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Diagonal cycle crossing for signalised intersection

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Abstract

Auckland City Council has developed an innovative cycling proposal to resolve a difficult continuity problem on a significant cycleway currently under construction. The planned State Highway 20 (Mt Roskill) cycleway will run in parallel with the motorway corridor but at its western end the off-road cycleway finishes at a large signalised intersection. Cyclists wishing to continue westwards are presented with the difficult situation of attempting to cross the large and complicated intersection diagonally. This would normally require cyclists to dismount and use two pedestrian phases to reach the desired side of the intersection.

Designers ViaStrada and Maunsell have developed an innovative concept, which proposes a diagonal cycle phase to run concurrently with opposing right-turning traffic (i.e. during the 'single diamond phase'). This is believed to be the first of its kind in NZ, and whilst the concept is described in the Dutch CROW manual, it appears that it has not been tried before in The Netherlands either. This paper will present the concept, and discuss its benefits and risks.

This paper has been co-authored by Axel Wilke (ViaStrada), Matthew Hinton (Maunsell) and. Daniel Newcombe (Auckland CC)

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Glossary of Terms

Cycle lane	A portion of the carriageway that has been designated by road markings, signs or pavement surfacing use of cyclists.
Cycleway	Shared pathway for pedestrians and cyclists alongside a road (but not on the carriageway), or away from a road (e.g. through a park).
Early start	At traffic signals, introducing a movement earlier than other movements that are operated in the same signal phase.

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1. Introduction

As part of its commitment to develop a comprehensive cycle network across the city, Auckland City Council (ACC) has identified the State Highway (SH) 20 corridor and Richardson Rd as key components for cycle infrastructure provision. This route is specified within the council's strategic cycle network. A 6 km long cycleway is being built alongside SH 20 in conjunction with Transit NZ and will stretch from Onehunga in the south-east to the intersection with Richardson Road and Maioro Street in the north-west (the Maioro Street interchange), which is where SH 20 will end (see Figure 1).

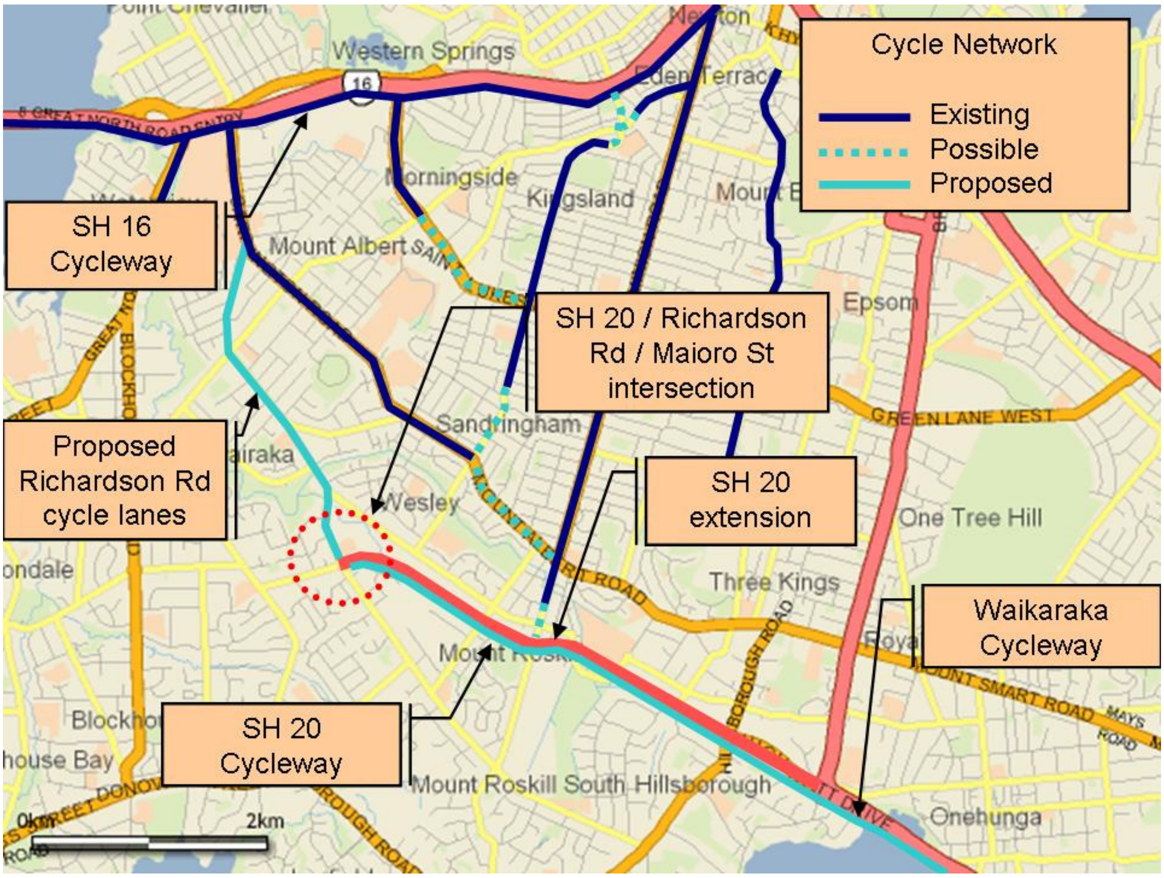

Figure 1: Cycle network highlighting the SH 20 / Maioro St / Richardson Rd intersection

It is important that this key piece of the cycle network is complemented by further facilities that provide for the many cyclists expected. Therefore the council commissioned Maunsell to investigate the feasibility of cyclist facilities from this intersection towards the existing Northwestern cycleway on SH16 and adjacent cycle network links.

2. Background

ACC estimates that upon opening, around 920 cyclists per day are expected to use the SH 20 cycleway. The estimate of use rises to 1,600 cyclists per day after 20 years. Around 300 to 400 cyclists per day are expected to use the Maioro St interchange initially.

The Maunsell study identified the desirability for on-road cycle lanes along the Richardson and Woodward Roads link to create a continuous cycle facility from the Waikaraka cycleway and the SH 20 cycleway (together approx. 10 km long) along the Richardson Road / Woodward Road / Carrington Road link (approx. 5 km) to the Northwestern cycleway.

To create a complete westbound route, the intersection of the Richardson Rd / Maioro St becomes critical, as cyclists coming from the SH 20 cycleway are required to cross to the diagonally opposite side of the intersection to reach the planned on-road cycle lanes along Richardson Rd. Eastbound cyclists are not faced with the same difficulty in reaching the SH 20 cycleway, as they have only one leg of the intersection to cross, and they are entering the intersection coming from a cycle lane.

Initial investigations by Maunsell identified this intersection as a critical location but did not define a solution other than requiring cyclists to dismount and use at least one pedestrian crossing phase on foot. This study was reviewed by ViaStrada, who proposed the innovative diagonal cyclist crossing.

It needs to be clearly understood that the intersection proposal is at an early stage and has not yet gone through the usual audit processes, public consultation, key stakeholder input or political decision making. It is therefore likely that measures described here and design details shown in this paper will differ from what is eventually going to be implemented.

3. Description of the Problem

Figure 2 shows a possible layout of the Maioro Street interchange. The proposed SH 20 cycleway is a shared facility for pedestrians and cyclists and is located along the south side of the State Highway. Cycle lanes are proposed for Richardson Road.

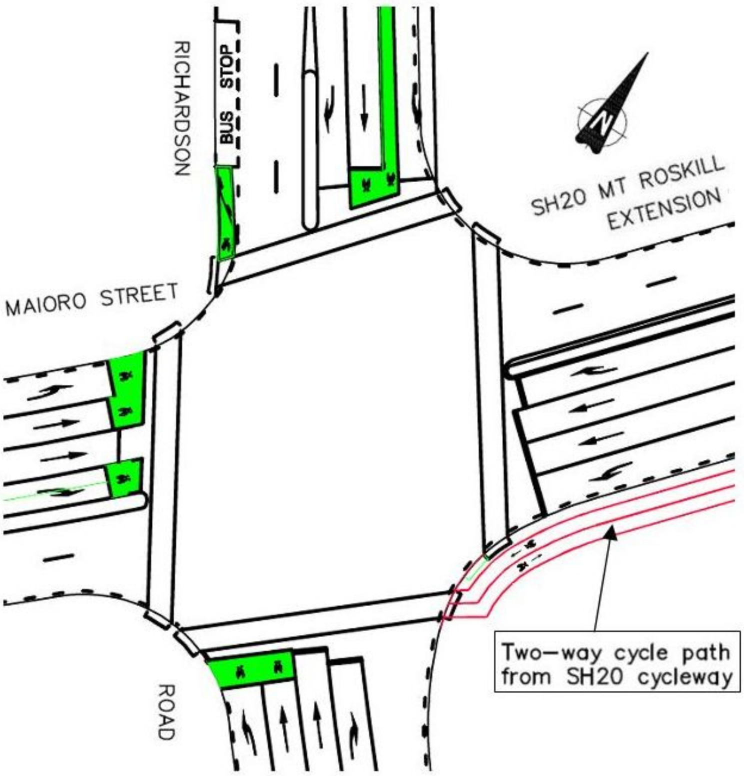

Figure 2: Possible layout of SH 20 / Maioro Street / Richardson Rd intersection

The intersection is likely to be operated with three phases, as shown in Figure 3.

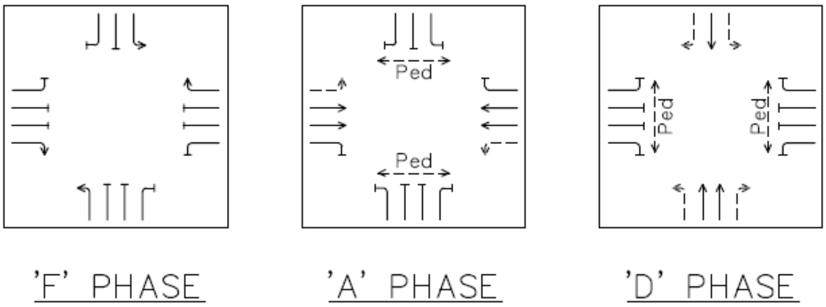

Figure 3: Signal phasing diagram for conventional intersection operation[1]

Crossing the intersection like a pedestrian

The problem with the intersection arrangement is that cyclists on the SH 20 cycleway going towards the Maioro Street interchange and intending to turn right cannot do so directly. The conventional solution is for those cyclists to cross the intersection in two stages, either in a clockwise (movements 1 and 2) or anti-clockwise direction (movements 3 and 4), as indicated in Figure 4.

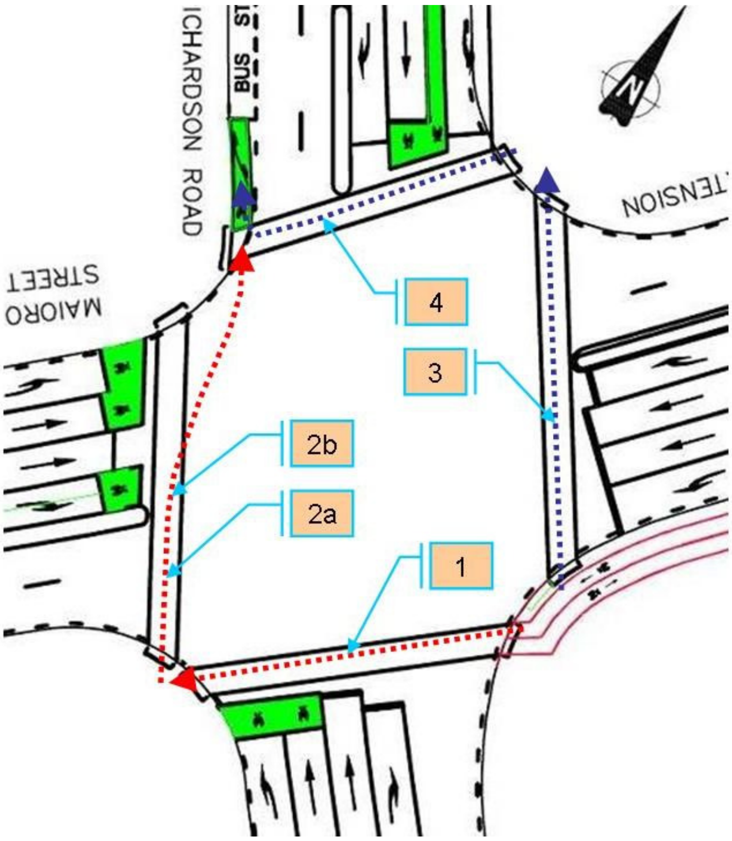

Figure 4: Cyclists turning right by walking their bike as a pedestrian

In the first stage (1), cyclists would cross to the far side of the intersection at the same time as the State Highway traffic has a green light (i.e. during the 'A' phase). In the second stage (i.e. during the 'D' phase), cyclists would walk across the Maioro Street departure lanes (2a) and could then ride the second stage of this crossing (2b), as they are no longer in conflict with other traffic.

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[1] A solid arrow indicates a priority movement. A dashed arrow indicates a movement where traffic either has to give way to other traffic, or to pedestrians. A bar instead of an arrow head indicates a movement facing a red light. Pedestrian movements are marked as such.

Alternatively, cyclists could first walk across the State Highway approach (3) during the ‘D’ phase, and then walk across Richardson Road (4) during the ‘A’ phase.

Whether to cross the intersection in a clockwise or anti-clockwise direction would depend on the crosswalk that is given a green light first.

The Traffic Regulations (1976), which were in force until February 2005, were explicit in that pedestrians had the right of way on a signalised pedestrian crosswalk over turning motorists, and that cyclists did not have the right of way. The Road User Rule (NZ Government, 2004a), which replaced the Traffic Regulations, is somewhat ambiguous about the right of way for cyclists using a crosswalk. Wilke (2005) explored the issue and concluded that the legal situation requires clarification. Land Transport NZ has confirmed that it was not the aim to change the intent of the Traffic Regulations with the conversion to the Road User Rule, and that this issue does need to be clarified, which has not been done yet (R. Gibson, pers. comm.). Hence, the only legal way for cyclists to start crossing the intersection coming from a pathway is to walk their bike across the crosswalk. When riding their bike, they would in this case not have the right of way over turning motorists.

Hook turn

When crossing the intersection in a clockwise direction, the second stage of the crossing could either be done by walking the bike across as described above, or alternatively, a hook turn facility could be created in the south quadrant of the intersection.

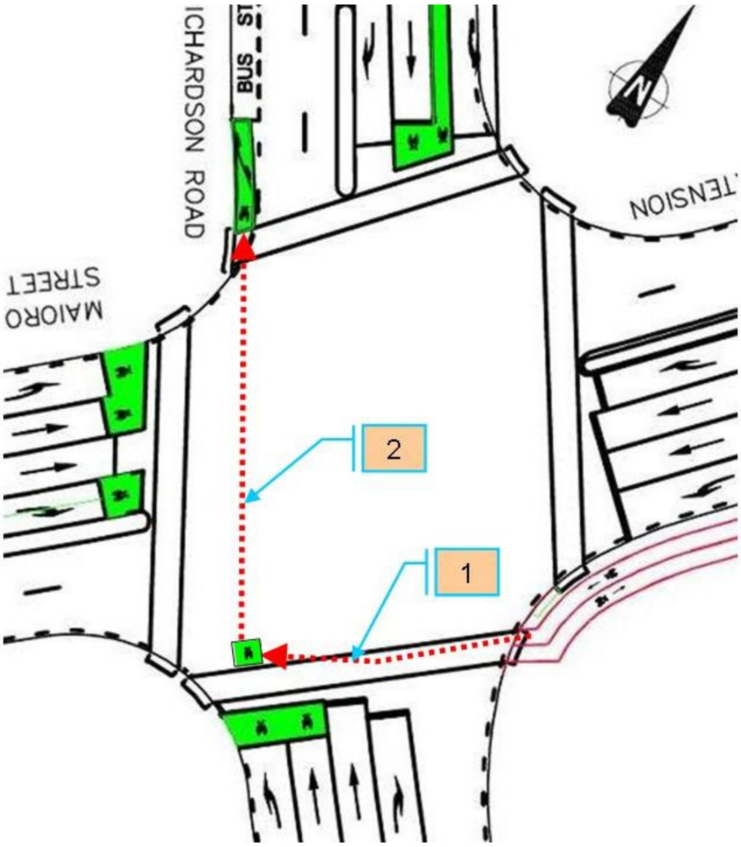

Figure 5: Cyclists turning right using a hook turn facility

This would enable cyclists to cycle the second stage of the right turn manoeuvre, but since the hook turn facility would be placed in front of the Richardson Road south approach, an exclusive left turn could not be operated during the ‘F2’ phase (see the red circle in Figure 6). Since this particular left turn movement is predicted to be very heavy, this would unduly compromise the intersection capacity. A hook turn facility is thus not desirable.

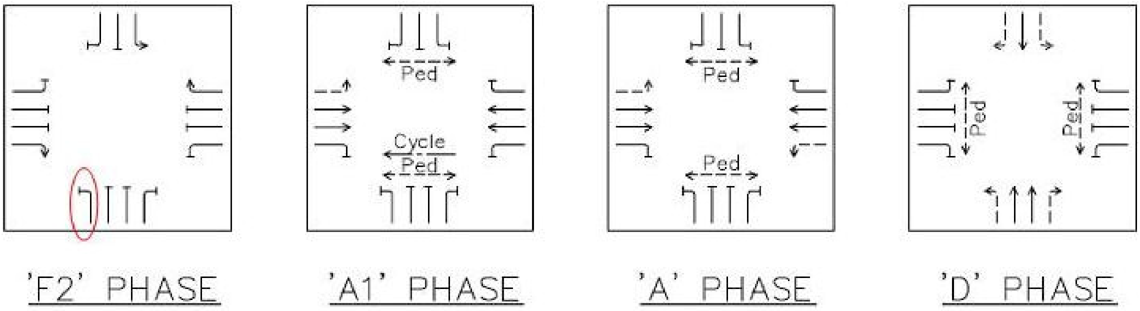

Figure 6: Hook turn phasing arrangement

Assessment of the conventional solution

The conventional intersection operation offers a poor Level of Service (LOS) to cyclists coming from the pathway:

- Cyclists will have to walk their bike across two crosswalks.
- Cyclists will have to wait twice for their signal phases.

Assuming a cycle time of the signals of 150 sec during the peak, it will take cyclists between 75 and 170 sec to get across the intersection, with the average time being 129 sec (see Appendix 1 for calculations).

4. Proposal

Description of the proposal

The proposed solution seeks to resolve these problems by creating a new diagonal crossing phase for cyclists from the SH 20 cycleway (see Figure 7).

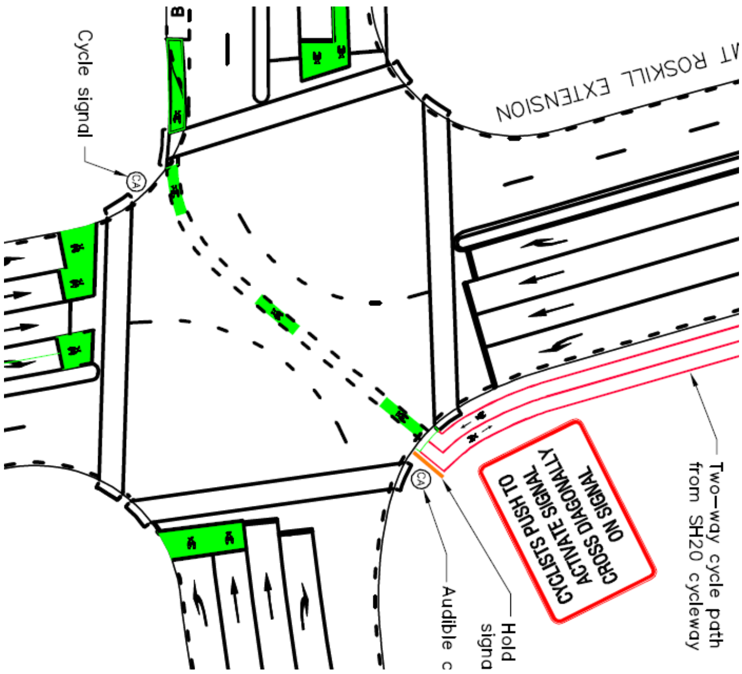

Figure 7: Diagonal crossing proposal

The suggested treatment of the diagonal crossing includes a cycle lane marked with continuity lines and ‘cycle’ symbols on green colouring at intervals that is clear of vehicle tracking. The intention is to keep the cycle lane narrow, thus “channelling” cyclists through the intersection while maximising the clearance from vehicle swept paths. The State Highway right turning movements are also guided by continuity lines, creating a separation between cyclists and other traffic.

Figure 8 shows the proposed phasing diagram. Cyclists would traverse the intersection during the ‘F1’ phase at the same time as the right turn movement for the State Highway traffic is operated.

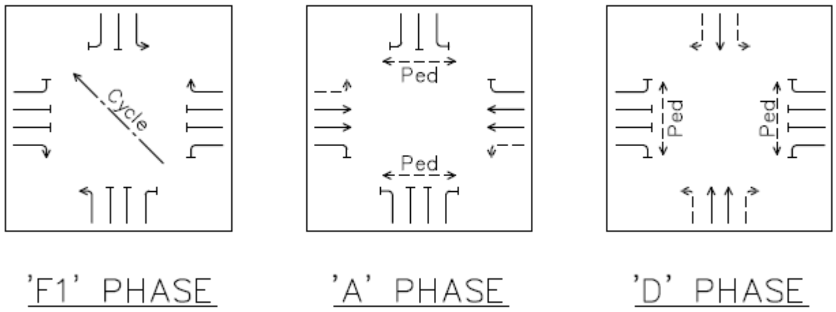

Figure 8: Diagonal crossing phasing arrangement

Figure 9 shows the intersection with the diagonal crossing and tracking for B-trains. The swept path analysis of available road space for the opposed right turn movements confirms the opportunity to provide for this one-way cycle movement, as there is a generous clearance of some 6-7 m between the truck movements. This is predominantly a result of the large format intersection. Austroads (2005, Section 6.7.5.8) states a minimum single opposed right turn vehicle clearance of 1.0 metre, which is easily exceeded with the proposed layout.

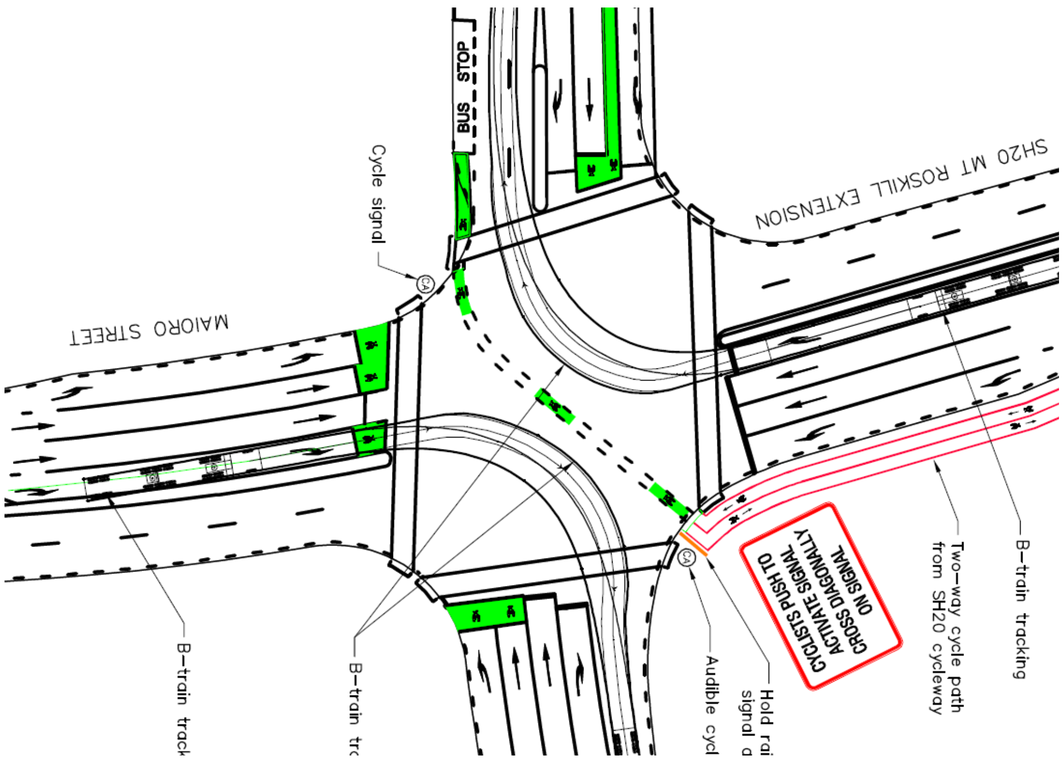

Figure 9: Swept path analysis for diagonal crossing layout

Three aspect cycle signals would be provided at the limit line and on the diagonally opposite side of the intersection in compliance with the Traffic Control Devices Rule (NZ Government, 2004b, clause 6.2(1)). A call-accept arrangement (Figure 11) is proposed, where cyclists would be detected using a detector loop and/or the call can be placed with the push button. Once the call has been registered by the signal controller, a light will illuminate the cycle aspect on the unit (Figure 10). This gives cyclists confirmation that their signal phase will be introduced in due course.

Figure 10: Call-accept detail

An early start for the diagonal crossing is considered, so that cyclists enter the intersection prior to right turning traffic. Also under consideration is an audible signal that will change when the lights turn green, so that cyclists start without delay, getting the full benefit of their early start.

Figure 11: Call-accept arrangement

In summary, the proposal for the diagonal crossing design includes:

- A cycle lane defined by continuity lines and highlighted with ‘cycle’ symbols on green colouring at intervals.
- An early start for cyclists and an audible signal, so that cyclists make full use of the early start.
- Continuity lines to guide right turning traffic (especially trucks) through the intersection.
- A call-accept arrangement for cyclists.

Interestingly, the proposal is described in the recent latest edition of the Dutch cycle design manual (CROW, 2007, page 288) as an “experimental facility”. Enquiries with one of the co-authors of that manual were inconclusive, but it appears likely that the concept has as yet not been implemented in The Netherlands (T. Zeegers, pers. comm.). The authors don’t know of any other international examples either. CROW discusses where such a facility would be applicable, how it would be implemented, and what needs to be considered. The analysis in this paper aligns with the CROW assessment.

Assessment of the proposal

Making the same assumptions about peak cycle times of the signals and green split as before, it will take cyclists between 15 and 160 sec to cross the intersection, with the average time being 88 sec (see Appendix 2 for calculations). This is an average reduction of 41 sec (or 30%) compared to the conventional case, involves waiting for one crossing manoeuvre rather than two, and allows cyclists to ride across the intersection rather than wheeling their bike across the crosswalks as a pedestrian. The average delay for cyclists is comparable to that of motorists.

The intersection proposal with a diagonal crossing offers an adequate LOS to cyclists, which doesn't disadvantage cyclists compared to motorists.

Further considerations

When the cycle crossing is in operation, the 'F1' phase needs to run for at least 19 sec[2]. This might increase the phase time for the 'F1' phase over what might have been required by motor vehicles (i.e. the phase would 'gap out' when the queue of right turners had discharged), potentially making the intersection slightly less efficient. Other than this, the intersection capacity is not affected by the proposal.

Some cyclists may feel subjectively unsafe cycling diagonally across the intersection, with right turning traffic on either side of them. The position of cyclists in the middle of the intersection is not dissimilar to when cyclists start a right turn manoeuvre from a right turning lane. Nevertheless, in this particular instance, the option of crossing the intersection as a pedestrian using the crosswalks still exists. It is also worth noting that some cyclists already cross large intersections diagonally from a corner. The proposal is formalising this behaviour, while making it safer, as the setup will ensure that the through traffic (i.e. 'A') phase does not start while cyclists are using the diagonal crossing facility.

Discussions are yet to be had with Land Transport NZ as to whether the proposal needs to be undertaken as a formal trial. Either way, it is important that the intersection be monitored, so that mitigating measures can be undertaken should this be necessary, and that experience can be gained for other locations where such a measure would be of benefit to cyclists.

The presence of motorway traffic is a complicating factor in this project design, but both Auckland City Council and Transit NZ are committed to developing a design that is safe for all road users, helping to complete the Auckland cycle network.

5. Programme from here

The proposal will be developed by Auckland City Council as part of the overall Richardson Rd cycle lane project over the next year, with potential implementation in 2008 (pending standard public consultation and funding

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[2] This is the sum of 6 sec green, 3 sec yellow and 10 sec of red, during which cyclists can clear the 40 m diagonally across the intersection at a design speed of 4 m/sec (approx. 15 km/h).

approvals). The diagonal design itself will require careful scrutiny through the safety audit process and discussions with Land Transport NZ. Transit NZ will need to be involved to help integrate the proposal into their intersection and cycleway design. The unusual nature of the design may require extra consideration by Transit's design team.

Should the project be developed successfully through these stages, it could potentially be implemented as part of Transit NZ's construction of the Maioro St / Richardson Rd / SH 20 intersection, however it may not be possible to co-ordinate these programmes, in which case the diagonal crossing could be added at a later stage.

6. Conclusions

The SH 20 / Maioro Street / Richardson Road intersection is located on a key cycle network element where cyclists face the difficult task of having to turn right coming from a pathway adjacent to SH 20. The conventional solution would see cyclists having to walk their bike across two pedestrian crosswalks and provides a poor Level of Service (LOS). A hook turn facility is not desirable due to the conflict with a very heavy left turning movement.

A proposal has been developed, where a cycle lane goes diagonally across the intersection. Cyclists use the facility at the same time and in between opposing right turning motorists on the main road. The LOS for cyclists is as good as for motorists, and the LOS for motorists is not affected by the proposal.

The project will require the close co-operation of Auckland City Council and Transit NZ to develop an agreed and workable scheme that meets Transit NZ's operational and safety aims for the intersection, effectively the end of SH 20. Both Auckland City Council and Transit NZ are committed to developing a design that is safe for all road users. This innovative solution will help complete the Auckland cycle network with a facility that offers a good Level of Service to cyclists.

7. References

Austroads (2005) *Guide to traffic engineering practice: part 5, Intersections At-Grade.* Sydney, Australia.

CROW (2007) *Design manual for bicycle traffic.* English version. Ede, The Netherlands.

NZ Government (2004a) *Land Transport (Road User) Rule 2004 – SR 2004/427 – Rule 61001*. Wellington.

NZ Government (2004b) *Land Transport Rule Traffic Control Devices 2004 – Rule 54002*. Wellington.

Wilke, A (2005) *Cycle Paths at Signalised Cross Intersections.* Presentation given to Signals NZ User Group (SNUG), Christchurch, November 2005.
http://viastrada.co.nz/pub/cycle_paths_signals

8. Appendices

Appendix 1 – calculations for a conventional setup

Assume the cycle time is 150 sec and the intersection is operated with three phases, with a green split as follows:

- A phase (straight through on SH 20): 95 sec
- D phase (side street phase): 30 sec
- E phase (single diamond on SH 20) 25 sec

The sequence is EAD. The worst case happens when a cyclist just misses the beginning of the 'D' phase. The average crossing time is 129 sec.

Table 1: Crossing time requirements for conventional setup

phase time	phase 1	phase 2	phase 3	phase 4	phase 1	phase 2	phase 3	phase 4	total [sec]	direction
0	F	A	D		25	95	20		140	clockwise
5	F	A	D		20	95	20		135	clockwise
10	F	A	D		15	95	20		130	clockwise
15	F	A	D		10	95	20		125	clockwise
20	F	A	D		5	95	20		120	clockwise
25	A	D	F	A	95	30	25	15	165	anti-clockwise
30	A	D	F	A	90	30	25	15	160	anti-clockwise
35	A	D	F	A	85	30	25	15	155	anti-clockwise
40	A	D	F	A	80	30	25	15	150	anti-clockwise
45	A	D	F	A	75	30	25	15	145	anti-clockwise
50	A	D	F	A	70	30	25	15	140	anti-clockwise
55	A	D	F	A	65	30	25	15	135	anti-clockwise
60	A	D	F	A	60	30	25	15	130	anti-clockwise
65	A	D	F	A	55	30	25	15	125	anti-clockwise
70	A	D	F	A	50	30	25	15	120	anti-clockwise
75	A	D	F	A	45	30	25	15	115	anti-clockwise
80	A	D	F	A	40	30	25	15	110	anti-clockwise
85	A	D	F	A	35	30	25	15	105	anti-clockwise
90	A	D	F	A	30	30	25	15	100	anti-clockwise
95	A	D	F	A	25	30	25	15	95	anti-clockwise
100	A	D	F	A	20	30	25	15	90	anti-clockwise
105	A	D	F	A	15	30	25	15	85	anti-clockwise
110	A	D	F	A	10	30	25	15	80	anti-clockwise
115	A	D	F	A	5	30	25	15	**75**	anti-clockwise
120	D	F	A	D	30	25	95	20	**170**	clockwise
125	D	F	A	D	25	25	95	20	165	clockwise
130	D	F	A	D	20	25	95	20	160	clockwise
135	D	F	A	D	15	25	95	20	155	clockwise
140	D	F	A	D	10	25	95	20	150	clockwise
145	D	F	A	D	5	25	95	20	145	clockwise
									129	**Average**

Axel Wilke: assumed to take 20 sec to walk across Maioro Street

Axel Wilke: assumed to take 15 sec to walk across Richardson Road

Axel Wilke: assumed that the beginning of the A phase has just been missed

Axel Wilke: assumed to take 20 sec to walk across Maioro Street

Appendix 2 – calculations for diagonal crossing setup

Assume the same cycle time green split as per Appendix 1. With the diagonal crossing, the worst case happens when a cyclist just misses the beginning of the 'F' phase. The average crossing time is 88 sec.

Table 2: Crossing time requirements for diagonal crossing setup

phase time	phase 1	phase 2	phase 3	phase 4	phase 1	phase 2	phase 3	phase 4	total
0	F	A	D	F	25	95	30	10	**160**
5	F	A	D		20	95	30	10	155
10	F	A	D		15	95	30	10	150
15	F	A	D		10	95	30	10	145
20	F	A	D		5	95	30	10	140
25	A	D	F		95	30	10		135
30	A	D	F		90	30	10		130
35	A	D	F		85	30	10		125
40	A	D	F		80	30	10		120
45	A	D	F		75	30	10		115
50	A	D	F		70	30	10		110
55	A	D	F		65	30	10		105
60	A	D	F		60	30	10		100
65	A	D	F		55	30	10		95
70	A	D	F		50	30	10		90
75	A	D	F		45	30	10		85
80	A	D	F		40	30	10		80
85	A	D	F		35	30	10		75
90	A	D	F		30	30	10		70
95	A	D	F		25	30	10		65
100	A	D	F		20	30	10		60
105	A	D	F		15	30	10		55
110	A	D	F		10	30	10		50
115	A	D	F		5	30	10		45
120	D	F			30	10			40
125	D	F			25	10			35
130	D	F			20	10			30
135	D	F			15	10			25
140	D	F			10	10			20
145	D	F			5	10			**15**
								Averag	**88**

Axel Wilke: assumed that the beginning of the F phase has just been missed

Axel Wilke: assumed to take 10 sec to cycle diagonally across intersection