Cyclists at Wide Signalised Intersections

All-Red Time Extension with Single Loop

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Introduction

Late in 2000 the Christchurch City Council installed a special arrangement of detector loops at the intersection of Ferry Road and Fitzgerald Avenue in the interests of improving safety for cyclists. Concerns were raised regarding the safety of some cyclists at this signalised intersection as its width is such that slower cyclists who enter the intersection in the latter stages of the Ferry Road phase require more time to safely cross the intersection than that provided by the normal intergreen period. As a result a conflict emerges between these cyclists and the adjacent traffic from Fitzgerald Avenue at the beginning of its green phase. This problem also occurs at other wide intersections throughout Christchurch.

The design and the underlying philosophy are documented in the research paper *Cyclists at Wide Signalised Intersections: All-Red Time Extension on Demand* (Wilke, 1999). The trial site was evaluated by comparing a video of the intersection with a SCATS log of the traffic signals. The findings are summarised in the report *Cyclists at Wide Signalised Intersections:* Follow Up Investigation (Beban, 2001). Following this evaluation, a new design has been proposed.

Single Loop Detection

Problems with Previous Design

Beban (2001) has documented operational problems with the previous design, which is based on two detector loops within the intersection per direction of travel to detect slow cyclists:

- Missed system activations by cyclists.
- Inappropriate system activations.

The missed system activations by cyclists have two causes. Slow cyclists that are aware of the apparent danger tended to veer away from the cross traffic that was just about to enter the intersection from their left. That is, the cyclists were missing the loop by riding too far to the right for activation. As a second potential problem, conflicts of right turning motorists with opposing cyclists were listed.

Right turning motorists straddling the first detector loop mainly caused inappropriate system activations. This could be observed on a ‘reasonably regular basis’ (Beban, page 9). Another, but less frequent problem, were motorists on Fitzgerald Avenue creeping into the intersection during the all-red period, and then triggering the second loop.

Single Loop Design

Discussing all the options available as listed in Beban (2001), the project team[1] decided on implementing the design with the following characteristics, as shown in Table 1. A design drawing is reproduced in Appendix A.

Table 1: Intersection Movements (Bealey west approach)

Characteristic	Reason
Single loop further away from the limit lines.	The loop is less likely to be straddled by right turners. It is so far into the intersection, though, that a second loop is not required.
Chevron loop.	Loops with this shape are known to be more reliable when detecting cyclists than symmetripole or quadrupole loops.
Wider than the previous loops.	The loops extend further into the centre of the intersection, making it less likely that slow cyclists miss them when they try to keep clear of potentially entering cross traffic.
Pavement markings for opposing right turners.	These lane markings intend to guide turning motorists to commence their turn from a more central location in the intersection, reducing the likelihood of straddling the loops, and potentially encouraging more courteous behaviour towards slow cyclists.

Technical Design

The methodology of a spreadsheet-based design has again been employed. The equations had to be adjusted to take the different parameters into account, though.

The previous design had loop location and detection (time) windows as an output, whereas the new design is based on determining an appropriate location for a single loop, thus having the **loop position** as an **input**. As a consequence, the general **all-red** time needs to be increased, and is available as an **output**.

Figure 1 shows a graph with the graphical output of a design. The y-axis is time in seconds, with zero coinciding with the beginning of the all-red period. The lower horizontal line at 2.2 sec marks the existing length of the all-red period.

The x-axis is travel distance through the intersection, with zero at the cycle lane limit lines. As indicated above, the loop position has been decided based on the intersection layout, with the primary intention that right turning motorists do not straddle the loop. In this case, the loop was placed 21 m into the intersection, as shown by the vertical line.

The three diagonal lines represent slow cyclists, fast cyclists, and slow motorists, respectively.

The 'flattest' of the three lines represents the design car[2] used for determining the required (normal) all-red time. This design case is based on a slow car that passes the limit lines at the end of the yellow period (i.e. the start of the all-red period). The line takes the vehicle length into account (5m have been assumed), as well as the length of the detection loop (3m in this case), which is why the line does not pass through the origin. This has been done for the purpose of establishing the time when the design car is clear of the loop.

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[1] Bill Sissons – Signal Engineer; Alix Newman – Cycle Planner; Axel Wilke – Traffic Engineer; Lachlan Beban – Traffic Systems Graduate Engineer

[2] A design speed of 45 km/h is used for urban Christchurch intersections.

The 'next flattest' line represents a cyclists travelling at the 85th percentile speed[3]. The purpose of this line is to determine the beginning of the all-red time extension; hence the bicycle length is not being taken into account, as the arrival at the loop is the critical time. The intercept with the y-axis (i.e. the time the cyclists crosses the limit lines) has been computed following the following principles:

- The beginning of the yellow period is the start time (i.e. relative to the beginning of the all-red time, the yellow time begins at –4.0sec in this example).
- A reaction time similar to that used for motorists having to stop at traffic signals has been used (i.e. 1.5sec).
- A deceleration time for coming to a stop has then been added.

This methodology is consistent with procedures outlined in the yet to be published update of Austroads 7 (Traffic Signals), but differs from the procedures outlined in Austroads 14 (1999, section 5.4.3 (c))[4]. The following equation shows how the intercept with the y-axis is calculated (i.e. the time an 85th percentile cyclist is supposed to be able to stop).

$$t_{e\_85\%} = t_{reaction} + t_{deceleration} - t_y = 1.5 + \frac{v_{bike\_85\%}}{2*d} - t_y$$

where:

$t_{e\_85\%}$ = time when the 85%ile cyclist crosses the limit lines (sec)

$t_{reaction}$ = reaction time (sec) – assume 1.5 sec

$t_{deceleration}$ = deceleration time (sec)

t_y = yellow time (sec)

$v_{bike\_85\%}$ = 85%ile bicycle speed (m/s)

d = deceleration rate (m/s/s)

The 'steepest' line is the slow (i.e. 15th percentile) cyclist, which determines the design case for a new all-red time.

The intercept between the vertical line and the 15th percentile cyclist line determine the new required all-red time. In the example shown, the new all-red time is 3.3sec, which is an increase of 1.1sec from the current all-red time.

The higher value of the 85th percentile bike and the 15th percentile car determine the start of the detection window (i.e. the point in time when the all-red time extension can be called first). Initially, the design car sets this time, but with the loop further away from the limit lines, the 85th percentile bike becomes the critical case. Obviously, a driver travelling at the speed of the design car (i.e. 45 km/h), but running a red light, would call the all-red time extension. As this is undesired, it is more desirable to use the 15th percentile cycle as the design case, as this allows for some margin between the design car and the time a red-light runner would call the extension.

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[3] Speed measurements were undertaken in urban Christchurch midblocks, with the speed distribution based on 68 cyclists. The results are lower than the data quoted in Austroads 14 (1999), Table 5-2.

[4] Austroads 14 bases the calculations for clearance times on the beginning of the yellow period. This is unrealistic, though, as reaction and stopping time are neglected. In other words, it cannot be expected that cyclists don't enter the intersection with the lights being yellow.

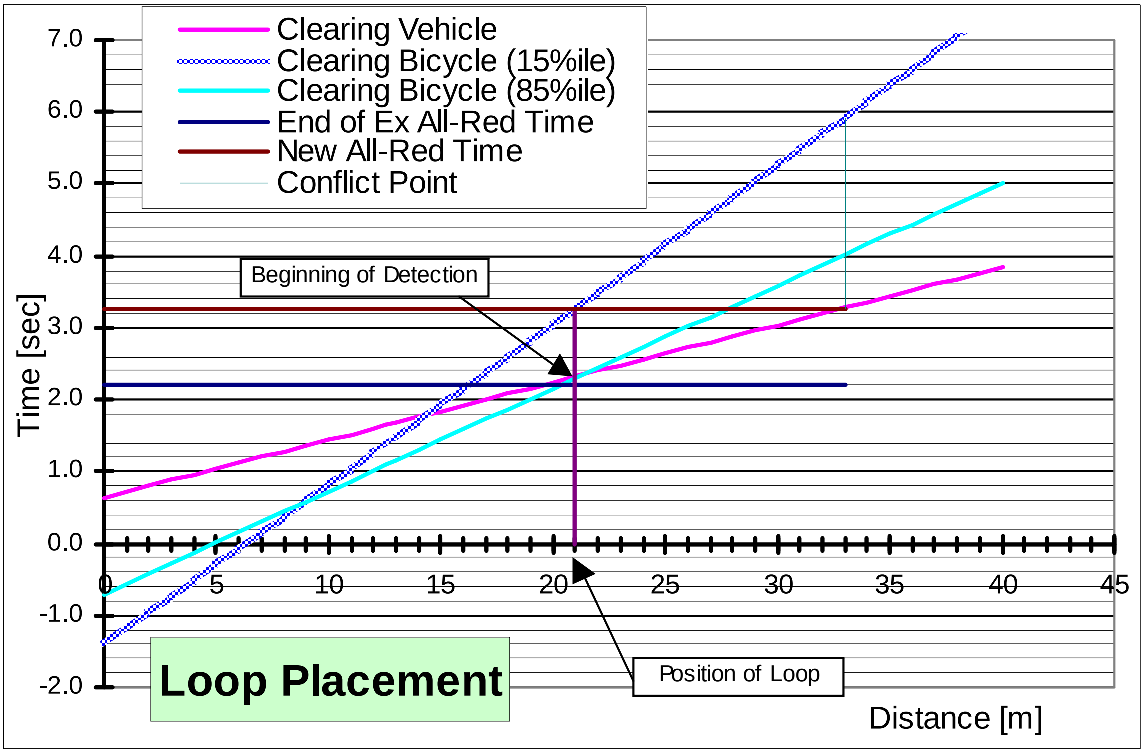

Figure 1: Design Chart

The all-red time extension can then be determined using the following methodology:

- The time needs to be determined when the 15th percentile cyclist has passed the conflict point with entering vehicles (note that the design chart shown in Figure 1 excludes the bike length, whereas the length needs to be taken into account when the objective is to get clear a conflict point).
- The normal all-red time can then be deducted.
- The time it takes an entering vehicle to reach the conflict point should also be deducted.
- A safety margin should then be added. Consistent with Austroads 7 procedures, 0.5sec has been chosen.

The following equation gives the travel time of the 15th percentile cyclist as a function of the travel distance, taking the length of the bicycle into account:

$$t(dist) = \frac{d_l + L_{bike}}{v_{bike\_15\%}} - t_y + t_{reaction} + t_{deceleration}$$

where:

where:	*t(dist)*	= time as a function of the travel distance (sec)
	d_l	= travel distance from the limit line (m)
	L_{bike}	= bicycle length (m) – assume 1.8m
	$v_{bike\_15\%}$	= 15th percentile bicycle speed (m/s)
	t_y	= yellow time (sec)
	$t_{reaction}$	= reaction time (sec) – assume 1.5 sec
	$t_{deceleration}$	= deceleration time (sec)

The next equation then yields the extended all-red time, where the distance to the conflict point must be used for the travel distance:

$$t_{ar\_ext} = t(dist) - t_{ar\_new} + t_{safe} - t_s$$

where: $t_{ar\text{-}new}$ = new all-red time (sec)

t_{safe} = safety margin (sec) – take as 0.5 sec

t_s = start up time for cross traffic (sec)

An additional check needs to be carried out for the single loop design. Faster cyclists who pass the detector loop prior to the start of the detection period need to pass the conflict point within the new all-red time period. If that is not the case, the new all-red time needs to be increased to cover this case.

Firstly, the minimum of the travel time to the loop (taking the bicycle length into account) and the beginning of the detection time determines the worst case. From there, the travel time to the conflict point, the safety margin, and the entering time need to be taken into account. This can be expressed with the following equation:

$$t_{ar\_new} = \min\left(t(dist), t(detect)\right) + \frac{d(conflict - loop)}{v_{bike\_85\%}} + t_{safe} - t_s$$

where: $t_{ar\text{-}new}$ = new all-red time (sec)

$t(dist)$ = travel time to the loop including bike length (sec)

$t(detect)$ = travel time to the detector loop (sec)

d = distance (m)

$v_{bike\_85\%}$ = 85^{th} percentile bicycle speed (m/s)

t_{safe} = safety margin (sec) – take as 0.5 sec

t_s = start up time for cross traffic (sec)

Discussion

The new design is simpler, as it uses only one loop per direction of travel. Whereas the previous design made it virtually impossible for red light runners to abuse the system, this guarantee is no longer given, and it should be monitored whether motorists become aware of this and start abusing the system. It will be complicated to determine whether red light running is being encouraged by the system, though.

Both the old and the new design do not require any road user education, which may counteract the possible risk of motorists abusing the system.

The biggest disadvantage of the new design is that the normal all-red time needs to be increased. This is somewhat balanced by the fact, though, that the first extension was regularly called by right turners in the first design.

Ferry / Fitzgerald Intersection

The intersection of Ferry Road and Fitzgerald Avenue had already been chosen as a trial site, and the new design will be implemented there. Appendix A shows a design drawing, with Table 2 showing some design parameters. Note that the design is symmetrical for the two Ferry Road approaches.

Table 2: Design Input and Output Parameters

Input Parameters	
Travel to Loop	21 m
Travel to Conflict Point	33 m

Existing All-Red Time	2.2 sec
Output Parameters	
New All-Red Time	3.3 sec
Extended All-Red Time	5.3 sec
Beginning of Detection Time[5]	2.3 sec

Conclusions

It is expected that the new design will overcome the problems reported in Beban (2001). It is necessary to undertake follow-up investigations, checking that the system works as intended, and that motorists do not abuse the system by deliberately running red lights, as they too can call the all-red extension on demand.

[5] Relative to the beginning of the (new) all-red time.