EVALUATION OF SHARED-USE MARKINGS FOR CYCLISTS IN AUCKLAND

AUTHORS

Abhishek A. Pol
Dip(Civil), BE(Hons)
Department of Civil and Environmental Engineering
The University of Auckland
Email: apol500@aucklanduni.ac.nz

Sunil Prasad (Presenter)
Dip (Civil), Adv Dip (Civil), BE(Hons)
Department of Civil and Environmental Engineering
The University of Auckland
Email: spra578@aucklanduni.ac.nz

Seosamh B. Costello
BE(Civil), MSc(Eng), PhD, CEng, MIEI, MIPENZ
Department of Civil and Environmental Engineering
The University of Auckland
Email: s.costello@auckland.ac.nz

Amit Patel
BCom, GradDip(Mgt), MEngSt(Transp), GIPENZ
Auckland Transport
Email: amit.patel@aucklandtransport.govt.nz

Karl Hancock
BE Civil(Hons), GIPENZ
Flow Transportation Specialists
Email: karl@flownz.com

ABSTRACT

Auckland Transport recently trialled a shared-use arrow (sharrow) marking, at a number of sites on the Auckland road network. The marking consists of a bicycle symbol with two chevrons above it, and attempts to create a safer shared lane facility for cyclists in low volume, low speed environments. Sharrow markings remind motorists that cyclists also share the road on which they are travelling. In addition, they direct cyclists away from potential hazards such as parked vehicles and open doors by clarifying where cyclists are expected to ride. This research analysed video footage provided by Auckland Transport from the sites to determine if the sharrow markings influenced cyclist behaviour. Behaviour was assessed by measuring the lateral positioning of cyclists in the pre-marking and post-marking scenarios, and then statistically analysing the data. The results obtained suggest that the sharrow markings were successful in influencing cyclist behaviour, as intended, with the general trend indicating a shift in the lateral positioning of the cyclists towards the sharrow marking.

INTRODUCTION

According to the Cycling Advocates Network (CAN) of New Zealand here are about 1.27million cyclists in New Zealand with about 750,000 of those considered regular cyclists. Cycling is increasing in popularity, with about 20% growth over the five years between 2001 and 2006, or about 4% per year on average (CAN, 2007). The crash statistics for the year ended 31st December 2012 indicated that 8 cyclists died, 161 cyclists were seriously injured and 637 cyclists suffered minor injuries in police-reported crashes on New Zealand roads (Ministry of Transport 2013). This is about 6% of the total number of casualties from police-reported crashes involving motor vehicles in 2012.

While removing cyclists from the road altogether onto separated cycle paths or introducing dedicated cycle lanes on the road itself are the preferred solutions to improving cyclist safety, there are many reasons why such facilities cannot be installed. These include the following (Alta, 2004):

- Not enough cyclists;
- Too expensive;
- Requires loss of parking; and/or
- Requires road widening or other unacceptable trade-offs.

In such situations the use of shared-use arrow (sharrow) markings has been shown to be effective overseas. A sharrow is a type of pavement marking affixed to the road surface that encourages the cyclists to ride in the lateral position indicated by the marking (Brady et al. 2011a), thereby directing cyclists away from potential hazards such as parked vehicles and open doors by clarifying where cyclists are expected to ride. Sharrows also remind motorists that cyclists share the road on which they are travelling. The marking consists of a bicycle symbol with two chevrons above it, and attempts to create a safer shared lane facility for cyclists in low volume, low speed environments. A standard sharrow marking is included in Figure 1 below.

Figure 1: Standard Sharrow Marking

Auckland Transport recently trialled sharrow markings at a number of sites on the Auckland road network. The sites were chosen based on observed cyclist numbers and specific road environment characteristics. The sites in question and their respective road environment characteristics are as follows:

- Riddell Road, Glendowie (no marked parking lane)
- Point Chevalier Road, Point Chevalier (marked parking lane)
- Elstree Avenue, Glen Innes (approach to roundabout with Taniwha Street)

This paper covers the analysis of the video footage provided by Auckland Transport from the sites to determine if the sharrow markings influenced cyclist behaviour. A review of the literature is included on similar studies, the methodology used is outlined, the results are presented and discussed and, finally, conclusions are drawn, including lessons learned.

LITERATURE REVIEW

Shared-Use Markings

Designs for shared-use markings are quite varied and readers are referred to Alta (2004) for examples of this variation. They also reported that the San Francisco Department of Parking and Traffic undertook a human factors survey of the three most commonly used marking designs in the United States in an attempt to choose a preferred design. The three markings included were a bike-and-chevron marking, a bike-and-separate-arrow marking and a bike-in-house symbol, as shown in Figure 2 below.

Bike-and-chevron marking *Bike-and-separate-arrow marking* *Bike-in-house marking*

Figure 2: Commonly Used Shared Lane Markings (Source: Alta, 2004)

The study compared driver and cyclist comprehension of the three alternative designs. The results indicated that although all three markings encouraged motorists to be more aware of bicycles, significantly more respondents thought the bike-and-chevron marking indicated a shared use lane than the bike-and-separate-arrow marking. In addition, the bike-and-chevron marking was more likely to elicit the response to slow down than the bike-in-house symbol. Finally, the bike-and-separate-arrow marking frequently conveyed the incorrect message “bike straight only at the intersection ahead.”

Location of Shared Pavement Markings

Alta (2004) also conducted assessments to theorise an appropriate spacing for cyclists to be able to avoid the door zone, which is the area where cyclists risk hitting an open door of a parked vehicle. By measuring vehicles’ open doors they found that the 85th percentile for the door zone extended 2.9m from the kerb at the study location. This distance included 2.1m for the parked vehicle from edge of the kerb and 0.8m is for the opened door width. From this study they concluded that cyclists needed to ride at least 0.8m from parked vehicles to be moderately safe from an opened door zone.

They further recommended that pavement markings be implemented with the centre of the shared lane marking being at 3.4m from the edge of the kerb. This distance was observed to accommodate the 85th percentile distance of open door clearance (2.9m) plus 0.2m of shy distance (distance between cyclist’s tire to edge of kerb) plus half of the average cyclists width of 0.6m.

Sharrow Marking Studies

A number of sharrow marking studies have been undertaken, in an attempt to understand the impact of sharrow markings on the behaviour of cyclists and drivers. Studies from the United States, in particular, are prominent in the literature and a number of these are described below.

Gainesville, Florida, USA

Pein, Hunter and Stewart (1999) conducted one of the earliest before-and-after comparison studies into Sharrow markings, in the city of Gainesville, Florida, USA. The modified bike-in-house marking shown in Figure 3 below was used in the study. In this study the road had a wide kerb lane of 4.6m from the kerb edge and the centre of the shared-use arrow was placed at 1.1m from the kerb edge.

Figure 3: Shared-Use Arrow (Source: Pein, Hunter & Stewart 1999)

The study results showed that the average distance from cyclist to kerb before installation of the shared-use arrow was 0.48m and that after installation of the shared-use arrow this increased to 0.56m. This increase of approximately 8cm was statistically significant. In addition, after examining the distribution of the distances from cycle to kerb, it was noted that a greater proportion of cyclists rode between 0.5m and 0.8m from the kerb, indicating that the cyclists had additional manoeuvre space, or safety zone, in the direction of the kerb in the event that a motor vehicle encroached into their space.

The mean distance between passing vehicles and cyclists before installation of shared-use arrows was 1.8m and after installation of the shared-use arrow this increased to 1.9m. This additional space of approximately 4cm when passing cyclists was not statistically significant. The distance of vehicles from the kerb also increased slightly.

San Francisco, USA
As reported in Alta (2004), the San Francisco Department of Parking and Traffic conducted research to assess the effectiveness of two particular types of sharrow markings in their ability to influence safe cyclist and motorist co-existence on the road. The two markings tested were 1) bike-in-house design and 2) bike-and-chevron design. The bike-in-house marking was painted along one side of the road, and the bike-and-chevron marking was painted on the other side of the road. The objective of these markings was to improve the position of cyclists and motorists on roads where a bicycle lane did not exist.

The study focussed on the positioning of cyclists and motorists, cyclist behaviour, and cycle to motorist interaction. From this they concluded that the shared-lane markings increased the distance of cyclists from parked vehicles as well as the distance between cyclists and passing vehicles. Also the marking type bike-and-chevron significantly reduced the number of wrong-way cyclists by 80% and reduced the number of sidewalk cyclists by 35%. Overall, therefore, the bike-and-chevron marking had a stronger impact on motorist positioning and in reducing wrong-way cyclists. It was also preferred by cyclists surveyed. Based on these findings, the project team recommended the bike-and-chevron marking be used as a standard marking for shared-use lanes on appropriate streets in San Francisco.

Austin, Texas USA
Brady et al. (2011a) conducted an observational study on the operational effectiveness of three cycle safety devices on suburban roads in Austin, Texas. The three safety devices in the study consisted of a shared lane marking (sharrow), “Bicycles May Use Full Lane” signs and coloured bicycle lanes at areas where the bicycle lane intersects the through traffic. Out of the three safety devices tested, the shared lane markings were most effective in encouraging cyclists to ride in the centre of the allocated shared space, and maintain their lateral positioning.

In another study conducted by Brady et al. (2011b) on three sites in Austin, Texas, to evaluate the effect of shared lane markings on cyclists and motorists safety, they found that these markings had an overall positive influence on improving cyclist safety and motorist manoeuvres when passing a cyclist. The safety factors associated with the the cyclists that were evaluated in this study were whether the cyclist followed the positioning indicated by the marking. Site 1 had an increase of 0.11m in the cyclist lateral position (lateral distance between the front wheel of cyclist and the on-street parking markings). It was noticed that events of motorists passing the cyclists was significantly reduced, as the sharrow created a clear lane for the motorists to avoid driving on. Site 2 had an increase of 0.20m in the cyclist lateral position (lateral distance between the front wheel of cyclist and the kerb). Site 3 had a slightly less profound effect on the lateral positioning of the cyclist. However, this shift in the lateral position of the cyclists decreased the number of cyclists riding in the range of the door openings of the parked cars.

Based on the results obtained from the trial, Brady et al. (2011b) recommended that shared lane markings like sharrow markings be used on multilane roads, especially where installing a dedicated lane is not practically possible.

Cambridge, Massachusetts, USA
Hunter et al. (2011) carried out a before and after sharrow markings study on behalf of the Federal Highway Authority (FHWA), in the city of Cambridge, Massachusetts. The bike and chevron design shown in Figure 4 below was used in the study. The sharrows were placed 3.05m away from the kerb to ensure cyclists did not intervene in the door-opening path of any parked vehicles. The study investigated whether the sharrows improved cycling positioning when cars were parked in the on-street parking. The study found that the cyclists positioning while passing a parked vehicle increased by 0.05m. This indicated that cyclists were riding further away from parked cars, hence reducing the risk of any “dooring” incidents. In addition, motor vehicle spacing from parked motor vehicles increased after the sharrow marking was installed, resulting in more “operating” space for cyclists.

Figure 4: Sharrow Marking (Source: Hunter et al. 2011)

Miami Beach, Florida, USA
Hunter, Srinivasan and Martell (2012) conducted a study in Miami Beach, Florida, analogous to that undertaken in Cambridge, Massachusetts, with similar findings. It was concluded that sharrow markings influenced the positioning of cyclists and motor vehicles.

METHODOLOGY

Prior to undertaking this research study, Auckland Transport had already chosen the trial sites based on observed cyclist numbers and specific road environment characteristics, as previously outlined. The bike and chevron design, shown to be the most effective in previous studies, was chosen as the preferred marking to adopt, as was their location. The sharrow markings were placed at 2.9m, 3.4m and 3.5m from the kerb at Riddell Road, Pt. Chevalier Road and Elstree Avenue, respectively. Finally, Auckland Transport arranged for the video footage to be collected at all sites, pre- and post-marking. The cameras were installed on light poles at the site so that cyclists and drivers were not influenced by the presence of the camera.

The steps undertaken in this research study, to analyse the video footage from the sites to determine if the sharrows influenced cyclist behaviour, are outlined below:

Step 1 – Site Visits

Step 1 consisted of a visit to the study sites to obtain physical measurements of the road cross section and, post-marking, the sharrow marking position. All the measurements were taken from the kerb, which served as the reference point. Figures 5, 6 and 7 below show the three study locations, with the arrows indicating the location of the video camera at each site.

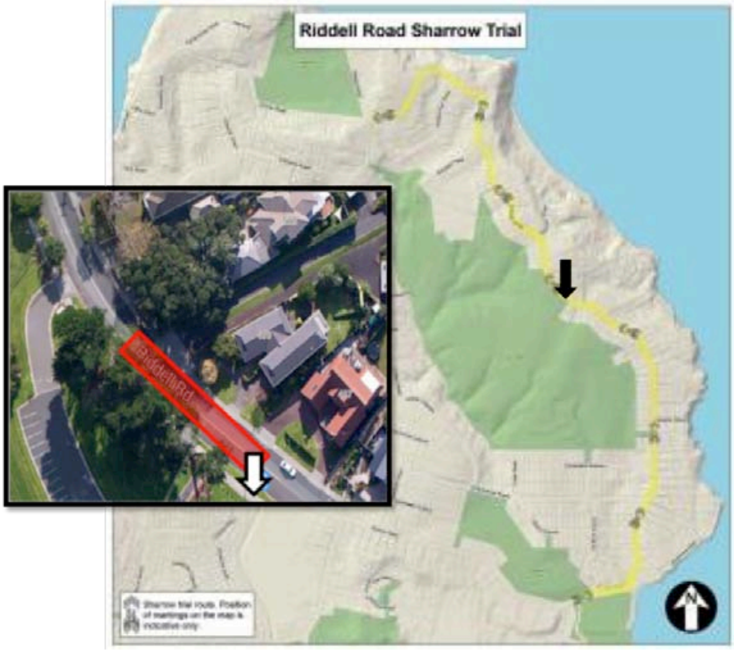

Figure 5: Riddell Road Site

Figure 6: Elstree Avenue Site

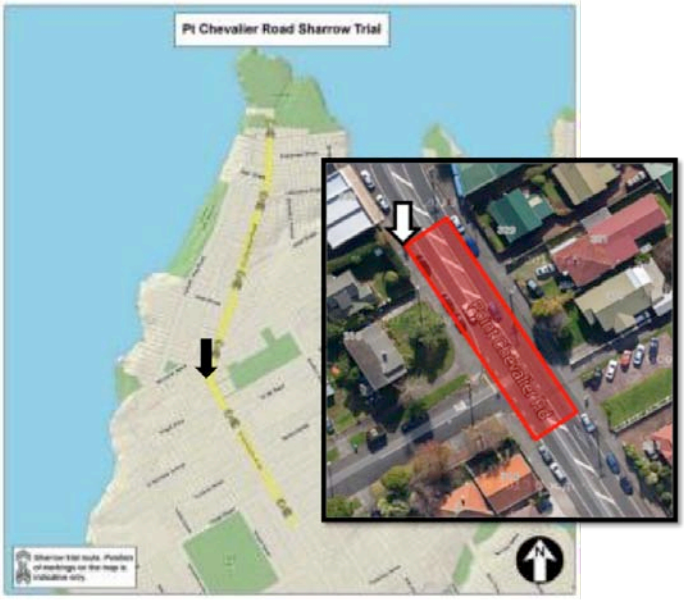

Figure 7: Point Chevalier Road Site

Step 2 – Processing of the Video Footage

Step 2 was focused on extracting screenshots of cyclists from the video footage as they occupied the camera shot. Freeware software called 'InstantShot!' was used to download screenshots at 2 second intervals – chosen to ensure that no cyclists were missed from the screenshots. Screenshots containing images of cyclists were then extracted and, where necessary, the best screenshot was chosen where multiple screenshots existed for the same cyclist. A total of 72 hours of video footage was analyzed during this step.

Step 3 – Digital Template

Step 3 involved creating a digital template in AutoCAD using the road cross-section measurements obtained from Step 1. A separate template was created for each site and for weekdays and weekends (as the camera position changed). Using the kerb as the starting point, digital lines were created longitudinally at 0.5m spacing. Due to the quality of the video images provided for the study, there was no further benefit to be obtained from a closer spacing. The 0.5m spacing allowed measurements to be taken to the nearest 0.25m. An example is shown in Figure 8 below for the Riddell Road site.

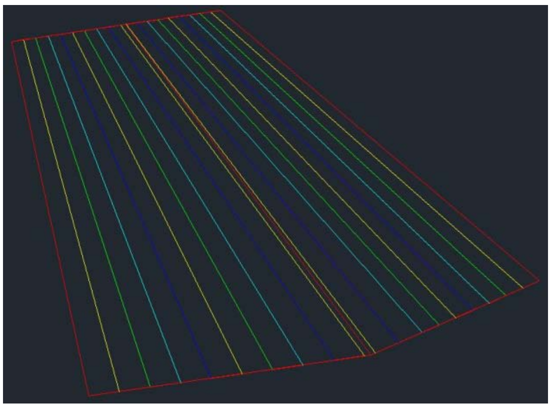

Figure 8: Digital template for Riddell Road (weekend)

Step 4 – Measurement using Template Overlay

The digital templates created in Step 3 were overlaid on the screenshots obtained in Step 2. This process was done in AutoCAD, having imported the screenshots, due to its ease and functionality to precisely overlay the grids onto the screenshots. An example is included in Figure 9, again for Riddell Road.

For each screenshot a distance reading from the kerb to the cyclist was recorded in an excel spreadsheet. A separate worksheet was prepared for each site, for weekend and weekday, and for the pre-marking and post-marking scenarios. Each screenshot, and therefore cyclist, was identified with a unique identifier and was therefore traceable.

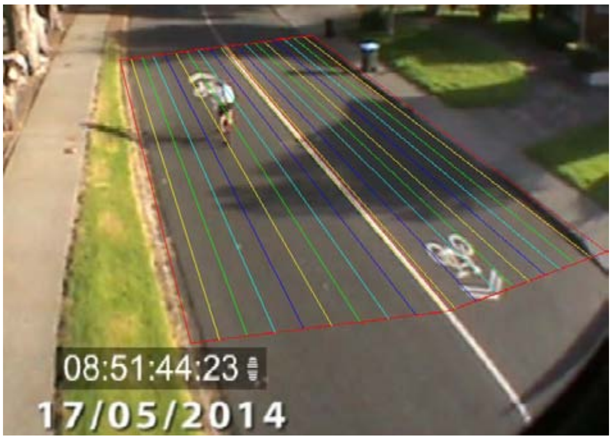

Figure 9: Template Overlaid on screenshot

Step 5 – Statistical Analysis

An Analysis of Variance (ANOVA) was conducted on pre- and post-marking measurements to assess if there was any change in the mean position of the cyclists after the sharrow marking was implemented and to ascertain if there was any statistical significance to these changes. The null hypothesis (H_0) was that there was no difference in the means.

For the purpose of carrying out the Analysis of Variance (ANOVA) tests on the data, the following assumptions were made:

- The samples were normally distributed.
- The samples had equal variance.

To test the normality assumption, a ‘normcheck’ was done on the data using the freeware statistical software package “R”, originally developed at the University of Auckland. All datasets passed the normality check. For samples with unequal variance, tested using the Levene test, the means were not used in the comparisons. However, those samples were still considered for assessing the spread of the data.

RESULTS

This section contains the results from each study site. A change in the lateral positioning was measured in terms of the cyclists’ mean distances from the kerb. The lateral spread of the cyclists on the road was measured in terms of their standard deviation to assess if the spread had narrowed or widened after the implementation of the sharrow. Lone or single cyclists were separated out from cyclists travelling in a group, due to their different characteristics.

Single Cyclists

Table 1 below includes a summary of the results from the analyses for single cyclists.

	Riddell Road		Elstree Avenue		Pt Chev Road		
	Weekend	**Weekday**	**Weekend**	**Weekday**	**Weekend**	**Weekday**	
Mean (m)	1.46	1.46	2.44	2.42	2.96	3.14	**Pre**
	1.49	1.90	2.78	2.25	2.91	3.21	**Post**
Difference (m)	0.03	0.44	0.34	-0.17	-0.05	0.07	
Frequency	68	132	36	12	24	18	**Pre**
	58	20	25	13	20	7	**Post**
Standard Deviation	0.52	0.62	0.86	1.05	0.33	0.51	**Pre**
	0.60	0.81	0.73	0.53	0.47	0.37	**Post**
Difference (m)	0.08	0.19	-0.13	-0.52	0.14	-0.14	
P-value (ANOVA)	0.751	0.005	0.117	0.617	0.66	0.725	
Levene Test	0.234	0.894	0.345	0.043	0.17	0.175	
95% Confidence Interval (m)	1.33-1.59	1.35-1.57	2.15-2.74	1.75-3.09	2.82-3.10	2.89-3.39	**Pre**
	1.33-1.65	1.52-2.28	2.48-3.31	1.93-2.57	2.68-3.13	2.88-3.55	**Post**

Table 1: Summary of Results for Single Cyclists

Riddell Road

The mean lateral positioning of single cyclists on Riddell Road (weekend) increased by 0.03m from 1.46, pre-marking to 1.49m post-marking. However, there was no evidence of a significant difference in the means (p-value = 0.751). For the weekday data, the mean lateral positioning increased by 0.44m, from 1.46m to 1.90m. There was strong evidence that the means were different (p-value = 0.005). Figure 10 shows a significant shift of the distribution of cyclists positioning towards the sharrow marking. Figure 10 below, along with all subsequent distributions, were plotted from data created using the ‘random number generation’ function in Microsoft Excel, with the same mean and standard deviation as the study dataset. This was carried out to smooth the distributions for demonstration and visual comparative purposes. The frequency values have not been recorded on the graphs for this reason.

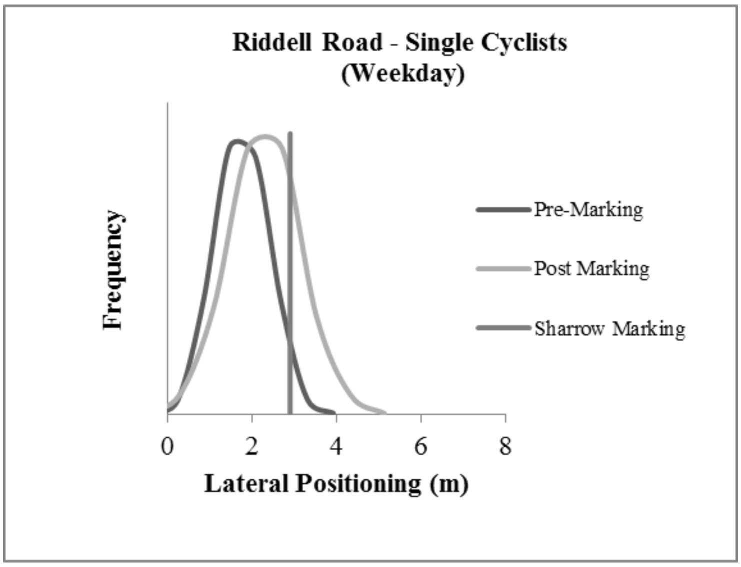

Figure 10: Distribution for Riddell Road - Single Cyclists (Weekday)

Elstree Avenue

The mean lateral positioning of single cyclists in Elstree Avenue (weekend) increased by 0.34m from 2.44m to 2.78m, however there was no evidence of a statistically significant change based on the p-value of 0.117.

The lateral spread of single cyclists on the weekday changed significantly, indicated by a standard deviation change from 1.05m to 0.53m, a change of 0.52m, indicating that the cyclists were riding in a narrower distribution. This finding is backed up by the unequal variance in the mean distances (levene test p-value = 0.0431). Figure 11 shows the difference between the distribution of the pre-marking and post-marking data.

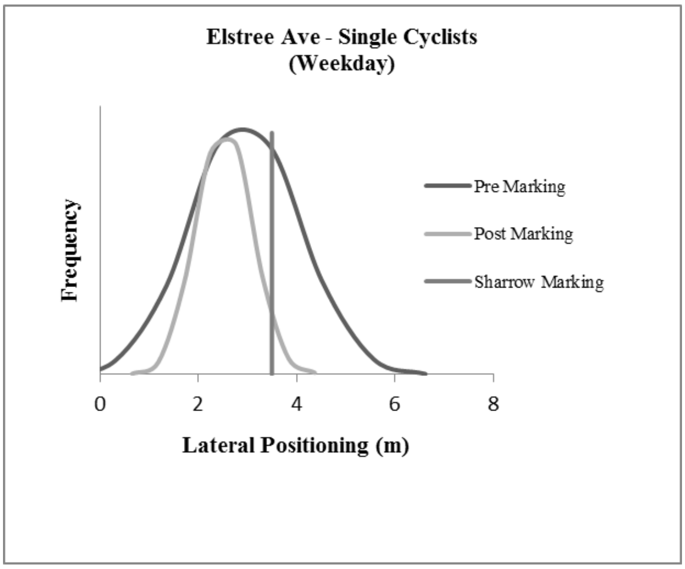

Figure 11: Distribution for Elstree Ave - Single Cyclists (Weekday)

Point Chevalier Road

The mean lateral positioning of single cyclists for this study site were insignificant for both the weekend and weekday with a p-value of 0.661 and 0.725, respectively. A unique factor only associated with this study site was the dedicated parking lane. This might suggest that the cyclists were already influenced by the presence of the lane marking, taking that as a reference instead of the kerb. However, the low number of data points for this site mean that the results are not conclusive.

Group Cyclists

Table 1 below includes a summary of the results from the analyses for group cyclists.

	Riddell Road		**Elstree Avenue**		**Pt Chev Road**		
	Weekend	**Weekday**	**Weekend**	**Weekday**	**Weekend**	**Weekday**	
Mean (m)	1.63	1.91	2.78	2.59	3.44	-	**Pre**
	1.89	2.15	3.10	2.74	2.78	-	**Post**
Difference (m)	0.26	0.24	0.32	0.15	-0.66	-	
Frequency	39	161	55	8	4	-	**Pre**
	64	51	39	18	5	-	**Post**
Standard Deviation	0.70	0.87	0.93	0.58	0.47	-	**Pre**
	0.79	1.12	0.85	0.76	0.59	-	**Post**
Difference (m)	0.09	0.25	-0.08	0.18	0.12	-	
P-value (ANOVA)	0.091	0.107	0.092	0.642	0.116	-	
Levene Test	0.738	0.072	0.450	0.607	0.492	-	
95% Confidence Interval (m)	1.40-1.86	1.78-2.05	2.53-3.03	2.11-3.08	2.69-4.19	-	**Pre**
	1.70–2.09	1.84-2.47	2.82-3.37	2.36-3.11	2.04-3.52	-	**Post**

Table 2: Summary of Results for Group Cyclists

Riddell Road

There was an increase of 0.26m in the mean lateral positioning of the group cyclists (weekend), and there was weak evidence of a statistically significant change in the mean positioning of the cyclists (p-value = 0.091). The lateral positioning increased from 1.63m to 1.89m. Figure 12 shows the slight shift of the distribution towards the sharrow.

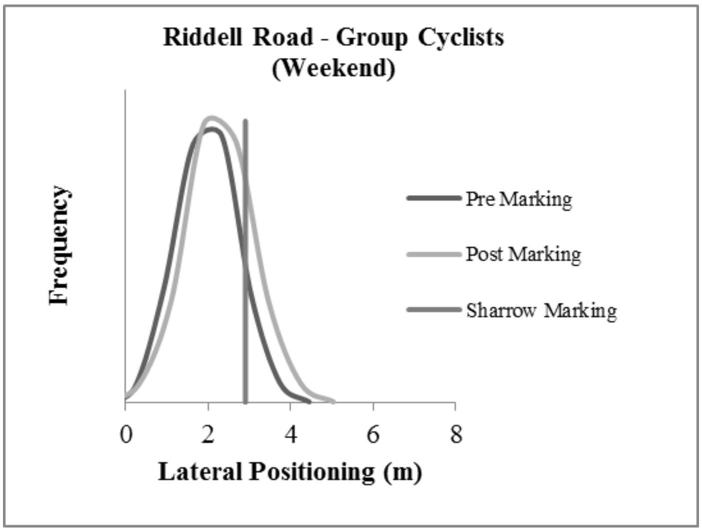

Figure 12: Distribution for Riddell Road - Group Cyclists (Weekend)

The lateral spread of group cyclists (weekday) changed significantly, as the standard deviation changed from 0.87m to 1.12m, a change of 0.25m, indicating that the cyclists were riding in a wider distribution. This finding is backed up by the unequal variance in the mean distances (levene test p-value = 0.0716). Figure 13 shows the difference between the distribution of pre-marking and post-marking data.

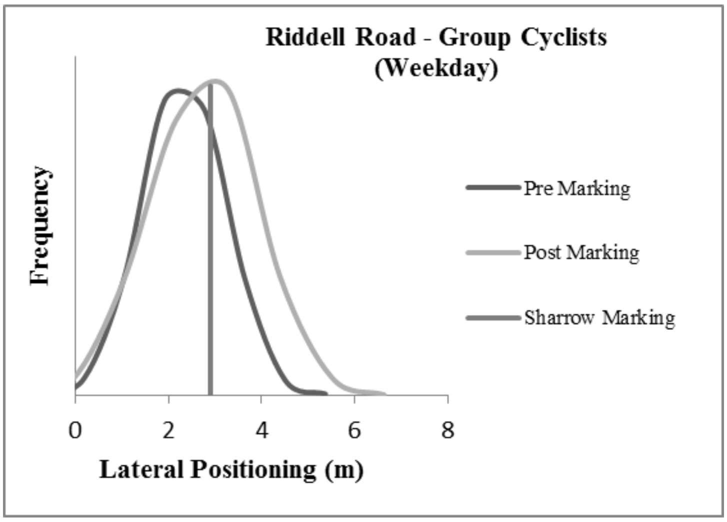

Figure 13: Distribution for Riddell Road - Group Cyclists (Weekday)

Elstree Avenue

The mean lateral positioning of grouped cyclists for Elstree Avenue (weekend) increased by 0.32m towards the sharrow. An increase from 2.78m to 3.10m, and there was weak evidence of a significant change in the mean (p-value = 0.092). Figure 14 shows the shift of the distribution towards the sharrow marking.

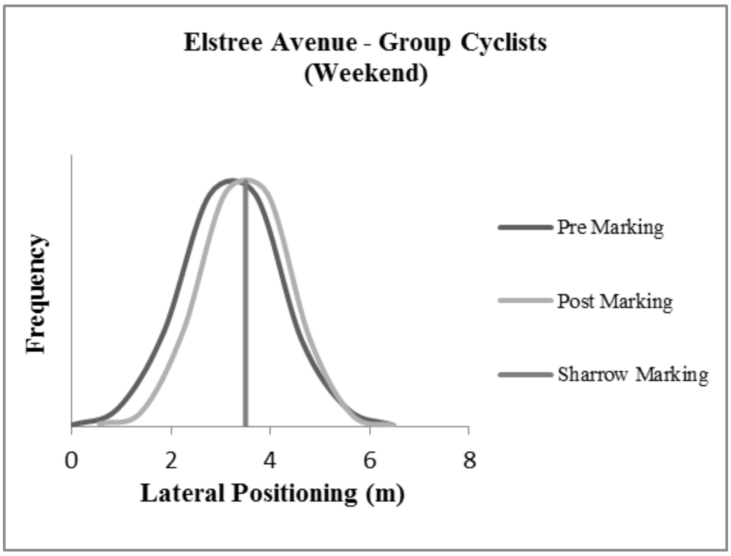

Figure 14: Distribution Curve for Elstree Ave - Group Cyclists (Weekend)

For the weekday data, the increase in lateral positioning was 0.14m, however, there was no statistical evidence of a significant change (p-value = 0.642).

Point Chevalier Road

There was no significant change in the lateral positioning of grouped cyclists on the weekday (p-value = 0.116) and there was no data available for the weekend.

DISCUSSION AND CONCLUSION

In general, the sharrow markings were successful in influencing the behaviour of cyclists. Elstree Avenue and Riddell Road had an increase in the mean lateral positioning of the cyclists for both single and group cyclists. However, not all increases were statistically significant. The spread of the distributions were also influenced. Both of these sites looked at cyclist behaviour in relation to the sharrows independent of parked vehicles or whether a vehicle was passing (due to very low numbers).

Point Chevalier Road, however, showed no statistically significant change between pre- and post-marking. The low number of data points for this site is probably the reason for this and the results are therefore not conclusive. This was unfortunate as the site had a dedicated parking lane and was therefore the only site from which to assess the positioning of cyclists when a parked vehicle is present. In order to assess the behaviour of cyclists when cars are parked at the side of the road, it is recommended in future studies that the research design needs to manufacture this scenario, i.e. cars need to be deliberately parked at the sites when the video footage is being collected on roads with reasonable quantities of cyclists.

REFERENCES

Alta (2004). *San Francisco's Shared Lane Pavement Markings: Improving Bicycle Safety*. San Francisco Department of Parking & Traffic, San Francisco, USA.

Brady, J., Loskorn, J., Mills, A.F., Duthie, J. and Machemehl, R.B. (2011a). Operational and Safety Implications of Three Experimental Bicycle Safety Devices in Austin, TX. *90th Annual Meeting of the Transportation Research Board*, 23-27 January 2011, Washington, D.C.

Brady, J., Loskorn, J., Mills, A., Duthie, J. and Machemehl, Randy B. (2011b). Effects of Shared Lane Markings on Bicyclist and Motorist Behavior", *Institute of Transportation Engineers, ITE Journal*, vol. 81, no. 8, pp. 33-38.

CAN (2007). *Facts about Cycling in New Zealand*. Cycling Advocates Network of New Zealand, New Zealand.

Hunter, W.W., Srinivasan, R., and Martell, C.A. (2012). *Evaluation of Shared Lane Markings in Miami Beach*, Florida, University of North Carolina, Highway Safety Research Center, Miami Beach, USA.

Hunter, W.W., Srinivasan, R., Thomas, L., Martell, C.A. and Seiderman, C.B. (2011). Evaluation of Shared Lane Markings in Cambridge, Massachusetts. *Transportation Research Record: Journal of the Transportation Research Board*, vol. 2247, no. 1, pp. 72-80.

Ministry of Transport (2013). *Crash Statistics for the Year Ended 31 December 2012*, Ministry of Transport, Wellington, New Zealand.

Pein, W.E., Hunter, W.W. and Stewart, J.R. (1999). *Evaluation of the Shared-Use Arrow*. Florida Department of Transportation Pedestrian and Bicycle Safety Section, Gainesville, USA.

ACKNOWLEDGEMENTS

The authors wish to acknowledge Auckland Transport for providing the video footage to analyse in the research.