Maximising junction efficiency with complex interstage design and 'Intelligent' phase delays

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Once the geometry of a signal controlled junction is established and the detection infrastructure is decided upon, the final key to maximising junction efficiency and reducing delays is to ensure the controller configuration is designed in such a way that lost time is minimised and stage changes are optimised. Irrespective of the mode of operation, ensuring that the phase-to-phase transition for critical conflicting phases is as short as possible is paramount in achieving maximum operational performance. The objective of this paper is to show how the critical path from stage X to stage Y (or stage Z via Y) can be reduced to the minimum possible value by utilising special conditioning functions and timers. When stages contain phases which may not appear or can be deleted, the optimisation process becomes more complex necessitating unorthodox techniques.

INTRODUCTION

Towards the end of 2009, Greater Manchester Passenger Transport Executive (GMPTE) completed works in which the City Centre tram tracks were replaced following nearly 20 years of service. Limited resources were made available to the Greater Manchester Urban Traffic Control Unit (GMUTC) to investigate operational efficiency savings at the traffic signal controlled junctions. GMUTC made a strategic decision to upgrade all of the old traffic signal controllers along the routes. This appeared to be the best opportunity to undertake such a task, as it would coincide with the proposed disruption to the tram service.

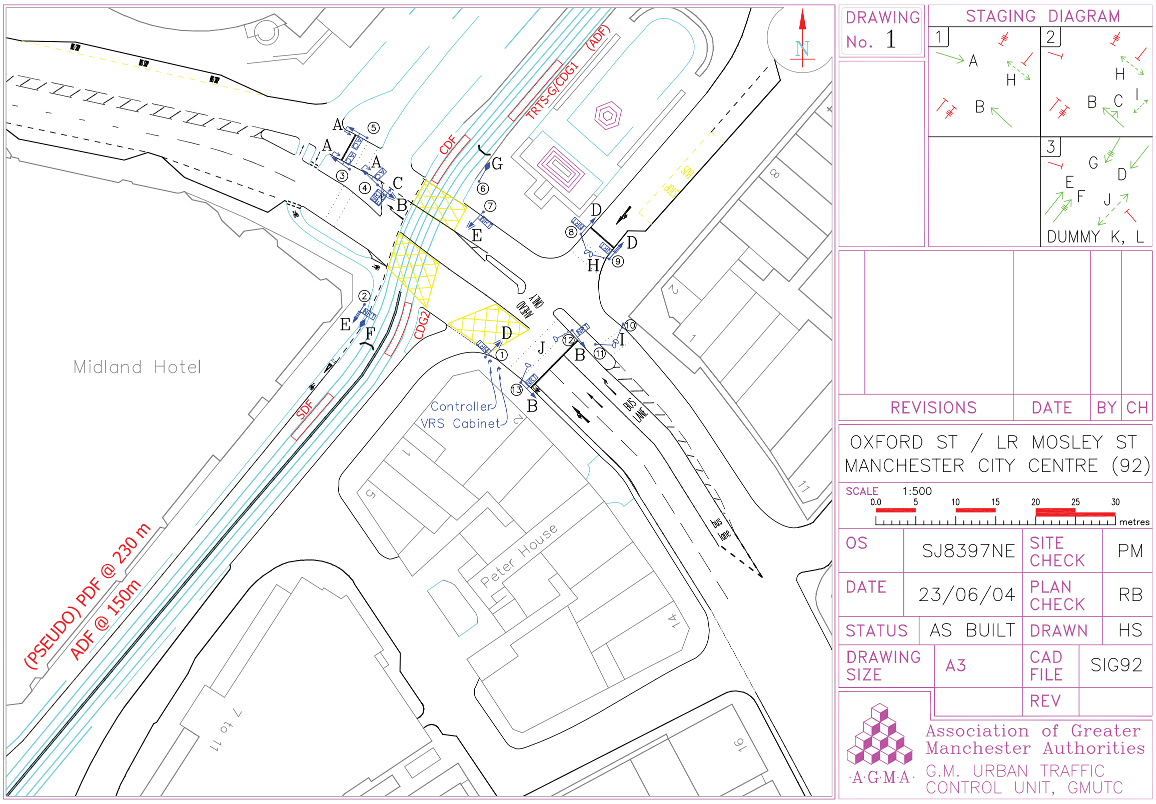
The signal cabling and ducting infrastructure in the city centre has insufficient capacity to be modified significantly. This is a result of an understandable reluctance to alter or amend Light Rail Transit (LRT) junctions due to the potential problems of disruption to operation and working safety zones near the tram ‘permanent way’.

Some of the junctions in the City Centre were running fixed time UTC for significant parts of the day. The tram stages seemed inefficient and slow to react and hence allowing full priority would have caused congestion problems due to the lack of coordination and wasted cycle time. Greater Manchester’s Metrolink system is one of the first modern tram networks in the country. With the enhanced computing capabilities of modern traffic signal controllers and the benefit of twenty years of LRT operational experience, the opportunity existed to improve the efficiency of the LRT signals that have historically been less able to provide a good service to the tram traffic.

The lack of LRT priority invariably introduces delays to the trams, causing timetabling issues and increased passenger journey times. In order to achieve full priority at a greater number of sites, it is important to minimise the effect that a randomly appearing LRT stage has on the conflicting traffic stage(s). Obviously this is not always an option. If the LRT stage can be reduced to the shortest safe length possible, neighbouring signals are not exceptionally close, and the required network cycle times are not excessive, then full priority can be achieved.

With a distinct lack of available vehicle detection and even pedestrian phases with push-button demand units, the only way to maximise efficiency is to consider the parameters relating to the LRT phases and how the tram detection is used to best effect. The design of the interstages is of critical importance to ensure that time is not being wasted waiting for inconsequential phases to appear and terminate. In addition, phase delays must be succinct, appearing for the correct length of time in relation to the phases that were present at or before the end of the stage.

This project concentrates on two elements of interstage design that help minimise the length of an LRT stage, where the time saved would be better reallocated to the ‘main road’. Many other features are included within the controller specifications to help make efficiency savings which have been developed through discussions with Stuart Mulliner at Siemens,



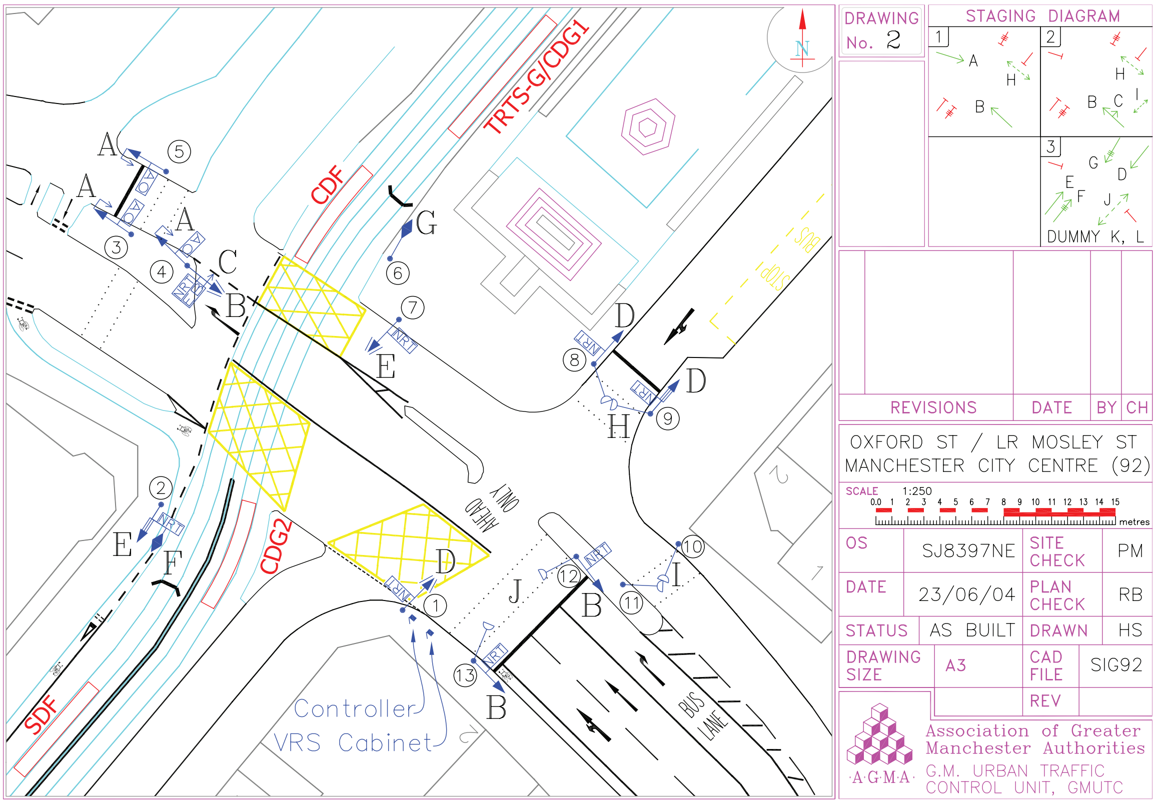
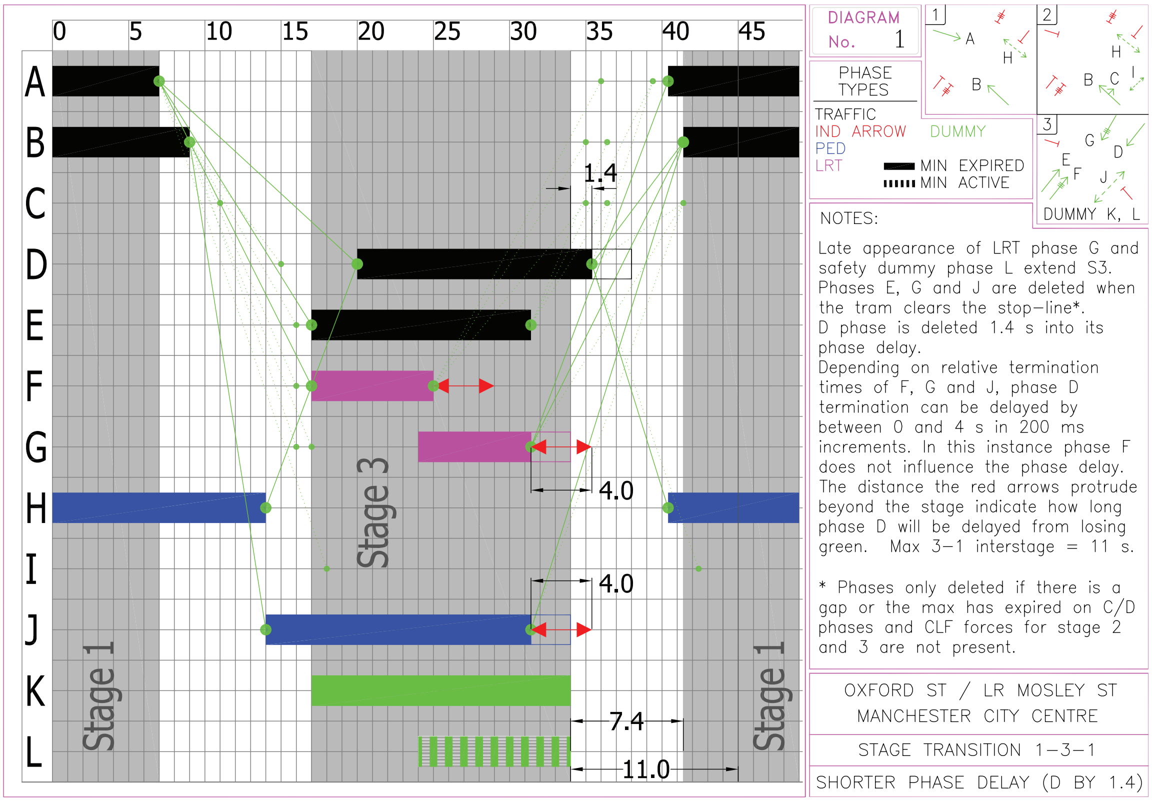


Figure 1 and Figure 2 show the signal arrangement at the project site, the junction at Oxford St/Lower Mosley St (St Peter's Square). The drawings are not to scale.

drawing on his extensive knowledge of LRT signalling gleaned from working on Greater Manchester Metrolink and with customers from Nottingham and Blackpool for example.

A number of improved controller configurations are now operational in the City Centre resulting in significant improvements to tram journey times. The controller configuration for Oxford St/Lower Mosley St (St Peter's Square), on which this project is based, is now operational. The efficiency improvements realised have resulted in the junction running in UTC mode with full priority enabled even throughout both morning and evening peaks when previously priority mode was disabled.

The drawings in Figures 1 and 2 show the signal arrangement (not to scale).



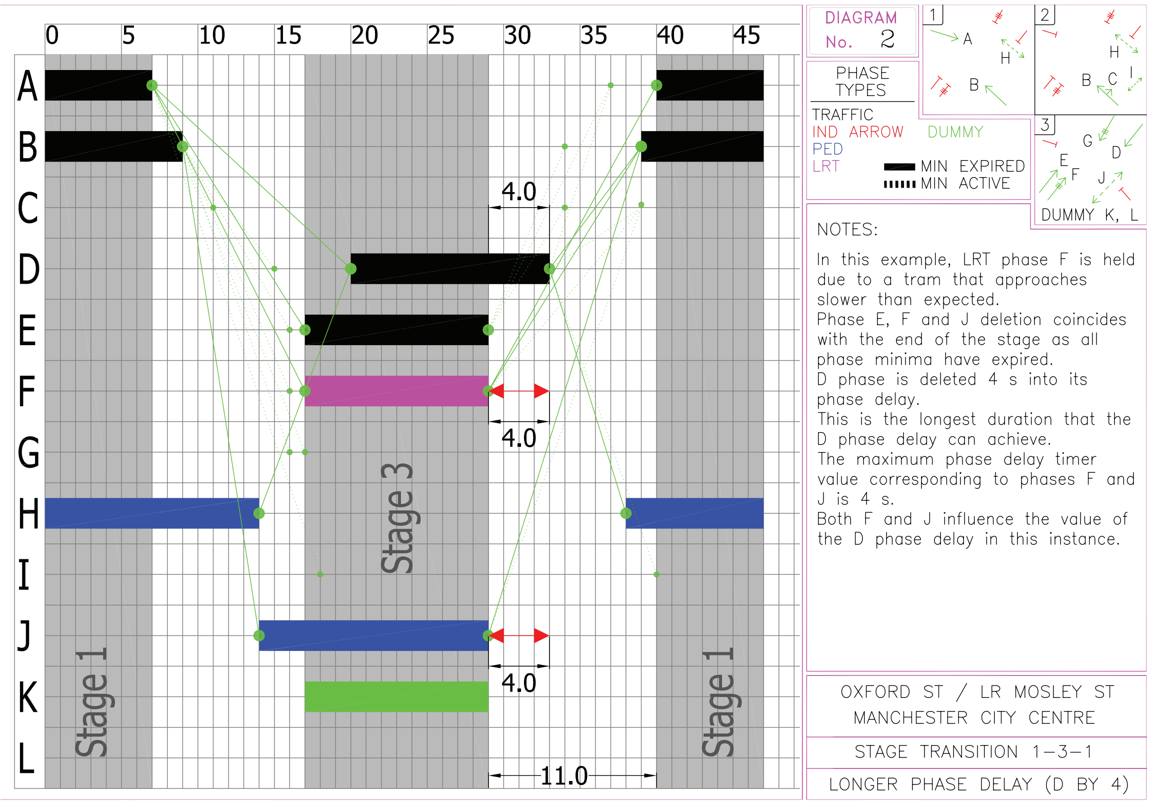


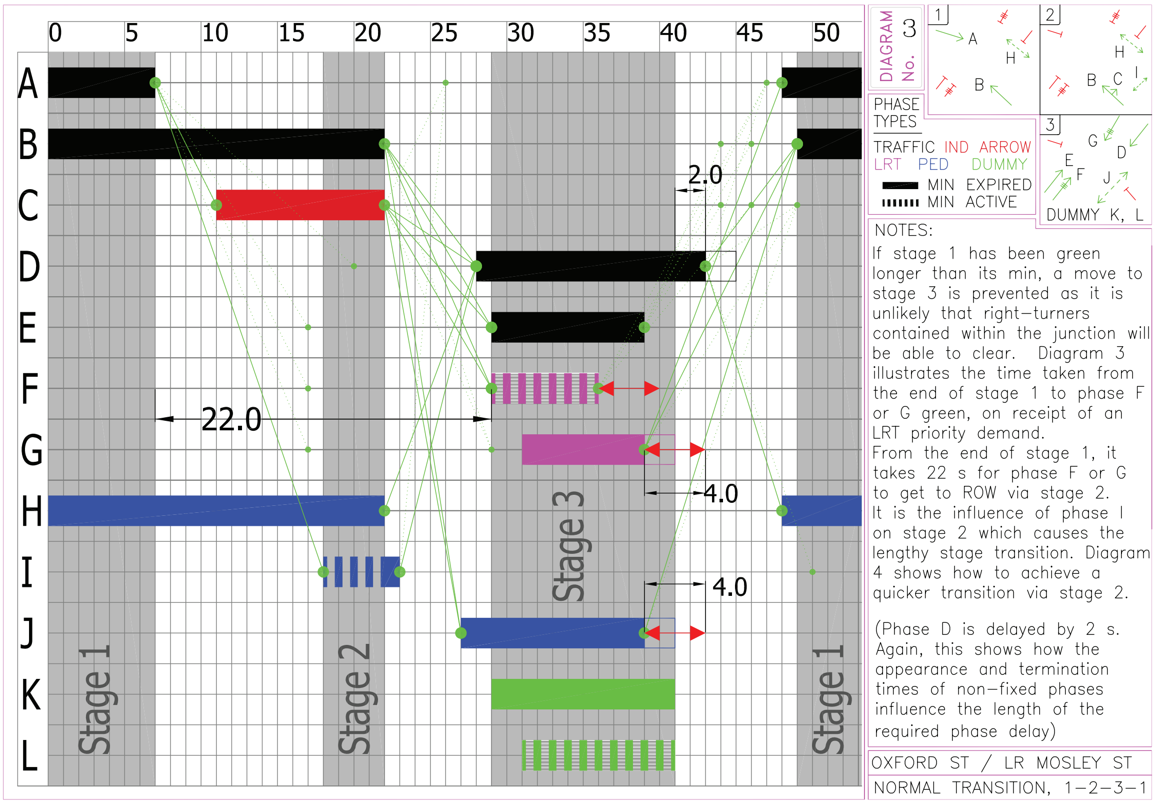
Figure 3 and Figure 4 illustrate how the random appearance and termination of certain phases such as LRT, ped, traffic and dummy, affect the 3-1 interstage.

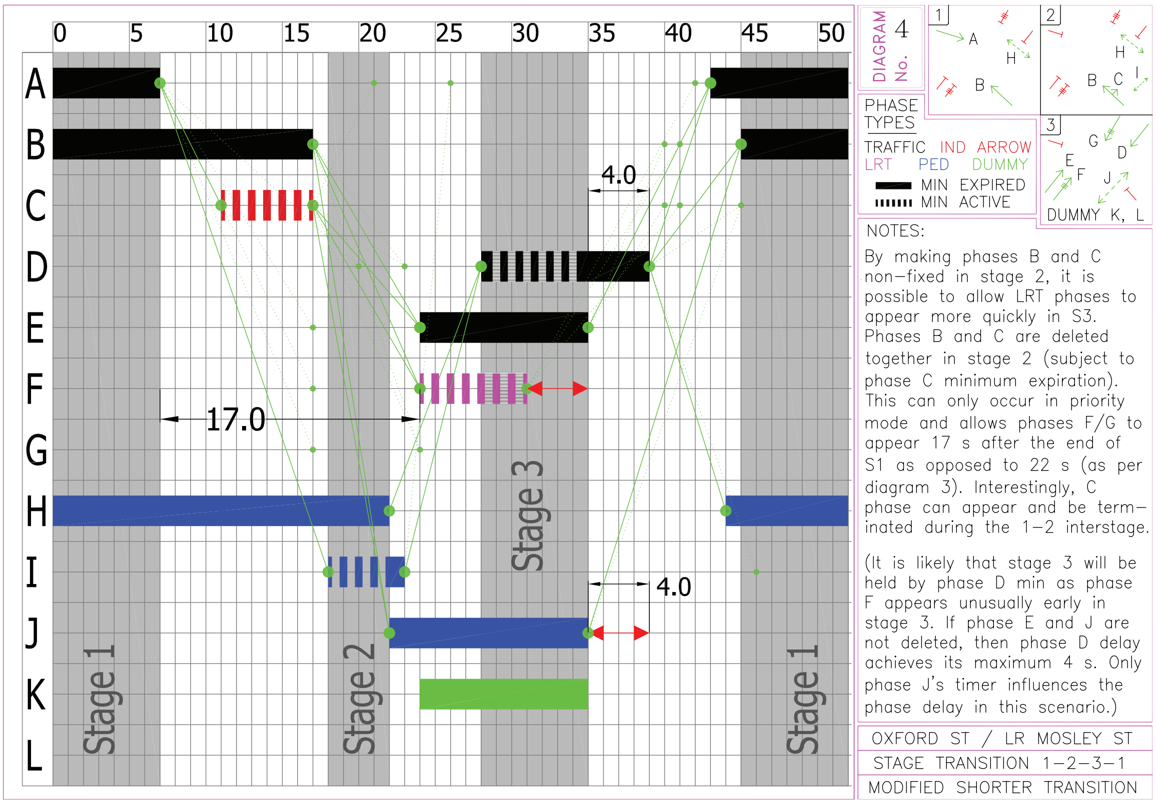
‘INTELLIGENT’ PHASE DELAYS

Deleting phases within a stage is often desirable to minimise their effect on the phases appearing in the following stage. For example a pedestrian phase in a ‘walk with traffic’ stage which has run for longer than its minimum and has an onerous following intergreen, is often best dealt with by terminating during the stage in which it runs. This is especially true when a site is under MOVA control and phase delays are not normally an option as a way of recouping the lost time incurred in the interstage.

If a phase is deleted well before the end of the stage in which it runs, it can negate the need for phase delays entirely. Conversely, if the stage ends just after the phase is deleted, almost the full value of the phase delay would be desirable. The proximity of the

Figures 5 and 6 (Diagrams 3 and 4) show 'intelligent' phase delays in action. The benefit of terminating traffic phases B and C before the end of stage 2 is demonstrated in Figure 6.





problem phase(s) termination time relative to the end-of-stage decision time affects the value of the ideal phase delay.

Figures 3 and 4 show interstage diagrams numbered 1 and 2 which illustrate graphically how the random appearance and termination of certain phases (LRT, ped, traffic and dummy) affect the 3-1 interstage.

Below is an excerpt from a request for an EPROM reconfiguration for the junction of Oxford St/Lower Mosley St in Manchester. There are 3 phases that potentially affect the optimum phase delay time for phase D; D being the only traffic phase in stage 3 worthy of consideration in capacity terms.

'Intelligent Phase Delays:

The actual length of phase delay 29 will be determined by its associated timers.

PD No. 29: D by 10 s on a 3-1

'Phase delay' timers are to be held reset when their related LRT or ped phase is at green.
Phase D will be deleted within its phase delay only when all corresponding timers have expired.
D Phase delay timer, 3-1 (related to F phase) = 4
D Phase delay timer, 3-1 (related to G phase) = 4
D Phase delay timer, 3-1 (related to J phase) = 4'

The above shows the relative ease by which the intelligent phase delays are achieved. The values of the timers relate to the difference between the intergreen of the deletable phase and the phase which will benefit from the phase delay. For example if F to B is 10, and D to B is 6, the timer value is 4 s.

The phase delay always runs to its optimum length regardless of when phases F, G and J were terminated. In addition, if any of the phases have not appeared in the previous stage, the phase delay timer will not be active and thus will not serve to extend the phase delay.

The actual phase delay value must be at least the value of the greatest auxiliary timer. This is the value which would be calculated if the phase subject to early termination is still present at the end of the stage; in this case 4 s. The value shown in the above example is 10 s which is a somewhat arbitrary figure which was chosen to emphasise the difference between this phase delay and other standard phase delays.

COMPLEX INTERSTAGE CONSIDERATIONS

Deleting non-fixed phases within stages can be useful to achieve efficiency savings as detailed above. This is commonplace when the phases in question are normally detrimental to vehicle phase capacity maximisation.

In the following example I have shown how in certain circumstances it is useful to manipulate the traditional appearance of traffic phases to achieve faster progression to a nominated stage for priority purposes.

At the junction of Oxford Road/Lower Mosley St, I have allowed a 1 to 3 move in priority mode only if the demand is received whilst stage 1 is in a minimum. This is because the right turn flow can be so significant that the reservoir cannot be cleared without the benefit of a right turn arrow stage if the main stage has been green for too long.

Bearing in mind that stage 1 is the main stage, it is likely that priority demands may be received well into stage 1, necessitating a move to stage 3 via the indicative arrow stage 2 in order to clear the right turning buses.

The outbound LRT phase demand input (TRTS-G) is received immediately before it wishes to depart its platform stop. The inbound LRT input (prepare detector) is received around 17 s from the point at which a 'proceed' signal should be displayed based on the tram's cruise speed.

In both cases, it is important that the transition through stage 2 is as short as possible to prevent delaying the tram should the demand be received in stage 1.

By making B and C non-fixed in stage 2, both phases can be terminated even before the 'G' bit is generated, allowing tram phases F and G to appear much more rapidly after stage 2. Phase C in fact, appears and is terminated in the 1-2 interstage, where stage 2 is defined only by the fixed phases H and I. This can only occur in priority mode, ensuring that stage 2 only runs for the minimum time. In addition it prevents the less than desirable situation in which stage 2 is being forced under UTC control and phases B and C have been deleted.

Without this modification to stage 2, phases B and C would not be deleted early. Although the stage length would still be controlled by the minimum green of phase I, phase C would run for 5 s beyond its minimum green. This would result in a 22 s interval between stage 1 losing green and phase F gaining green; this is 5 s longer than the desired 17 s, delaying the tram.

Interstage diagrams 3 and 4 (Figures 5 and 6) show the difference between a conventional 1-2-3-1 stage transition and the more efficient modified transition.

CONCLUSION

The ideas and methods discussed in this report were formulated to achieve performance improvements in very specific circumstances. Junctions incorporating tram signalling normally allow only one vehicle through per green signal phase, after which the phase is deleted. This is an important feature which is needed because the first tram through the junction will cancel the green signal (if still illuminated) and the all-red extensions when the clear/cancel detector is operated.

At most junctions it is not necessary to delete phases before the stage has ended. However, it is always worth considering whether valuable time is being wasted either in an interstage or by being allocated to non-critical, inconsequential phases via phase delays or unnecessarily long stages, elongated by pedestrian phases.

Traffic Signal Engineers will frequently consider that if phase delays are calculated correctly, delays will be minimised and capacity maximised.

Consider a VA stage change in which the vehicle detection allows a gap change from a stage. If a parallel pedestrian phase which terminates at the end of the stage has a longer intergreen to the next critical traffic phase than the traffic phase losing right-of-way, then a phase delay will be applied. However, as a gap has been found, there is no traffic; in this case the phase delay is wasted. If the pedestrian phase had been deleted at an earlier point, the phase gaining right-of-way would be free to appear in the shortest possible time without any 'wasted' green.

Although it is time consuming to consider every permutation of allowable stage changes, it is certainly worth optimising at least all the cyclic stage change transitions. Significant delay savings are possible especially at complicated multi-phase junctions, with the effects becoming more pronounced as the cycle time is reduced and the proportion of lost-time increases.

CONTRIBUTORS AND PARTNERS

The project in financial terms was very small. Greater Manchester Passenger Transport Executive and Manchester City Council financed a proportion of the work, with the Greater Manchester Urban Traffic Control Unit financing the remainder.

Stuart Mulliner and David Jordan of Siemens Traffic Control in Lowton, Greater Manchester advised on configuration possibilities available and whether certain ideas were achievable.

AUTHOR'S DETAILS
Richard Butler was the winner of the 2010 Brian Simmonite Award presented at the JCT Traffic Signal Conference and Symposium in September. His award winning paper is published here. Richard can be contacted on +44 (0) 161 247 3160 or by email at r.butler@manchester.gov.uk