TECHNICAL NOTE

INTERSECTION IMPROVEMENTS THROUGH BACK TO BASICS TECHNIQUES

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ABSTRACT:

Signalised intersections in our major urban areas frequently do not perform to their fullest potential. The consequences can have significant effects on safety, delays, congestion and pollution. Non-compliance e.g. red-light running is of particular concern. Significant work is currently being undertaken in Auckland to combat red light running through use of enforcement cameras. But is tackling the symptom rather than the cause the best way to proceed?

Issues surrounding the operation of signalised intersections that lead to poor operation, driver frustration and non-compliance will be explored. At a time when we should be obtaining the most efficient use out of our existing networks, improving road safety, conserving resources and reducing emissions, it is all the more important to look at what we have already got and use it to its optimum potential.

Solutions to better operate signalised intersections without altering physical intersection extents and at low cost are discussed. The aim of the presentation and technical note will be to promote discussion and debate.

INTRODUCTION

The government seeks, in the short to medium term, through the Land Transport Funding system, to provide:

> "Improvements in the provision of infrastructure and services that enhance transport efficiency and lower the cost of transportation through:
>
> - Better use of existing transport capacity" (Ministry of Transport, 2009)

In New Zealand's major cities, traffic signal intersections are a significant piece of infrastructure that effect the efficiency of the transport networks for private motorists, freight movements and for public transport operators. The efficient or inefficient operation of these intersections will therefore affect the success of achieving this Government Policy Statement (GPS) objective in the short to medium term.

It is therefore important that the operation of traffic signal intersections is optimised as far as possible. Poor operation of traffic signal intersections results in unnecessary congestion, increased use of fuels (hence carbon emissions) and affects safety.

Optimisation can be achieved by examining the existing provision and better using it, for instance, through improved traffic signal timings or amended road markings. Such changes can be undertaken without physical amendments to the infrastructure and therefore benefits can be achieved economically. Although some road controlling authorities have been undertaking some work in this area on particular corridors with traffic signal controlled intersections, it is clear that more can be done.

This technical note is intended to promote discussion. It details some of the key issues surrounding the poor operation of traffic signals and describes some possible solutions that are available based on basic traffic engineering principles.

THE ISSUES

Use of Available Road Space

Many major traffic signal intersections are much wider than the roads connecting them in order to provide multi-lane approaches, including short lanes. Typically, observations show that at these intersections, some of the lanes are only used partly during the green time or that the short lanes are not fully utilised (Royce, Jurisich and Dunn 2006). The reasons for this can be varied including blocking of the short lane, reluctance by motorists to use the short approach lane if there is only a short merge or depart lane on the exit from the intersection or poor road markings.

Longer traffic signal cycle times reduce the effectiveness of short lanes. Often short lanes are only used in the first part of the green period when vehicles have been able to enter the lane. However, once these have discharged the lane can often run empty thereby providing no further benefit or capacity to the intersection. The longer the cycle time, the less effective the short lane as fewer vehicles use the lane over any particular given period of time.

Consider an example of a short lane which is typically used by 5 vehicles per cycle. At a 120 second cycle time, this would equate to 150 vehicles over an hour. For the same configuration but operating at 110 second cycle, this would equate to approximately 164 vehicles which as a 9% increase.

Often the multi-lane approaches are fed from a single upstream lane. This can ultimately limit the capacity of the intersection once traffic has emptied out of any short lanes at the intersection (Royce, Jurisich and Dunn 2006).

Cycle Times

Cycle times at traffic signal intersections are frequently determined by SCATS with no fixed upper limit. As traffic demand grows the optimisers keep increasing the length of the cycle times often exceeding 120 seconds with some cycle times having being observed up to 180 seconds.

As highlighted above where there are short lanes, longer cycle times also reduce the benefits of these lanes.

Longer cycle times generally result in increased queuing and delay due to the longer red times on opposing traffic signal phases.

Pedestrians are adversely affected by long cycle times, particularly if a pedestrian wishes to cross two arms of the intersection. The Highway Capacity Manual (2000) as cited by the Federal Highways Agency (2004) indicates that pedestrians are often only prepared to wait 30 seconds before looking for opportunities to either cross against the red man signal or walk away from the intersection and cross the road uncontrolled. In New Zealand, pedestrians appear to be a little more tolerant but they are often observed crossing against a red signal if the opportunity exists. This can affect safety with increased exposure to pedestrian-vehicle conflicts.

Inefficient Phase Changes

The combined effect of poor use of multi-lane approaches and long cycle times is often inefficient phase changes. This occurs when traffic has emptied from the short lanes and the rate of discharge across the limit line has dropped below that of full saturation. For increasing phase lengths, headways also generally increase due to the time required for vehicles to start up and move or vehicles that are at the free flow speed having not been interrupted on their journey by the intersection.

Often phases are held on green for traffic that has not been delayed by the traffic signals. This may be acceptable in networks where there are well coordinated, closely spaced intersections, however, where there is a high degree of platoon dispersal, headways are large and hence the discharge rate across the limit line is generally low.

By allowing the phase to continue operating during these times results in low utilisation of the green and inefficient operation of the intersection.

Issues Summary

The issues described above result in inefficient operation of traffic signals. This can result in safety issues as motorists may choose to make poor decisions when travelling through the intersection. For instance, some motorists may choose to travel through an amber signal or even into the red period rather than stopping to wait through a signal cycle. Long cycle times penalises pedestrians with long wait times.

OPTIONS

A number of suggested options to address the issues outlined above are described below. These are based on basic traffic engineering principles or practices and could be implemented without physical alteration to the geometry of the intersection. Any options adopted should be used only after sufficient observation of the intersection at various times of day and over a period of time. It is only through observation of the operation of the intersection that areas of inefficient operation can truly be identified. Consideration also needs to be given as to how the intersection may relate to other intersections.

Options discussed are:

- Enhanced use of short lanes through changes to road markings and shorter signal cycles;
- More appropriate use of signal cycles considering actual traffic operation and intersection efficiencies;
- More flexible detection; and
- Off peak operation.

Enhanced Use of Short Lanes

Enhanced capacity could be provided through the better use of existing lanes on multi-lane approaches. Motorists may need to be encouraged to make better use of these lanes. This could be achieved by reviewing the lane markings on the approach to the intersection to direct motorists more appropriately into lanes. Consideration needs to be given to constraints at the intersection that may discourage use of the lanes such as parking. Extending parking restrictions may provide improved merge lengths are thereby encourage motorists to make better use of lanes (Royce, Jurisich and Dunn 2006).

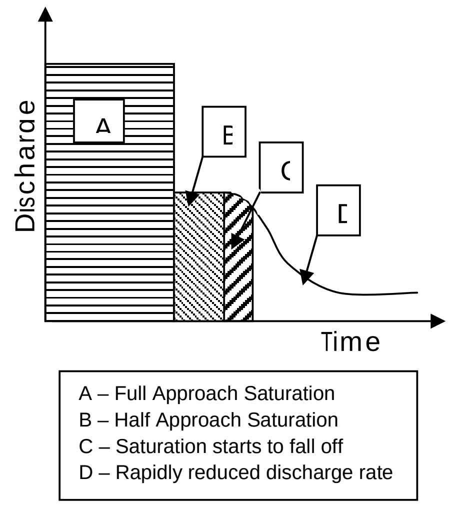

Figure 1 – Discharge Rates

Where there are various multi-lane approaches, short cycling the intersection can provide significant additional throughput. This technique allows maximum capacity whilst both the short and long lanes discharge at saturation, the green is curtailed a short time after the short lane is fully discharged enabling vehicles to fill up the short lanes. This reduces the length of time when only long lanes are discharging and the approach operates at less than full capacity. This is illustrated in Figure 1. In area A, full discharge is achieved for the full and short lane, once the short lane is empty the discharge drops significantly to B. At some point in time any long lane will no longer discharge at full saturation and this will start to drop. Short cycling maximises the use of green during period A and part way into period B.

Cycle Times

Although theoretically as traffic demands increase, longer cycle times are required, in practice this does not necessarily result in greater efficiencies in the operation of the intersection. Lengthy phase times occur with long cycle times which results in vehicle headways increasing significantly thereby resulting in poor saturation across the limit line. The effect therefore can be inefficient use of green at longer phase times. For instance, increasing the cycle time from 120 to 180 seconds results in just a 2% increase in capacity (Federal Highway Administration, 2008).

As noted above, cycle times can be lengthy. With long green times the discharge rates drop (as indicated in Figure 1 by Area D). Green times should be restricted so as to ensure optimal discharge rate during the green and once this starts to drop the green should be curtailed. For example in Figure 1, ideally the green should end no later than the end of period C as the discharge rate drops significantly after this time. The exact point is a matter of judgement and may need to be fine tuned over a period of time.

Longer cycle times have been associated with red light running with the potential for safety problems as some motorists may not be prepared to stop if the lights change due to the anticipated wait time before receiving a further green signal (Federal Highways Administration, 2004).

Further benefits of reduced cycle times include shorter pedestrian wait times and improved motorists' perception of the operation of the intersection as there are fewer periods when the intersection appears inefficient and they receive a green signal quicker.

By imposing upper limits on the cycle time, green phase times will automatically be reduced; better utilisation of green time will be achieved and hence more efficient use of the green time and the intersection.

Upper limits of the cycle time (if specified) often vary from country to country and even between roading authorities. 120 seconds is frequently used as a maximum but where pedestrians phases are included a lower cycle times are often advised. In some circumstances, longer cycle times may be required, although this should be by exception rather than the norm and should be limited to peak periods only.

Detection

The majority of traffic signal intersections operating in New Zealand rely on limit line detectors only. These are used by SCATS to determine timings. They are also used in isolated intersections to extend the green period before changing to an opposing phase. Typically, the detectors are set to extend the phase by 4 seconds before allowing the phase to terminate if there have been no further vehicles across the detector. This is to allow a vehicle which may be approaching the intersection in the dilemma zone to be able to reach the limit line before the signals change. However, in reality, this can reduce the responsiveness of the traffic signal intersection to terminate the phase.

As an example, as shown in Figure 2, once the last vehicle on the approach has past the limit line detector at A, the phase will not change for a further 4 seconds when the vehicle is at B. There is a further 6 second intergreen before an opposing stage can start up. Therefore the total clearance is effectively 10 seconds. At 50 kph this could result in the last vehicle being around 140 m away from the intersection (placing it a C) before any opposing vehicle starts to move.

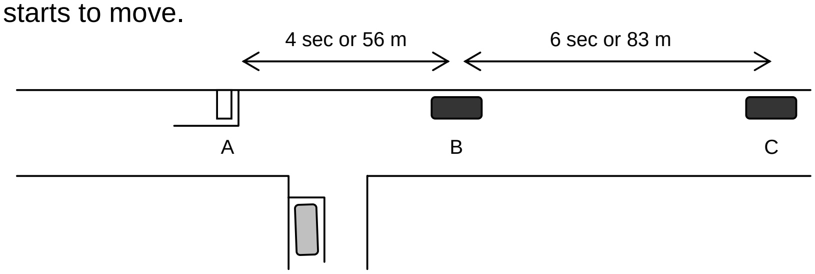

Figure 2 – Effects of limit line detection at 50kph

By using advanced detection, the intersection can be more responsive. By placing a detector at around 40 metres from the intersection, this can be used to extend the phase rather than the limit line detection. Therefore the 4 seconds can effectively be eliminated thus saving 4 seconds on the cycle time. If this occurs on each approach to the intersection, particularly when traffic flows are lower, then the intersection will cycle much quicker. This will reduce driver impatience and may lower the occurrence of drivers on an opposing approach proceeding through a red light.

Off Peak Operation

Many traffic signals are operated in coordinated networks using SCATS. However, in low flow conditions, particularly over night or off peak, when coordination is not always necessary, dropping the central control of the intersection from SCATS to local control will allow the intersection to operate more effectively to demands without being reliant on the operation of other intersections in the area to allow a phase change. This may reduce red light running at quiet periods when some motorists may choose to continue through the signals rather than wait unnecessarily for the signal to change into their favour.

CONCLUSION

By applying basic traffic engineering theory, improvements to traffic signal intersections can be made without investment in physical alterations. The possible options outlined in this technical note make better use of the existing infrastructure through improved optimisation and traffic behaviour. Such improvements can enhance the value of this infrastructure, improve safety through more efficient operation and reduced red light running and provide benefits to non-car users.

The options described will not be applicable to all intersections and changes should only be made after sufficient observation of an intersection at various times of day and over a period of time to fully understand how motorists and other road users use it.

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