THE CHANGING SIGNAL FACES OF CYCLING

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ABSTRACT

It's time to give cycle signals a face-lift!

Equipped with signal aspects in the shapes of arrows and discs, traffic engineers have control over each individual motor vehicle movement at an intersection, giving flexibility to the intersection phasing and thus achieving maximum efficiency and safety. In contrast, provision for cycling is limited to a standard cycle signal, a blanket cover for all cycle movements from the same intersection approach. This makes it impossible to operate two cycle movements from the same approach independently and generally limits cycle phases to operating only when the most-restricted cycle movement can. People on bikes who are frustrated with being unnecessarily held back may choose to run a red cycle signal; this could negatively influence other cyclists (including those less capable of judging the situation for themselves), result in conflict with pedestrians or motor vehicles, and irritate drivers.

To address this problem, Christchurch City Council and Auckland Transport commissioned ViaStrada to conduct an official traffic control device trial of directional traffic signals for cyclists. The new signals have been installed at four intersections. Assessments of user behaviour (compliance and conflicts), user understanding, and user satisfaction have been undertaken at three of the intersections and will soon be carried out at the fourth.

The results are satisfying. Compliance of both people on bikes and motorists was shown to increase with the introduction of the directional cycle signals. The success rate for surveyed users interpreting the various scenarios shown to them was pleasingly high, showing that the devices used are intuitive to users. Survey respondents were generally in favour of the new signals.

Our industry has been tasked with creating an efficient, modern, safe, and environmentally sustainable transport system; directional cycle signals will contribute to this by improving the cycling level of service and therefore increasing the cycling mode share.

1 BACKGROUND

1.1 Problem

Traffic signals for cyclists were introduced to the Land Transport New Zealand Traffic Control Devices Rule in 2004 (it is thought the device was used in Christchurch as early as 1976[1]); this was innovative at the time. However, having only one type of traffic signal for cyclists precludes the ability to control individual movements (e.g. turning versus through) separately. In comparison, arrow signals are commonly used to give flexibility to motor vehicle movements. Therefore, cyclists are disadvantaged in comparison to drivers in terms of engineers' ability to provide for them. Cycle signals with directional components are common overseas, especially in Europe.

The problem is increasingly evident as the complexity of cycle networks increases and separated cycleways are introduced. One example is the diagonal cycle crossing installed at Beach Road / Te Tao Crescent in Auckland in 2014. The cycle signal was green when cyclists could cross the intersection diagonally, and red when the general traffic could go. The problem was that the cycle signals also applied to people wishing to cycle straight ahead, meaning they must be stopped for most of the intersection phase time, including when it would be perfectly safe to continue straight ahead parallel to the adjacent through traffic. Many cyclists wished to travel straight ahead and chose to run a red light rather than accept the unnecessary delay. Before the trial, Auckland Transport had no way of signalising the two cycle movements separately.

Figure 1: Beach Road diagonal crossing with original signals

The behaviour experienced at the Beach Road diagonal crossing is not surprising; Alrutz, Willhaus, Meyhöfer et al. (1996) showed that cyclist compliance with signals is proportional to the ratio of green time they receive compared to parallel through traffic. The inefficiency and inequality that result from grouping all cyclists according to the lowest common denominator will result in compliance issues.

1.2 Proposed solution and trial objectives

Christchurch City Council and Auckland Transport have commenced an official traffic control devices trial of directional traffic signals for cyclists that enable independent operation of multiple cycling movements from

[1] At the Deans Avenue / Kilmarnock Street intersection, to give cyclists access between the stem of the T and Hagley Park. It is difficult to identify exactly when the cycle signals were installed here; the intersection was signalised in 1976, and there is no record that the cycle signals were introduced afterwards, which suggests that the cycle signals were there from the beginning.

the same approach. ViaStrada was commissioned to conduct the trial.

The purpose of the trial, as outlined in the Gazette notice (NZ Government, 2017), is to:

a. Enable the installation of directional cycle traffic signal displays that incorporate an arrow in the same signal aspect with the cycle symbol […];
b. evaluate the safety and effectiveness of traffic signal displays that allow cyclists on the same approach to an intersection to move in different directions at different times; and
c. assess cyclists' and other road users' understanding of and compliance with traffic signals that control directional movement of cyclists at intersections with cycle traffic signals.

1.3 Project status

At the time of writing this paper, three of the four trial sites had undergone interim evaluation (required 3 to 6 months after installation), and the subsequent submission of the interim report, the findings of which are summarised in this paper. As per Traffic Note 10 (NZ Transport Agency, 2011), all four sites will require interim evaluation plus final evaluation (required 18-24 months after installation). The interim report is not publicly available, but the final trial report will be published in due course.

2 DEVICE TRIALLED

The decision to trial directional cycle signals stemmed from a push to trial small near-side signals to replace far-side signals for cyclists; one of the issues this sought to address was the lack of ability to assign directional meaning to cycle signals, but the Traffic Control Device Steering committee directed that regular or large signals with directional components would be a better solution. Several overseas examples were identified and discussed amongst representatives from the NZ Transport Agency (cycling team and traffic control device regulators), enthusiastic RCAs, traffic signal hardware suppliers, and ViaStrada, to determine the specifications for the mask (layout) and light qualities of the signal aspects. This was an iterative process, which included some initial testing of hardware off- and on-site (see section 3.2.2) to verify the signals were considered appropriate.

The directional cycle traffic signals trialled had the following characteristics:

- Signal aspects of 200–300 mm diameter (depending on distance from limit line)
- Masks involving cycle symbols and arrows of 5 mm line width (for a 200 mm diameter signal) or 7.5 mm width (for a 300 mm diameter signal).
- Modern lanterns comprising LEDs
- A diffuser that distributes the light evenly across the aspect giving a consistent light emission across the symbol defined by the signal mask.
- A coloured lens between the diffuser and the mask.
- Signal aspect design based on that shown in Figure 2 with various options for aligning the arrow (left turn, bear left, straight ahead, bear right, right turn).
- Mounted at heights appropriate for cyclists.

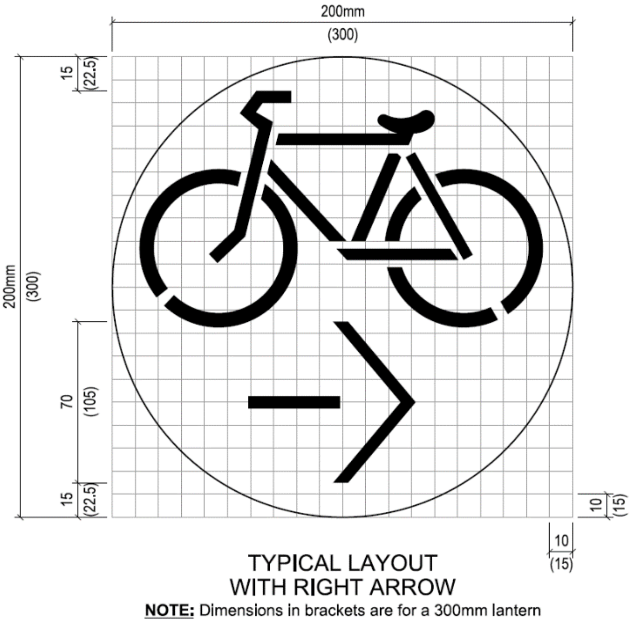

Figure 2: Dimensions for typical directional cycle signal lantern aspect layout

The RCAs were given some flexibility in terms of choosing the size of the signals, as well as the arrangement and positioning of signals, which was useful to stimulate public and professional feedback on the optimal arrangements and the visibility and clarity of the signal aspects.

3 METHODOLOGY

3.1 Trial sites

Four sites were selected for the trial, two each in Auckland and Christchurch. In the figures below, the cycleway approaches studied are circled, with arrows for the corresponding cycle movements.

1. **High Street / Madras Street / St Asaph Street ("HMSA") Christchurch, installed July 2017**
   - From the St Asaph St east approach cyclists can travel straight ahead on St Asaph St or take the diagonal crossing to High St
   - From High St, cyclists can travel on the diagonal (used as a comparison)

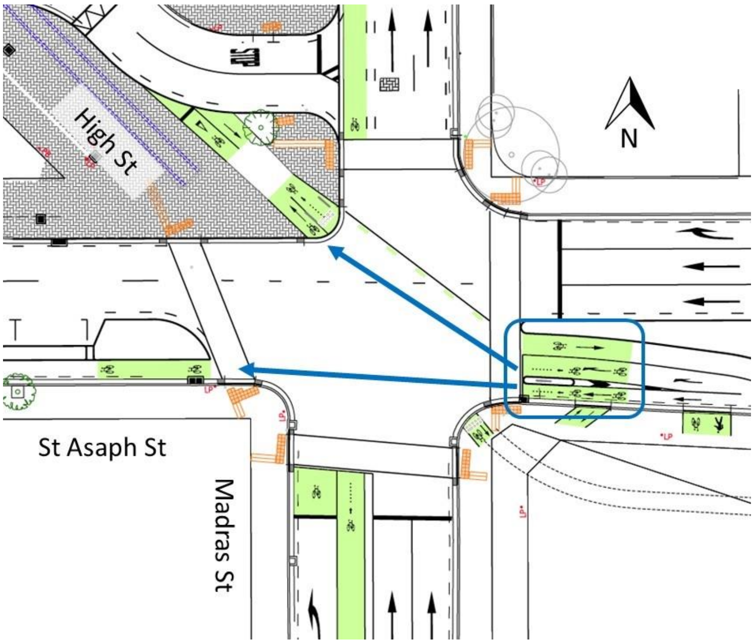

Figure 3: High St / Madras St / St Asaph St site map

Figure 4: Green diagonal cycle signal, High St / Madras St / St Asaph St

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2. **Beach Road / Te Taou Crescent ("BTT") Auckland, installed November 2017**
   - From the Beach Rd south approach cyclists can travel straight ahead on Beach Rd or take the diagonal crossing to the Beach Rd cycleway

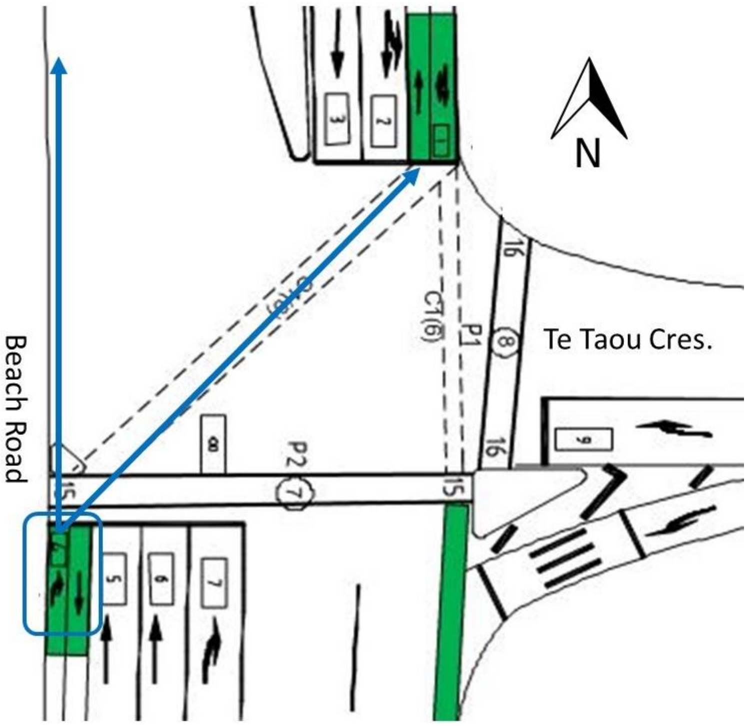

Figure 5: Beach Rd / Te Taou Crs layout

Figure 6: Combined primary signal head, Beach Rd / Te Taou Crs

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3. **Nelson Street / Victoria Street ("NV") Auckland, installed February 2018**
   - From the Nelson St south approach cyclists can travel straight ahead to Nelson St north or turn right onto Victoria St east

Figure 8: Combined far-side signal head, Nelson St / Victoria St

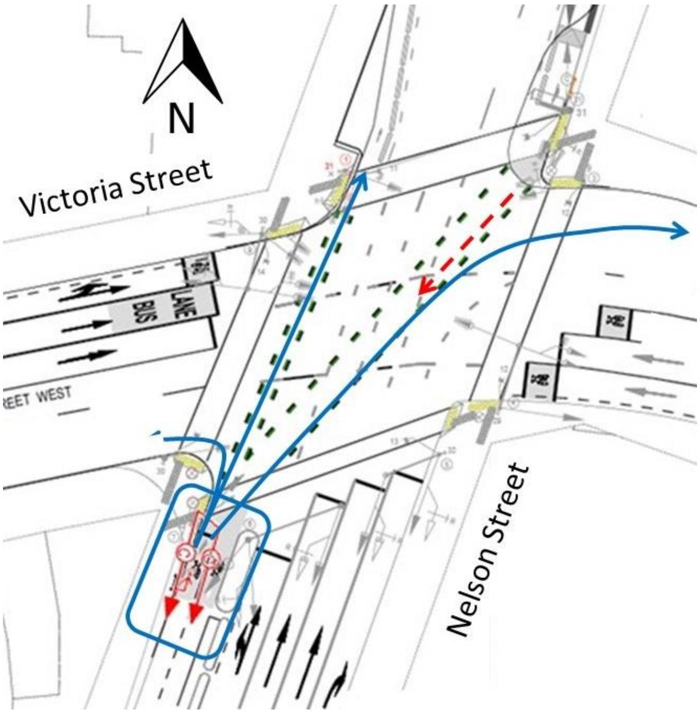

Figure 7: Nelson St / Victoria St layout

4. **Antigua Street / St Asaph Street, Christchurch ("ASA") installed December 2018, interim evaluations not yet undertaken**
   - From the Antigua St north approach cyclists can travel straight ahead to Antigua St south or take the diagonal crossing to St Asaph St west

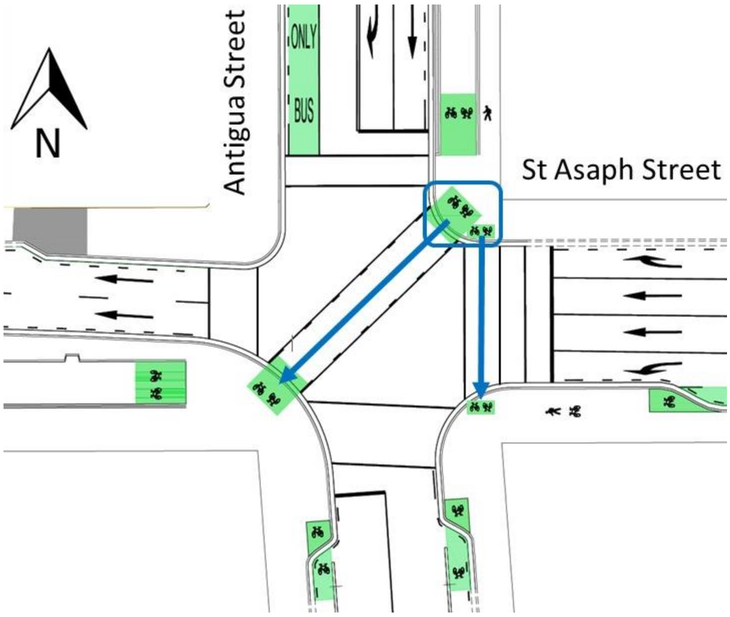

Figure 9: Antigua St / St Asaph St layout

Figure 10: Directional cycle signals on Antigua St north approach to St Asaph St

3.2 Evaluation stages

Ultimately, the evaluation will compose five distinct stages; this paper covers the first four stages, i.e. up to the interim evaluations, which have been undertaken for three sites.

3.2.1 Before studies

At sites where the cycleway existed prior to the introduction of the directional cycle signals, user behaviour data were gathered to develop an understanding of the baseline characteristics.

3.2.2 Hardware testing

Prior to commissioning the signals, various options were tested at the High St / Madras St / St Asaph St site, to confirm that the masks and lantern arrangements were considered suitable when viewed in a live traffic environment.

3.2.3 Initial "novelty" period monitoring

The initial months after installation are considered the "novelty" period, during which road users generally behave differently while they adjust to the change. It would be unwise to conduct full evaluations during this period, and it is necessary to allow time for behaviours to stabilise after a major change. During the novelty period, the RCAs monitored the sites closely via CCTV, to identify any initial safety issues. No remedial action was required.

3.2.4 Interim evaluations

Three to six months after the installation, user behaviour at all sites was evaluated. User understanding and satisfaction surveys are also be conducted at this time. This information was compared with the baseline data from the before studies and forms the basis of the interim report.

For the High St / Madras St / St Asaph St site, two interim evaluations were undertaken due to initial problems with the cycleway lane markings.

3.2.5 Final evaluations

The final evaluations will be conducted 18 to 24 months after the installation of the directional cycle signals. The nature and extent of the final evaluations will be dictated by the TCD Steering Committee, based on their review of the interim report.

3.3 Evaluation components

3.3.1 User behaviour

Video footage was recorded and analysed to evaluate cyclists' behaviour and the severity of any non-compliant actions. The following parameters were noted:

- Approach location – which cycle lane they used (if applicable)
- Time of arrival – at the limit line
- Cyclist's signal state (green, yellow, or red) at arrival
- Other cycle signal (i.e. for the adjacent cycle movement) state at arrival (if applicable)
- Time of departure – crossing the limit line or a defined threshold line beyond which the cyclist would potentially be in the path of conflicting traffic
- Cyclist's signal state at departure
- Other cycle signal state at departure (only if applicable)
- Cyclist compliance type – in terms of lane useage and compliance with traffic signals
- Cyclist trajectory – pattern of movement through the intersection – specific to each site
- Interaction severity for non-compliant (i.e. red light running) events – as per Table 1
- Analyst notes – further explanation, unusual occurrences, anomalies etc

Table 1: Interaction severity classification for non-compliant events

Score	Interaction type	Description
(0)	No potential for conflict	While the user violated a red light, there was no motor traffic in the conflicting direction and therefore no actual potential for conflict.
1	No incident	Cyclist does not need to alter course or speed to avoid conflict. The cyclist experiences no apparent stress.

Score	Interaction type	Description
2	Minor adjustment required	Cyclist may need to alter course slightly to allow for a comfortable passing distance, or gently brake or alter pedalling rhythm. The situation is unlikely to be perceived by the cyclist as unsafe but may be perceived as inconvenient. There is unlikely to be any sense of surprise or fright.
3	Major adjustment required	Cyclist may need to significantly alter course or adjust speed. There is a heightened level of stress, and possibly surprise or fright. However, the adjustment readily avoids a collision. Could also include the case where a driver runs a red signal and a cyclist chooses not to proceed on their green signal to avoid conflict.
4	Near-collision	A rapid change of course or speed is required by the cyclist or motorist (or both) to avoid imminent collision. A significant degree of fear and fright is likely. The parties may gesture to one another.
5	Collision	There is physical contact between the parties.

Motorist red light running was also observed for key motor vehicle movements (at some sites, this was limited by the angle of the camera and visibility of the general traffic signals). The analyst was instructed to record all instances when a motor vehicle proceeds through the intersection with the front of the vehicle having crossed the limit line when their signal was red, and note key information regarding time, trajectory, signal state, explanatory notes etc.

3.3.2 User understanding and satisfaction

Online surveys were developed for Christchurch and Auckland to gauge road users' understanding and satisfaction of the directional cycle signals using specific examples from the High St / Madras St / St Asaph St and Beach Rd / Te Taou Crs installations. The online surveys were open to anyone and included questions to distinguish their general use of various modes, and specific familiarity with the site(s).

Based on the online surveys, a face-to-face face survey was also developed, targeted at people on bikes who had just travelled through the survey site.

All respondents were questioned about:

- Interpretation of directional cycle signals (e.g. Auckland example in Figure 11)
  - For different signal displays
  - From the perspectives of riding a bike or driving
- Familiarity with the site since the installation of the directional cycle signals (for different modes of travel)
- General transportation habits
- Demographics – age and gender

The questions asked of only those familiar with the site targeted:

- Experience of the new cycle signals – safety, confusion, etc
- Opinions of the directional cycle signals – perceived benefits and disbenefits

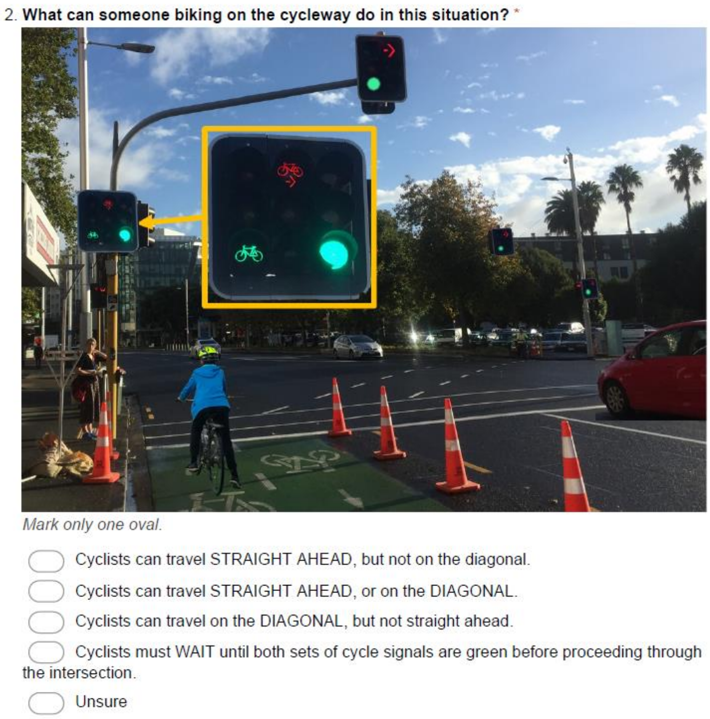

Figure 11: Example of interpretation from Auckland survey

The online surveys were advertised through various methods including: intercept surveyors passing out invitation cards to those who didn't participate in the intercept survey; Christchurch Major Cycle Routes newsletter; Facebook (shared by various parties); ViaStrada website.

4 RESULTS

4.1 User behaviour

4.1.1 Sample sizes

A sample of at least 100 cyclists per evaluation period per site was aimed for; this was always achieved before the entire footage had been gathered but, where budget allowed, the analyst was instructed to continue beyond the minimum level. Table 2 summarises the number of cyclists analysed and the number of red light running (RLR) motorists (turning left or travelling straight ahead from the approach adjacent to the cycleway studied) observed during the same periods.

Table 2: User behaviour sample summary

	Cyclists analysed		**RLR motorists from adjacent approach**		**Analysis time (hours:minutes)**	
Site	Before	Interim	Before	Interim	Before	Interim
High St / Madras St / St Asaph St	125	235	24	17	1:52	2:32
Beach Rd / Te Taou Crs	133	140	8	2	3:25	2:12
Nelson St / Victoria St	140	133	20	18	3:07	4:22

4.1.2 Cycling trajectories through the intersections

The cyclist trajectory data for all three sites showed an increase in the proportion of cyclists using the "new" movement made possible or clearer by introducing the directional cycle signals (i.e. the diagonal crossing at High St / Madras St / St Asaph St, the through movement at Beach Rd / Te Taou Crs and the through movement at Nelson St / Victoria St).

The interim report has a much more detailed analysis, especially for High St / Madras St / St Asaph St which involves two approach cycle lanes, but it is considered best to devote the limited space in this paper to presenting the results for compliance with traffic signals.

4.1.3 Cyclist compliance with traffic signals

Figure 12 summarises whether cyclists coming from the cycleway approaches studied complied with the relevant traffic signals and the resulting interaction severity of non-compliant manoeuvres, before and after the installation of the directional cycle signals.

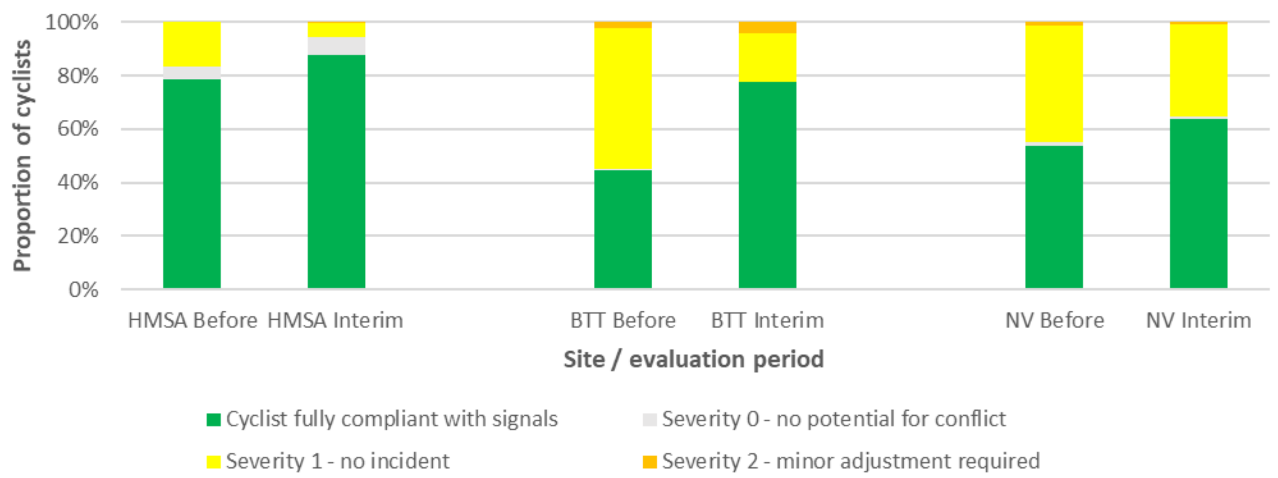

Figure 12: Cyclist compliance with traffic signals and interaction severity of non-compliant movements

Note that the category "cyclist fully compliant with signals" has been used to distinguish from interaction severity level 0, as the latter assumes the cyclist did not comply with their traffic signals (i.e. ran a red light) but there was no opposing traffic present and therefore no potential for conflict. Table 3 shows the corresponding chi-squared test results to determine whether the change was significant.

A chi-squared analysis has been conducted to determine whether there has been a statistically significant difference. The null hypothesis is that the introduction of the directional cycle signals has not resulted in any change to cyclist compliance in terms of red light running; the alternative hypothesis is that the new signals have resulted in an improvement to cyclist compliance. For the observed change in compliance to be deemed statistically significant, the significance level output from the analysis should be 5% or lower.

Table 3: Chi-squared test: change in proportion of compliant to RLR cyclists after installation of directional cycle signals

Site	Compliant (non-RLR) cyclists		Non-compliant (RLR) cyclists		Chi-squared statistic	Significance level
	Before	Interim	Before	Interim		
High St / Madras St / St Asaph St	98	206	27	29	5.326	2.1%
Beach Rd / Te Taou Crs	59	109	74	31	31.766	0.0%
Nelson St / Victoria St	75	85	65	48	3.005	8.3%

Compliance at the High St / Madras St / St Asaph St intersection was already high (around 80%), which is related to the fact that the dominant flow is the through movement, which was already well-catered for by the traffic signals (as Madras Street is one-way, there is no conflicting left turn into the adjacent Madras Street approach, meaning the cycle signals have as much green time as the adjacent general traffic, minus the extra all-red time required for slower travel speeds). However, the increase in compliance at this site was not only due to the diagonal cycle crossing movement being legalised – a lower proportion of cyclists heading straight ahead ran red lights in the interim study. The non-compliance in the interim periods was largely due to through cyclists using the diagonal cycle approach as a means of overtaking slower cyclists, when through cyclists had a green signal; this accounts for nine out of 32 cyclists from the interim sample.

Compliance improved significantly at Beach Rd / Te Taou Crs, due to the popular through movement being made lawful while adjacent through traffic was operating. The non-compliance that did occur in the interim period is probably an indication that cyclists still felt safe travelling across the head of the T intersection at the end of the phase, or when the side street traffic was operating.

Compliance at Nelson St / Victoria St improved slightly with the introduction of the directional cycle signals, with a 91.7% confidence level (the lowest of the three sites, but still satisfactory). There remained a lot of red light running, predominantly by cyclists turning left, but also by those travelling straight ahead, whilst the vehicle left turn from the adjacent traffic lane was operated. This indicates that cyclists considered they were being unduly held back when there were no conflicting pedestrians or turning vehicles.

The clear majority of non-compliant movements were gauged as level 1 severity (from the 5-tier scale – see Table 1), i.e. there was some parallel traffic present but neither party had to make any adjustments to their speed or trajectory. No conflicts were greater than level 2, i.e. when the cyclist makes a minor adjustment to their trajectory or speed, without appearing to be worried by the situation. The High St / Madras / St / St Asaph St and Beach Rd / Te Taou Crs sites experienced a slight increase in level 2 severity interactions (from 0 to 1 and 3 to 6 respectively); these incidents generally involved cyclists crossing at the same time as a parallel pedestrian movement having first identified the presence of filter-turning vehicles and slowed down or altered their trajectory to avoid any conflict. In terms of safety outcomes, there is little difference between level 1 and level 2 incidents and therefore no cause for concern at the slight increase in level 2 severity incidents. At Nelson St / Victoria St the number of level 2 incidents decreased from 2 to 1 after introduction of the directional cycle signals. None of the 275 non-compliant incidents analysed were close to becoming a crash (level 4 or greater), which at the very least means we cannot prove that the intersection operation is not suitably safe. To draw a more confident conclusion, it would be necessary to have a baseline understanding of what proportion of conflicts at certain severity levels would be deemed "acceptably safe".

Overall, the low severities of interactions show that non-compliant cyclists are aware of the situation and generally judging themselves whether it is safe to proceed. This cycling behaviour is common at signalised intersections and can be a challenge for traffic engineers to improve upon. The key point for the behavioural studies is that the introduction of the directional cycle signals has improved the overall compliance of cyclists at the three study intersections, i.e. making them safer than the previous situation.

4.1.4 Motorist compliance with traffic signals

Table 4 summarises the chi-squared analysis for the motorist compliance data. The instances of motor vehicle red light running (RLR) per analysis periods (Table 2) have been taken as the observed values, with expected values derived from the averages of the before and interim RLR rates, i.e. assuming that there was no change in influence between the two samples (see the sample calculation in footnote 4). Note this is a different form of chi-squared analysis than that used for cyclist compliance, because it was not possible to undertake a comparative analysis since the number of compliant motor vehicles were not recorded (see the sample chi-squared statistic calculation in footnote 5). This is arguably less rigorous than a direct comparison of red light running to compliant motorists (as was performed for cyclists) and is based on the assumption that motor vehicle flows and intersection phase times were consistent between the before and interim samples (in reality, there would be some disparity due to the slightly different survey durations) but it is nonetheless considered a useful comparison.

Note only the motor vehicles that came from the approach adjacent to the cycleway studied and either turned left[2] or travelled straight through the intersection are analysed here[3].

Table 4: Observed rates of red light running motorists per minute and chi-squared statistics

	Observed RLR motorists [*minutes analysed*]		Expected RLR motorists		χ^2 **statistic**	Significance level
Site	Before	Interim	Before	Interim		
High St / Madras St / St Asaph St	24 [*112*]	17 [*152*]	17.4[4]	23.6	4.36[5]	3.7%
Beach Rd / Te Taou Crs	8 [*205*]	2 [*132*]	9.7	6.3	3.21	7.3%
Nelson St / Victoria St	20 [*187*]	18 [*262*]	15.8	22.2	1.89	17.0%

Table 4 suggests that the rate of motorist red light running has decreased at all sites, although the level of confidence at Beach Rd / Te Taou Crs and, even more so, Nelson St / Victoria St is not exemplary – having larger sample sizes or comparing with volumes of compliant motorists may improve the confidence levels.

The motorist compliance observations suggest that the directional cycle signals have not confused motorists to the point of making errors, although they may have been more cautious.

4.1.5 Pedestrian compliance with directional cycle signals

The video analyst did not specifically record pedestrian movements, however confirmed that they had not observed any instances of pedestrians trying to cross the intersection diagonally with the cycle crossings. At Nelson St / Victoria St, a significant number of pedestrians were observed crossing Nelson Street

[2] No left turn at High St / Madras St / St Asaph St, due to Madras Street being one-way.

[3] The right turning vehicles from the same approach were not analysed, as the footage provided generally did not include sufficient view of the right turn signals and traffic – either due to the camera angle, the distance to the signals, or the effects of sunlight or rain. As all intersections involve two lanes of traffic between the right turn lane and the cycleway, it is considered that the directional cycle signals should not be a distraction for right turning drivers.

[4] $E_a = \frac{24+17}{112+152} * 112 = 17.4$

[5] $\chi^2 = \frac{(24-17.4)^2}{17.4} + \frac{(17-23.6)^2}{23.6} = 4.36\ (using\ unrounded\ values)$

(perpendicular to the cycleway approach) while the diagonal cycle crossing operated, even though that crosswalk is not operated during this phase. Thus, it seems that pedestrians understand that the directional cycle signals are intended for cyclists only, but at Nelson Street they are comfortable managing potential conflict with cyclists to improve their LOS.

4.2 User understanding and satisfaction

4.2.1 Sample sizes

For the survey based on the High St / Madras St / St Asaph St site, 103 people responded to the online survey, and 43 participated in the intercept survey. For the survey based on the Beach Rd / Te Taou Crs site, 166 responded to the online survey and 39 participated in the intercept survey. Figure 13 shows the distribution of how familiar the participants were with the specific sites used as examples in the questionnaires.

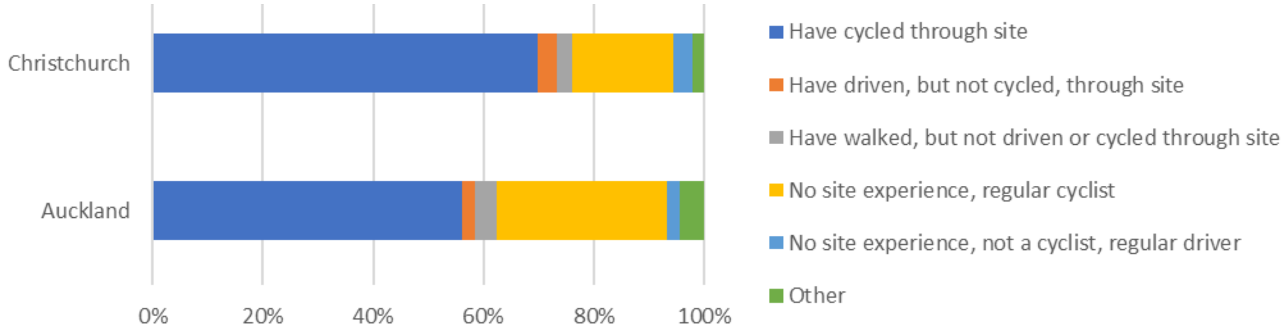

Figure 13: Survey respondents' familiarity with trial sites

4.2.2 Interpretation of different traffic signals and combinations

Figure 14 summarises the rate of correct responses to the four questions where users were asked to describe what a cyclist (Q2 and Q4) or a motorist (Q3 and Q5) could do in response to certain signal combinations as displayed in images (Figure 11 shows Q2 from the Auckland survey).

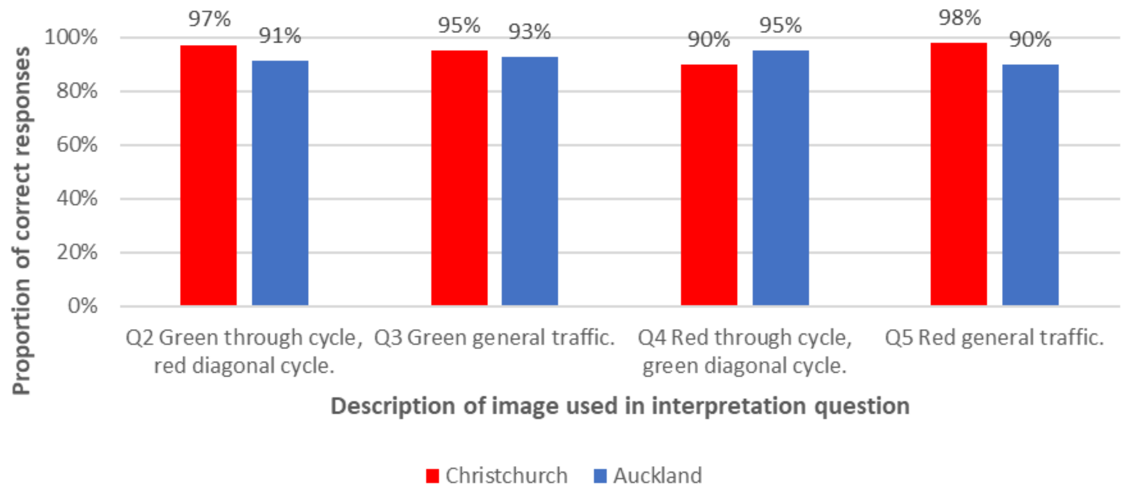

Figure 14: Interpretation of signal combination questions

At least 90% of respondents answered each question correctly – a highly satisfactory result.

When examining the response rates for various user groups, cyclists familiar with the sites generally had a slightly lower success rate than those who were regular cyclists with no site experience (the second largest group), particularly for the Auckland survey. This is assumed to be due to: ingrained behaviour (e.g. cyclists at Beach Rd / Te Taou Crs accustomed to running the red cycle signal prior to installation of the directional signals); intricacies of the actual site operation (e.g. both cycle movements may be included in certain phases at High St / Madras St / St Asaph St depending on whether pedestrian movements are demanded); and respondents familiar with the site being over-confident, reading the answer choices too quickly and missing the subtle differences between options.

Users without site experience and / or cycling experience were shown to have a good comprehension of the signal configurations, showing that the signals are self-explaining and easily interpreted.

4.2.3 Experiences and opinions of the directional cycle signals

About 20% of survey respondents from Christchurch and 27% from Auckland reported having experienced some difficulty or confusion related to the new directional cycle signals. Three of the 146 (2%) Christchurch survey respondents and 20 of the 205 (10%) Auckland survey respondents commented that the size of the cycle signals (200 mm diameter signals were used at the Auckland sites) or symbols within them could or should be increased.

It is considered that a certain level of confusion is acceptable (considering that the driver licensing system does not require 100% on tests). Many respondents suggested that levels of confusion will reduce over time, as more people become more accustomed to the changes. Basic education and promotion would also help improve understanding.

Part of the difficulty in distinguishing the signals was due to an initial light-spill problem evident in the hardware installed on-site (which turned out to be slightly different to the hardware tested initially). This issue has since been addressed, making the symbols clearer and more visible.

Obviously, the symbols used in the directional cycle signals are more intricate than a full round disc or arrow used for general traffic, hence the large size used at High St / Madras St / St Asaph St (the far-side signals are 300 mm in diameter, as opposed to the regular traffic signals which are 200 mm in diameter). Based on initial field tests with 200 mm lanterns, it may also be suitable in some locations to use smaller signals. The far-side signals at Beach Rd / Te Taou Crs, however, are 200 mm in diameter, which may be undesirably small given the size of the intersection.

Another difference between the Auckland and Christchurch sites is the placement of the cycle signals with respect to the general traffic signals and the road layout. In the Christchurch survey, one comment was made that it seems unusual that the cycle signals at High St / Madras St / St Asaph St are in separate groups. Comments regarding the location of the cycle signals were more numerous in the Auckland survey; several people suggested the signals were mounted too high, one noted that the Nelson St / Victoria St (i.e. primary) signals (Figure 8) were preferable to those at Beach Rd / Te Taou Crs (Figure 6) due to being separate from the general traffic signals, but one respondent identified the problem that the far-side signals at Nelson St / Victoria St (Figure 8) do not match the road layout.

As a result of the comments and issues regarding the size and placement of cycle signals, updates have been proposed for the *Cycling Network Guidance* (NZ Transport Agency, 2018) to include specific guidance on this topic; the key points being that cycle signals should be lower than and separated laterally from general traffic signals, with the signal columns for different cycle movements ideally being physically separated and positioned according to their respective approach cycle lanes.

4.2.4 Further comments

Most people who chose to give further comment when asked to explain the reasons for their experience and opinion rankings, or the survey in general, gave feedback not specifically related to the study sites or the directional cycle signals. Rather, they discussed other features of the sites (e.g. road layout, phasing, and coordination along the corridor), other sites, or provision for cycling in general, or other concerns with the sites that do not directly relate to the directional cycle signals. These comments are useful feedback for existing and future cycleway operations in Christchurch and Auckland but are outside of the scope of the traffic control device trial.

5 CONCLUSIONS

The interim report recommends some site-specific improvements, particularly for the two Auckland sites, for example: creating separate approach cycle lanes to correspond to the two cycle signal columns; replacing the far-side signals with 300 mm diameter aspects; improving the signal placement with respect to the cycleway layout and general traffic signals, in-line with the new additions proposed for the *Cycling Network Guidance* (NZ Transport Agency, 2018).

Overall, the new directional cycle signals have been successful. Their introduction has improved LOS for cyclists by enabling a greater proportion of green time to be given to certain movements and therefore increasing their equity with general traffic. Compliance of both cyclists and motorists has improved and users show a good level of interpreting the new devices in combination with general traffic signals. Thus, it has been recommended to continue the formal trial at all four trial sites (including the interim trials to be conducted at Antigua / St Asaph). Based on the interim results it could be expected that the device will eventually be approved for use across the country.

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