can be 'cut off' due to a conflicting priority demand (forcing the circulatory phase) if linking is applied.

Not cutting vehicles off, or not putting drivers on high speed entry approaches in the 'dilemma zone' is an important safety feature in MOVA, allowing vehicles on high speed approaches (slip roads for example) to pass through the signals on green (by setting STOPEN high). When priority linking is applied to the conflicting circulatory carriageway, it can ‘cut off’ the green signal on the high speed entry, increasing the risk of a driver being caught in the dilemma zone and running a red light. This can present an unwanted side effect of the linked system.

MOVA operates most safely on high speed roads when linking is not used, as the system is then free to identify individual vehicles on the approach and make the best decision as to when to close green on the high speed entry. However, sometimes it is necessary to link successive internal stop-lines at roundabouts to achieve platoon progression from the upstream stop-line.

I have also observed linking causing unnecessary delays on entry approaches. These unnecessary delays when linking is on are in part attributable to the ‘ON Delay’ timer which is necessary to maintain co-ordination during the peak periods, but cause additional delay for entry approach traffic during periods of lower traffic demand.

The following ways of controlling the application of Linked MOVA are available:

- Priority Facility code in MOVA dataset
- MOVA Timetabling
- Timetabled Priority Detectors from Traffic Signal Controller
- ON permanently for the duration of the upstream green
- ON permanently, but on only for duration of upstream saturation flow (Siemens special conditioning codes for ST950 ESLI)

The most desirable situation is where the linking is turned on for a suitable period of time in response to an increase in traffic demand. This ensures that drivers become accustomed to the linking being OFF during low flow off peak conditions but ON during high flow peak traffic demand periods.

2. Aims and Objectives

1. Controller to calculate in real-time when linking between streams should be introduced and removed
2. To reduce instances of red running when vehicles are ‘cut off’ on an approach
3. To reduce vehicle delays by removing linking when not required
4. To better control times of unexpectedly high traffic demand
5. Automate the application of MOVA linking so that it is not reliant on timetables or time clocks, reducing occurrences where the wrong setting of the controller time clock applies linking unnecessarily.

Figure 1 – Aerial Photograph of A64/ A1079 Grimston Bar Interchange

Figure 1 above shows an aerial view of the A64/ A1079 Grimston Bar interchange. Tidal flows are experienced at the interchange, with the dominant traffic flows travelling westbound towards York during the AM peak and eastbound during the PM peak towards Bridlington (A166) and Hull (A1079). Although the largest traffic volumes are present during the AM and PM peaks, significant traffic flows are experienced throughout the day.

3. M1 Junction 33 scheme

I briefly assisted Joel Dodsworth with the implementation of his scheme which used traffic feedback to influence MOVA linking timers at the M1 Junction 33 Catcliffe interchange. Joel used occupancy data from Sheffield City Council's UTC system and oversaturation flags from the local Gemini MOVA unit to determine the congestion state of the junction. Five congestion states were used ranging from Light to Heavy, each of these states altered timers to maximise capacity at a downstream flared section and also hold back traffic from upstream nodes.

I was impressed the use of congestion states to influence the operation of the interchange and decided to adapt this method for a different purpose at the A64/ A1079 Grimston Bar interchange.

4. Technical Details – A64 Grimston Bar Control Strategy

I specified 3 congestion modes to influence the strategy:

Cycle Time (CY)	***Condition selection***
< 50s	***Condition 1 – Light***
50s > 65s	***Condition 2 – Medium***
> 65s	***Condition 3 – Heavy***

I decided that the variable which determined the congestion mode would be the cycle time of salient nodes at the roundabout. In the AM peak this would be the Eastern side of the roundabout and conversely in the PM peak the western node would determine the congestion mode in line with the tidal flows experienced in and out of York at the interchange.

As MOVA is an adaptive control system, its cycle time varies from cycle to cycle. This effectively provides a source of real time feedback on the congestion state at the junction.

I specified that the controller would monitor the cycle time ran at these intersections and that this would trigger any congestion state change and hence linking between intersections.

The cycle time of salient nodes at the interchange is monitored, and if these are lower than pre-set threshold values, then no linking between intersections is applied.

If the cycle time meets or exceeds the pre-set threshold value, then linking is applied to the relevant downstream intersection. The cycle time assessment periods were initially as defined as 5 minute intervals throughout the day.

Two threshold levels of cycle time were specified, above which Medium and Heavy congestion states would run. These threshold values were set via special conditioning timers in the controller and were initially set to 50s and 65s.

I specified that the linking would be 'ON' during Medium and Heavy modes (if cycle time values were above 50s or 65s) and that the linking would be 'OFF' during Light mode (if the cycle time was below the threshold value of 50s).

5. Issues/ Problems encountered

One obstacle encountered during the design/ FAT phase was that the measured cycle time during some off peak periods would read very high, due to the fact that no opposing demands were present.

This was overcome by including in the special conditioning that the cycle time reading would be ignored if no opposing demands existed.

6. System Evaluation Tools

- Time monitoring records of congestion states
- Red running Surveys (Responsive Vs Timetabled) on high speed entry approaches
- Vehicle Delay surveys (Responsive Vs Timetabled) on entry and circulatory approaches

7. Data Collection - Manual Traffic Surveys

Manual traffic surveys were carried out at the site to collect the following data:

i. Incidences of red running on entry approaches
ii. Vehicle Delay
iii. Congestion Modes during peak periods and throughout the day

The manual surveys were carried out over two separate visits, one in the school holidays (Tuesday 11th and Wednesday 12th August 2015) and one when the schools were back (Tuesday 8th and Wednesday 9th September 2015)

On the first day the system was observed running with the responsive linking and on the second day observed running under the traditional timetabled linking method. This gave a direct comparison of the two systems both in terms of reduced vehicle delay and incidences of red light running.

The A64 northbound entry intersection and A1079 East controller were surveyed during the AM peak period (0630 – 0930). The A64 southbound entry intersection and A1079 West controller were surveyed during the PM peak period (1545 – 1845). On the timetabled day, the linking was applied by default throughout these time periods. On the responsive day, the controller was free to decide when the linking should be applied.

8. Red Light Running Vehicles Incidence Results

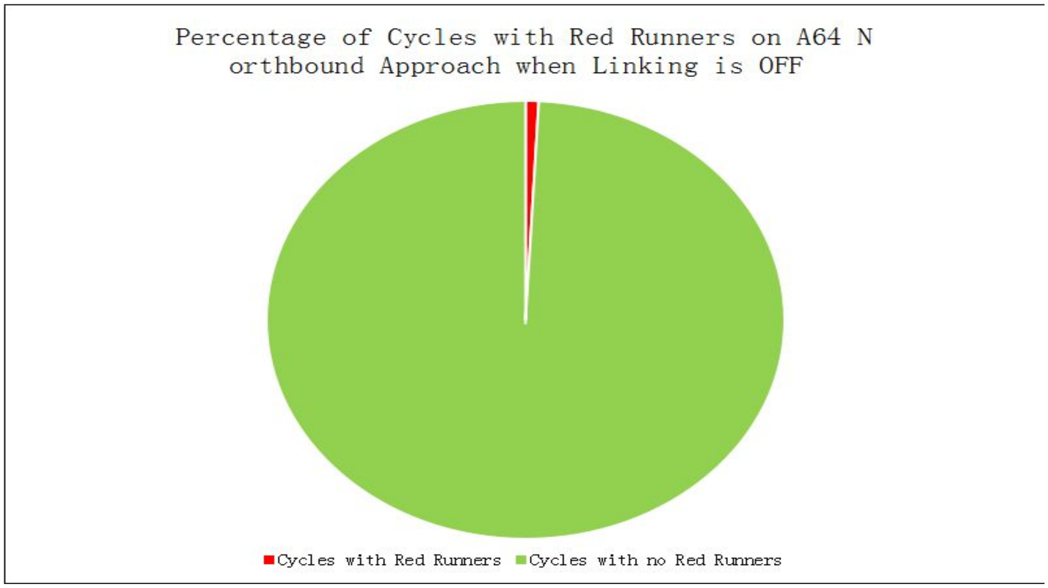

Figure 2 –Red Runners during times when no linking is applied to A64 Northbound entry

Figure 2 above shows the percentage of cycles on which at least one red running vehicle was recorded when the linking was off during the responsive days (11th August and 08th September) on the A64 Northbound entry. The sampled time was 101 minutes with a total of 122 cycles observed and 1 red running vehicle recorded. This equates to at least one red running vehicle being present on 0.8% of cycles or an average of 0.5 red running vehicles per hour.

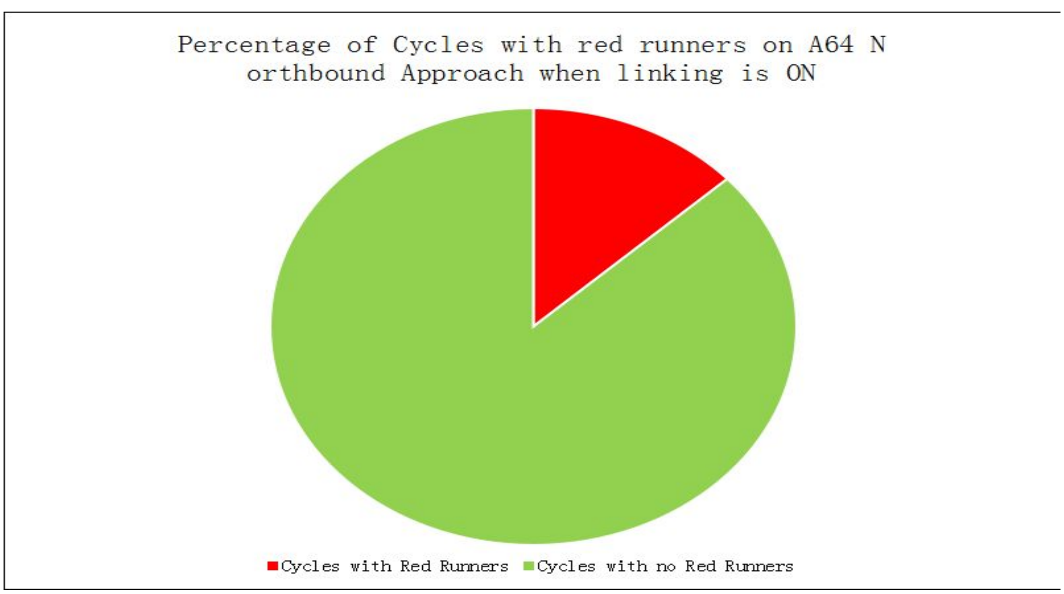

Figure 3 – Red runners during times when linking is applied to A64 Northbound entry

Figure 3 above shows the percentage of cycles on which at least one red running vehicle was recorded when the linking was on, potentially cutting off vehicles on the A64 Northbound entry approach. The sampled time was 266 minutes, 273 cycles were observed with 36 red runners recorded. This equates to at least one red runner being present on 13% of cycles, or an average of 8 red running vehicles per hour.

This sample includes data from both the responsive and timetabled days (11th, 12th August and 8th, 9th September), but only during times when the linking was on.

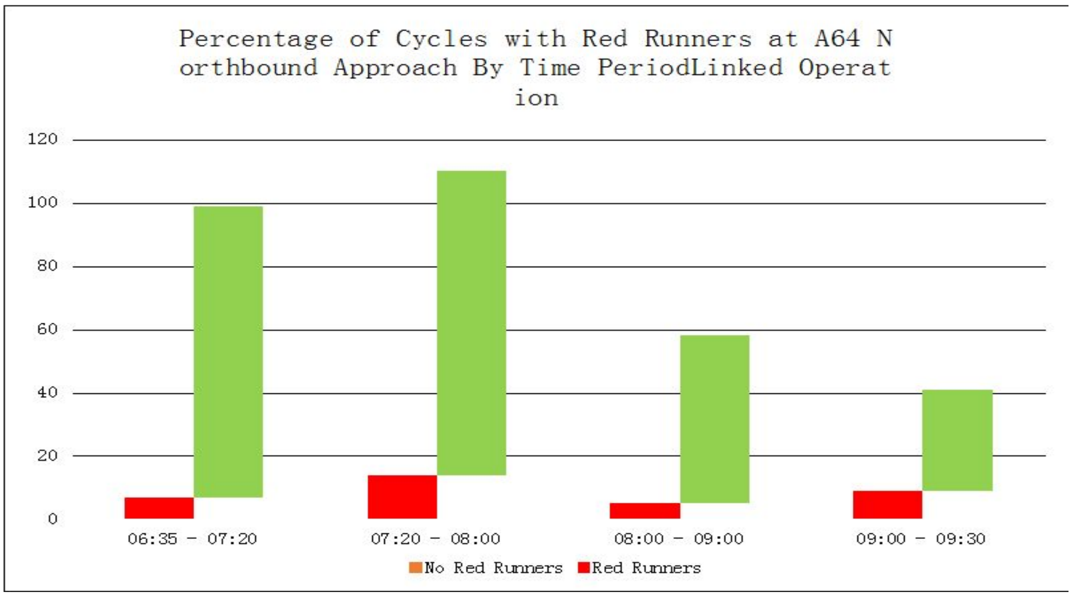

Figure 4 – Percentage of Cycles with Red Running vehicles by Time Period– Linked

Figure 4 above shows the percentage of cycles which contain red running vehicles by time period. There is a larger percentage of cycles with red running vehicles in the time periods directly preceding and following the 8am – 9am period. During time periods 07:20 – 08:00 and 09:00 – 09:30 red running vehicles are present on 14% and 28% of cycles sampled respectively, this is compared to time periods 06:35- 07:20 and 08:00 – 09:00 where red running vehicles are present on only 7% and 9% of cycles sampled respectively. These records span a total of 266 minutes, 273 cycles were observed with 36 red runners recorded.

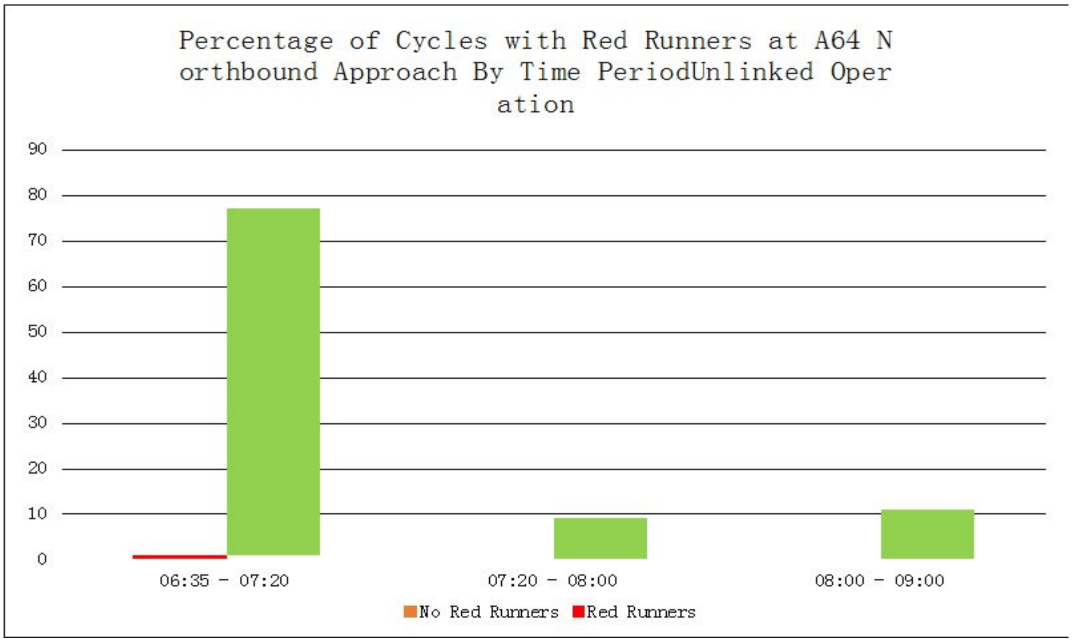

Figure 5- Percentage of Cycles with Red Running vehicles by Time Period – Unlinked

Figure 5 above shows only one red running vehicle was recorded when the streams were operating independently, this occurred between 06:35 and 07:20. These records span 101 minutes in total and 122 cycles.

9. Congestion Mode and Cycle Time Monitoring Results

One of the most important variables recorded was the times during at which the linking between streams was ON and OFF and also the duration of any ON times. This allowed the vehicle delay and red running vehicle results to be interpreted in relation to the linked Vs unlinked modes.

The surveys allowed typical ON/ OFF time profile and durations of the linking system to be plotted against the time of day. The graphs below at Figure 6 to Figure 10 show that the presence of the linking followed a distinct pattern in response to traffic demand.

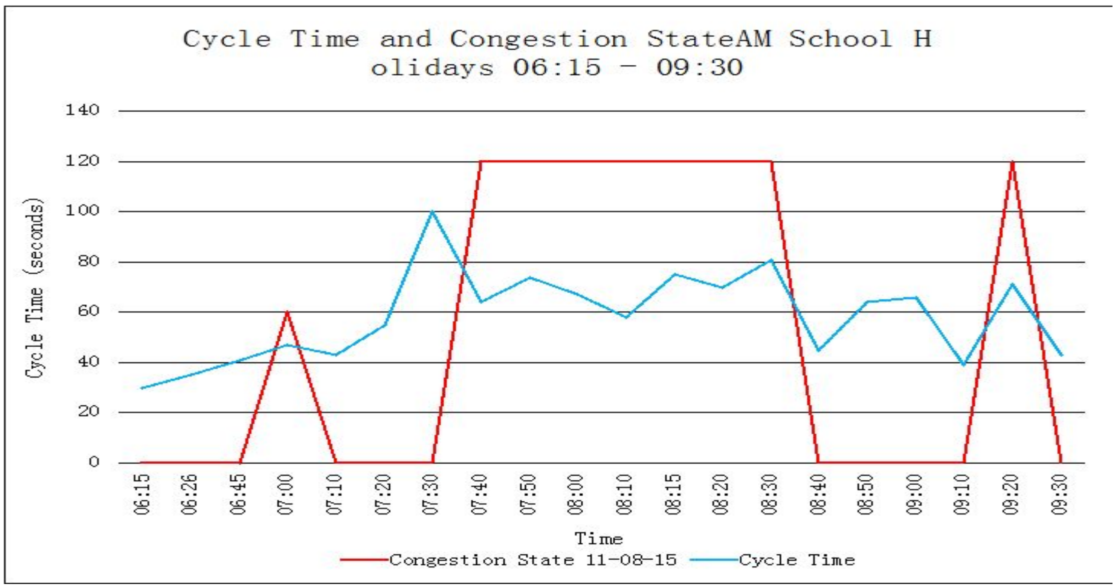

Figure 6 – Congestion State and sampled Cycle Time from East Controller during AM peak (linking is applied to the A64 Northbound entry node when red line is High or Medium) – Responsive Mode

Figure 6 shows the recorded congestion mode at the interchange and the sampled cycle time at the East controller during the AM peak period on 11th August 2015. This shows that the interchange was briefly in Medium congestion mode around 07:00 before reverting back to Light mode until 07:30. The interchange is then in Heavy congestion mode consistently from 07:40 until 08:30 before dropping back to Light mode at 08:40. The Medium Cycle time threshold used here was 50s and the Heavy was 65s. The sampled cycle time shows a good correlation with the congestion mode.

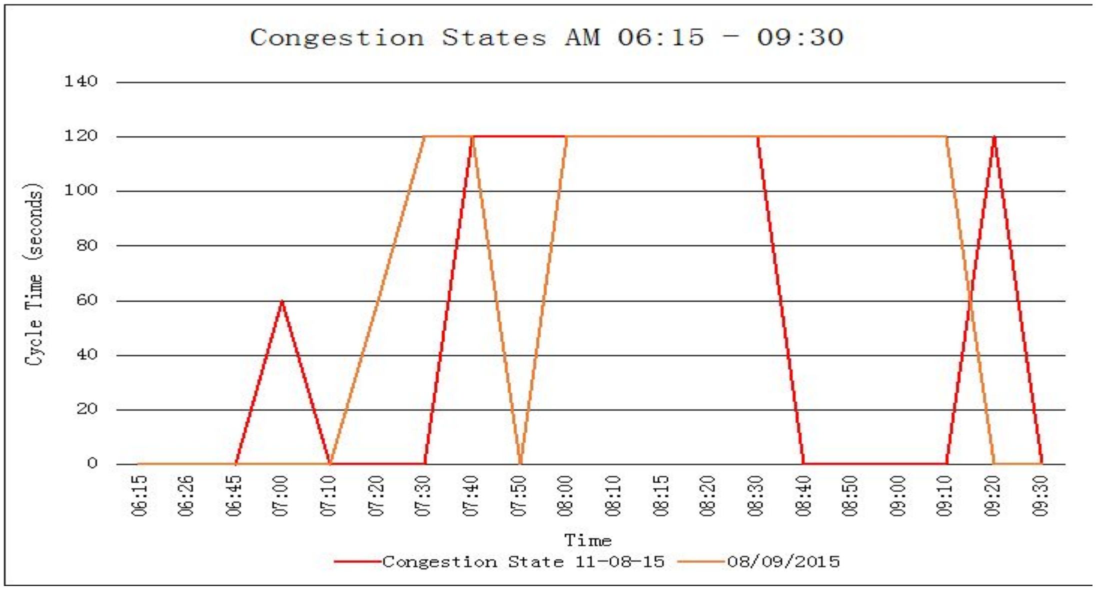

Figure 7 – Congestion states on 11-08-2015 and 08-09-2015

Figure 7 above shows the congestion modes recorded at the interchange during the AM peak period both during and outside the school holidays. It can be seen that the linking is introduced earlier and stays on for longer on the 08-09-2015 survey.

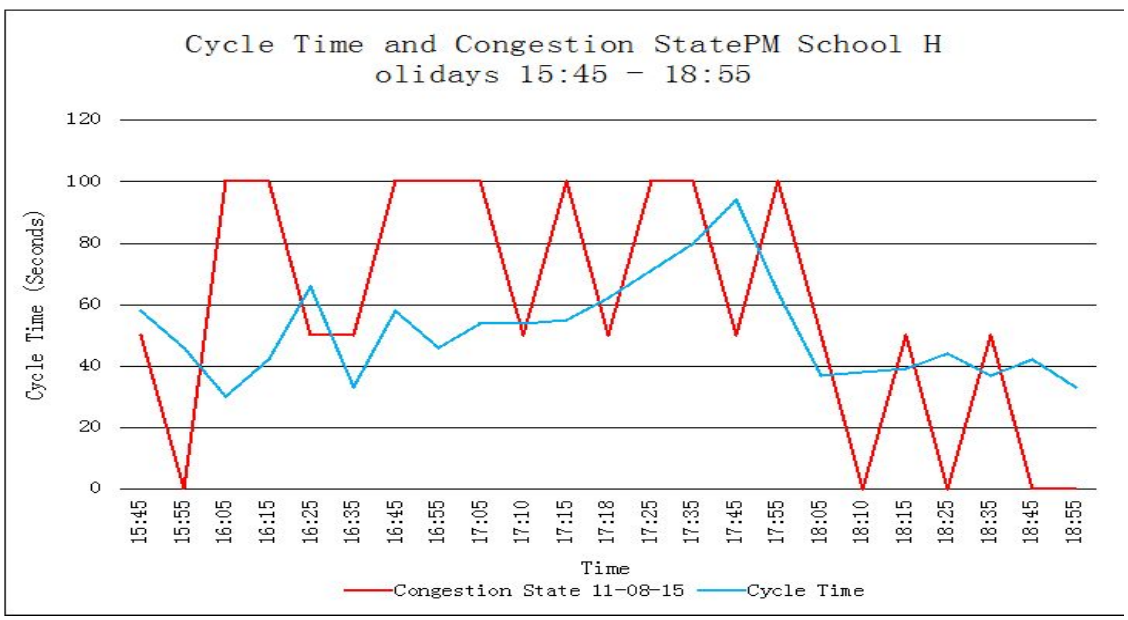

Figure 8 - Congestion State and sampled Cycle Time from West Controller during PM peak (linking is applied to the A64 Southbound entry node when red line is High or Medium) – Responsive Mode

Figure 8 above shows the recorded congestion mode and sampled cycle time at the West controller during the PM peak period on 11th August. This shows that the interchange runs either Medium or Heavy modes consistently (this means that the linking is applied to the A64 Southbound entry node) from 16:00 until 18:05. The Medium cycle time threshold was set at 42s and the Heavy at 65s. Again, the congestion mode shows a good correlation with the sampled cycle time, although it may be argued that the Medium CY threshold could be set at a higher value of around 50s to end the linking in a more consistent manner.

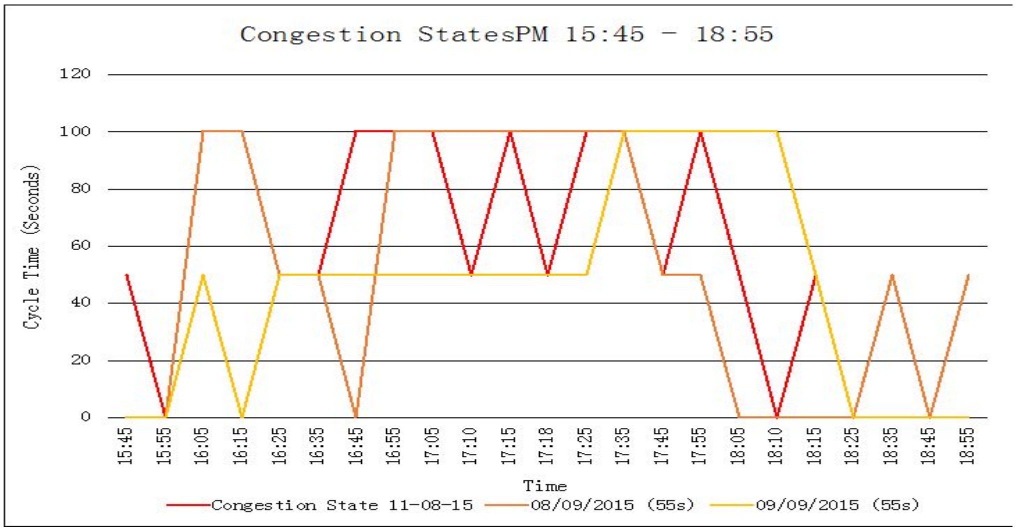

Figure 9 – Congestion States on 11-08-2015, 08-08-2015 and 09-09-2015

Figure 9 above shows the congestion mode recorded at the interchange during the PM peak period both during and outside the school holidays. The Medium cycle time threshold is set at 42s on 11th August and at 55s on the 8th and 9th September. It can be seen that the higher cycle time threshold provides a more consistent congestion mode for the interchange.

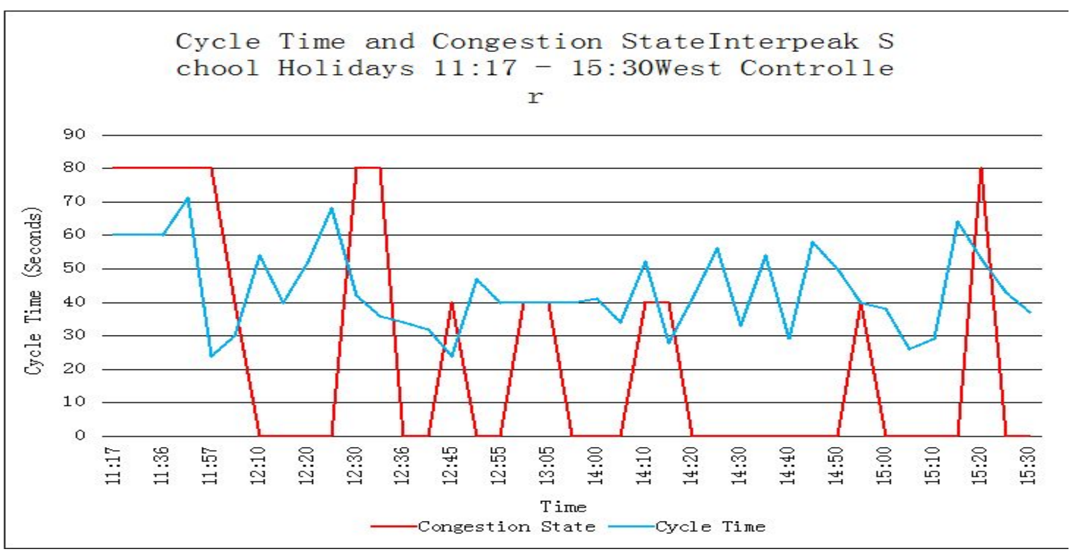

Figure 10 - Congestion State and sampled Cycle Time from West Controller during Inter peak, linking is applied to the A64 Southbound entry node when red line is High or Medium – Responsive Mode

Figure 10 above shows the congestion state recorded at the West controller from 11:17 until 15:30 on 12th August. This indicates that unexpected periods of high traffic demand are catered for throughout the day (particularly from 11:17 until 12:00 when an incident occurred at the interchange causing congestion).

10. Vehicle Delay Results

	Responsive		Timetabled	
	No. of PCU's	Average Delay per PCU (s)	No. of PCU's	Average Delay per PCU (s)
Circuatory at A64 Northbound	892	4	566	0
A64 Northbound	644	18	366	23

Table 1 – Average Vehicle Delay per Cycle over all sampled periods (seconds/PCU) at A64 Northbound exit approach 11th and 12th August 2015

Table 1 above shows the average delay per PCU in seconds recorded during responsive and timetabled operation over all the sampled records on the 11th and 12 August 2015.

The average delay on the A64 northbound exit approach is 18 seconds per PCU with the responsive operation, but rises to 23 seconds per PCU under timetabled operation.

The average delay on the circulatory at the A64 northbound is 0 second per PCU under timetabled operation, but rises to 4s per PCU under responsive operation.

Figure 11 below illustrates the vehicle delay recorded during timetabled and responsive operation.

Table 2 below shows the values of vehicle delay over like for like time periods on the responsive and timetabled days. These results include times when linking has been applied during the responsive operation. Results shows that the vehicle delay is more evenly shared across both approaches during the responsive operation.

Across all three like for like time periods, the responsive operation resulted in substantially lower average vehicle delay times per cycle on the A64 northbound exit approach and slightly increased delay times on the circulatory approach. If these savings were factored up to form a weekday AM peak hour saving, it would accrue a modest £9,000 saving per year (assuming these benefits could be applied as a standard morning peak hour).

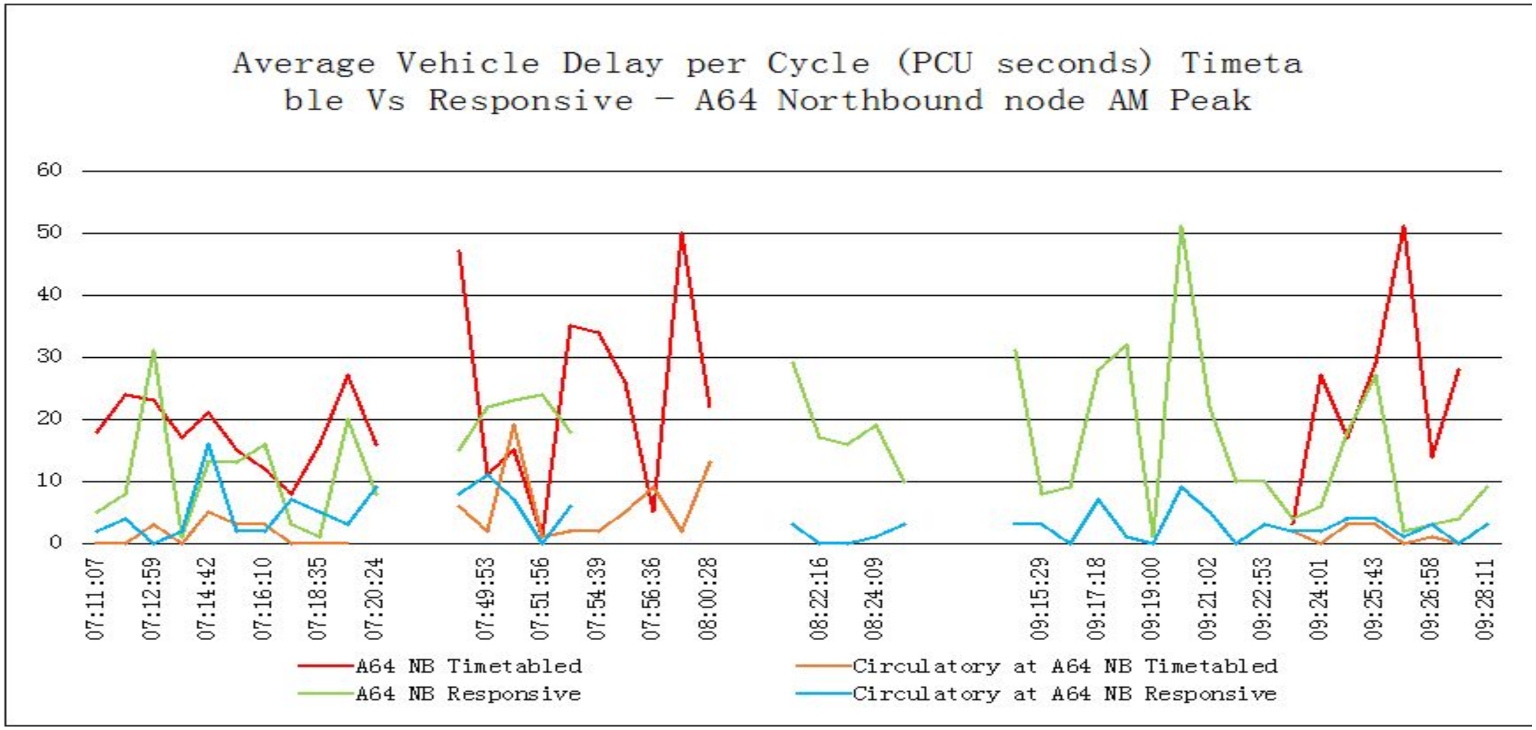

Figure 11 – Average Vehicle Delay per Cycle (seconds) - 11th and 12th August 2015 –A64 Northbound Exit AM Peak

Time Period		Total Delay (PCU seconds)		Number of PCU's		Average Delay per Cycle (seconds)	
		Responsive	Timetabled	Responsive	Timetabled	Responsive	Timetabled
07:11 - 07:20	A64 Northbound entry	1089	2502	105	142	10	18
	Circulatory at A64 Northbound	391	250	84	175	5	1
07:48 - 07:53	A64 Northbound entry	1849	1869	92	71	20	26
	Circulatory at A64 Northbound	720	486	117	152	6	3
09:23 - 09:28	A64 Northbound entry	851	2047	72	82	12	25
	Circulatory at A64 Northbound	196	191	86	129	2	1

Table 2 – Vehicle Delay Results -11th and 12th August 2015 – A64 Northbound Exit Node AM Peak

11. Conclusions

The system implemented MOVA linking between streams in response to feedback on traffic demand in real time. The system also responded to periods of unexpectedly high traffic demand, which would not have been included within the linking timetable.

The survey results indicate that a significant number of red light running incidences would be avoided on the A64 northbound approach with the responsive system compared to the timetabled system.

The calculated rate of red running over all surveys for the linked operation is 8 red runners per hour, this is compared to a rate of 0.5 per hour for unlinked operation.

Since the responsive system delivered an additional 50 minutes of unlinked operation and the associated green closure benefits on the A64 northbound exit approach, this would equate to a saving of 6 red running instances every AM peak at this location.

The system also affected vehicle delay at the interchange, sharing delay more evenly between the circulatory and the A64 northbound approaches, although it was identified that no significant overall benefit or dis-benefit arose from this re-distribution of delay.

There was still a reliance on time clocks to identify which node should be monitored, this was due to tidal flow patterns at the interchange.

In summary, the differences indicated between the responsive system and the standard timetabled system are:

- Appearance and duration of linking is more finely tuned to traffic demand during the AM and PM peak periods with the responsive system
- The responsive system reduces occurrences of red light running by omitting MOVA hurry call linking when upstream traffic demand is insufficient
- The implementation of the responsive system would have no significant overall impact on vehicle delay
- Unexpected traffic demand is catered for throughout the day (this would not normally be timetabled in the linking strategy)

An additional advantage of this system is that it is not reliant on feedback from external sources, and as such is not susceptible to communications downtime. Inputs and outputs are all contained within the controller cabinet.

This study has shown that implementation of a system which introduces linking between intersections in response to an increase in traffic demand has the potential to reduce the numbers of red running vehicles on high speed approaches. It has also indicated that no significant dis-benefit would be experienced in terms of vehicle delay in order to realise these safety benefits.

12. Further Applications

This method of using feedback on the state of the network to trigger a strategy could be extended to introduce MOVA linking between junctions on urban corridors.

Such a system could also be used to trigger SCOOT/ UTC control on a network and decide when to revert to fall back mode.

It should be noted that dependant on the junction type, the cycle time thresholds required will vary substantially. For example, a 5 stage junction may require the cycle time linking threshold to be in excess of 70 seconds.

13. Acknowledgements

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