CONTRACT REPORT

The Effects of WYLIWYG on Motorcycle Riders' Curve Negotiation – Final Draft Report

Project No: 002676

by Dr Peter Cairney and Rachel Beesley

for VicRoads

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SUMMARY

Background

The WYLIWYG (where you look is where you go) roadside delineation treatment appears to have been successful in reducing motorcycle crashes at one curve in Buckinghamshire, England. VicRoads engaged ARRB Group to investigate the treatment, adapt it as required for conditions in Victoria, and carry out an observational study of rider behaviour to discover whether the treatment reduces the risk associated with motorcyclists' curve negotiation.

Literature review

A brief literature review covered the essentials of motorcycle dynamics, curve negotiation skills and braking techniques, motorcycle crash involvement, and delineation for motorcyclists.

The WYLIWYG treatment

The WYLIWYG treatment consists of a series of evenly-spaced Vergemaster guide posts continued around the outside edge of a curve until the point at which the curve opens up. The effect is to keep directing the rider's gaze towards the vanishing point on the curve and to reduce the chances of fixating on a distracting feature, such as an open gate. Keeping the gaze in the right direction is assumed to result in the motorcyclist following an appropriate path.

Site selection and pilot observations

The trial was carried out on four suitable curves on a section of the C511. Two curves were chosen as treatment sites, and two served as control sites, one with chevron alignment markers (CAMs), the other with guide posts only. Pilot observations were conducted at each site to test methods and ensure there was adequate video coverage.

Method

Video cameras were positioned to enable the recording of speed and lateral position on the travel lane at three points at each of the treatment and control sites. Recordings were made before and after the installation of the WYLIWYG treatment. Measurements of speed and lateral placement were made from the video records. Analysis involved comparison of rider speeds and trajectories with recommended practice for curve negotiation, which involves decelerating on the approach to the curve and maintaining a steady speed or accelerating through the curve, and adjusting lateral position to widen the radius of the trajectory with respect to the curve.

Results

WYLIWYG appears to have had some positive effects on rider behaviour. At right-hand curves, speed profiles changed in the direction of

recommended practice, and there was a slight change in lateral placement in the direction of the recommended procedure. There appeared to be no beneficial effects at left-hand curves, and the speed profile at one of them appears to have moved away from the recommended pattern.

Other research suggests right-hand curves have higher crash rates than do left-hand curves, so that the beneficial effects therefore apply at the riskier sites.

These positive changes need to be seen in the context of other changes, e.g. overall increases in speed at both of the right-hand curves, and a movement away from the recommended speed profile at one of the left-hand curves.

Examination of the 95%ile values for speed and lateral placement showed that there was little change in these extreme values, and that there was no evidence to suggest that the speed or lateral placement of the riskiest 5% of riders had changed in the direction of greater risk following installation of WYLIWYG.

Implications

Two major limitations of this study are that the sites chosen are quite different from the original WYLIWYG site in the UK, and that the methods for capturing the data were of limited accuracy and precision. It is not certain that the positive changes in rider behaviour that were detected following installation of WYLIWYG outweighed the negative effects. The treatment did not appear to increase the risk to motorcyclists. Although there may be a role for the WYLIWYG treatment in providing more conspicuous guidance than is possible with conventional guideposts, or in providing better continuity of guidance than is possible with CAMs, the high cost of the WYLIWYG treatment, particularly its installation, is likely to be a barrier to its introduction. Questions for future research are suggested.

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1 INTRODUCTION

1.1 Background

A novel type of delineation appears to have been successful in reducing motorcycle crashes on one curve in Buckinghamshire, England. The treatment is based on the advice given to novice motorcyclists, 'Where you look is where you go' (WYLIWYG). The treatment consists of highly conspicuous guide posts to guide the rider's direction of gaze around a curve in such a way that the motorcycle follows an appropriate trajectory.

VicRoads engaged ARRB Group Ltd (ARRB) to investigate the treatment, adapt it as required for conditions in Victoria, and carry out an observational study of rider behaviour to discover whether the treatment reduces the risk associated with cornering experienced by motorcyclists, and to advise on whether the treatment is likely to reduce motorcycle crashes.

This study follows an earlier investigation of a perceptual countermeasure designed to result in an exaggerated perception of curvature by manipulating the cues from the guideposts (Mulvihill, Candappa & Corben 2008). In contrast to that investigation, the present investigation evaluates a treatment which is designed to reinforce the rider's perception of the true trajectory of the curve as a way of improving safe negotiation of the curve.

1.2 Purpose and Structure of the Present Report

This report is the final report of the project, bringing together all aspects of the design, installation and monitoring of rider performance. It follows earlier reports on the literature review, site selection and pilot observations (Cairney 2010), before data collection (Cairney & Beesley 2011a) and after data collection (Cairney & Beesley 2011b).

Section 2 covers the literature review, Section 3 describes the site selection and a pilot study, Section 4 covers the designs and installation of the WYLIWYG treatment, Section 5 describes the methods used in the observational study, and Section 6 reports the results. Section 7 concludes the report with a discussion of the results and recommendations. Detailed aspects of the results are reported in Appendix A.

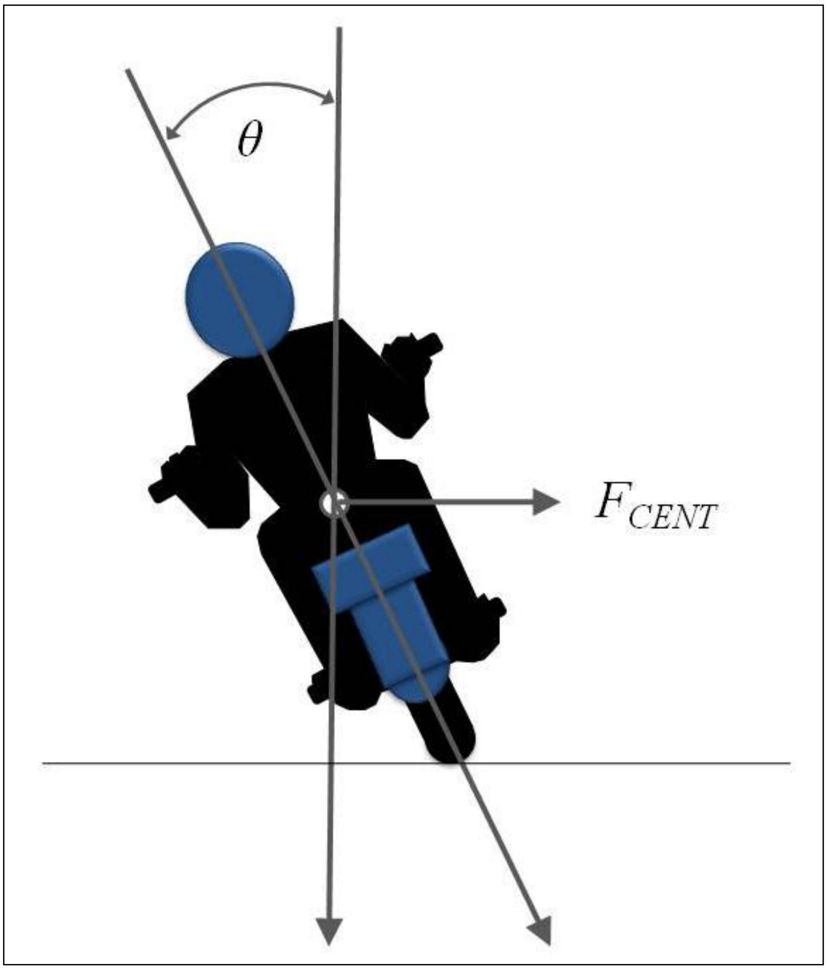
2 LITERATURE REVIEW

2.1 Data Base Search

The Australian Transport Research Index (ATRI) was searched using the following search terms – 'motorcycle and cornering', 'motorcycle and delineation', 'motorcycle and skill', and 'motorcycle and braking'. The US National Transportation Library database was searched using the term 'motorcycle and cornering and skill'. Relatively few references of interest were uncovered by these searches. Only items published after the year 2000 were examined for this review.

2.2 Motorcycle Dynamics

A four-wheeled vehicle relies principally on steering input to negotiate a curve, but a motorcycle relies on a combination of steering angle and lean angle to achieve the appropriate trajectory. The lean angle compensates for the centrifugal force generated by the turning movement, i.e. a force which pushes the motorcycle away from the centre of the curve (Fricke & Riley 1990). The relevant forces are shown in Figure 2.1.



Source: Adapted from Fricke and Riley (1990).

Figure 2.1: Lean angle and centrifugal force (F_{cent}) for a motorcycle during cornering

In an idealised model that assumes that the rider (and passenger, if carried) retains a fixed upright posture relative to the motorcycle, as illustrated in Figure 2.1, Equation 1 relates speed, curve radius and lean angle.

$$\tan \theta = v^2/rg \qquad (1)$$

where

v = motorcycle speed (metres/sec)

r = curve radius (metres)

g = acceleration of gravity (9.81 metres/sec^2)

θ = the lean angle from the vertical (degrees)

tan = the trigonometric function 'tangent'

For a particular path of travel, there is a unique lean angle associated with any specific speed which can be calculated from the equation.

Re-arranging the equation (see Equation 2) allows calculation of the radius of the turning manoeuvre from the motorcycle speed and lean angle, i.e.:

$$r = v^2/\tan \theta \, g \qquad (2)$$

2.3 Essential Curve Negotiation Skills

In the course of explaining their method for measuring lateral lane position, Mulvihill et al. (2008) discuss the recommended curve negotiation procedure for motorcyclists, based on the advice of experienced Victorian riders and the recommendations set out in the highly regarded publication 'Motorcycling Excellence' (Motorcycle Safety Foundation 2006). As they point out, many other high-quality publications are available which give similar advice.

The recommended procedure involves the motorcyclist decelerating to an appropriate speed for the anticipated curve radius. For a right hand curve, the motorcyclist moves to the left of the normal travel position, steers through the curve coming close to the centre line at the apex of the curve, then finishing wide to the left of the normal riding position (Figure 2.2). For a left-hand curve, the procedure is opposite, moving to the right at the start of the curve, closer to the edge at the apex, and back towards the centre at the curve exit. This effectively increases the curve radius, reducing the extent to which the motorcyclist has to lean in order to negotiate the curve. The high-risk points in this procedure appear to be:

- for right-hand curves, moving too far to the left and running into loose material near the edge of the carriageway at the entry and exit to the curve
- for left-hand curves, moving too far to the left and running into loose material at the apex of the curve
- for right-hand curves, near the apex of the curve, misjudging the line and crossing into the opposing traffic lane; leaning too far over, and losing control; not leaning over far enough, and following a trajectory which has too great a radius for the curve
- for left hand curves, moving too close to the centre line at the entry and exit to the curve.

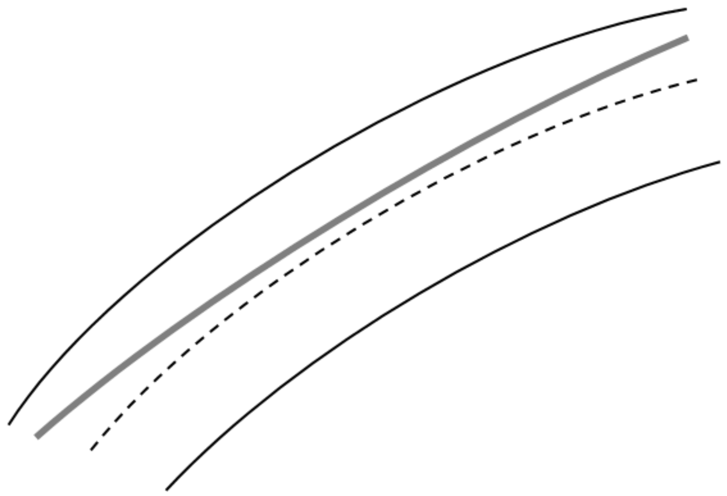


Figure 2.2: Recommended technique for motorcyclist's curve negotiation

Misjudging the speed at which the curve can safely be taken is also likely to contribute to an unsafe situation. This will lead to 'running wide' at the end of the curve, and to leaving the road in extreme cases. The rider can compensate by changing the steering angle which will tend to increase the lean angle in accordance with Equation 1. These actions may increase the risk of loss of balance due to the increased frictional demands placed on the motorcycle's tyres, or of incursions into the opposing traffic lane.

2.3.1 Braking

Braking is a critical skill for motorcyclists. Inexperienced motorcyclists are more likely to apply the brakes too hard or too suddenly, resulting in a loss of control.

Braking is most likely to be carried out correctly when the rider has sufficient advance notice of the amount of braking required to plan and execute the braking manoeuvre in an unhurried manner. Rapid braking in response to unexpected situations is more likely to result in unbalanced braking and consequent loss of stability.

Good advance information relating to the direction and severity of curves can therefore help motorcyclists plan their braking actions in good time, and thus reduce the risk of loss of control events caused by hurried, late braking.

The WYLIWYG treatment investigated in the present project is designed to give the rider enhanced cues regarding the curve direction and sharpness, and so should help in this process. The chevron alignment markers (CAMs) currently used on Australian roads would appear to make this information available over greater distances than do guide posts, so may be equally or more effective in conveying this information. The perceptual countermeasure treatment evaluated in the earlier Mulvihill et al. (2008) study was based on different principles. It was intended to produce an exaggerated impression of the curvature, with the intent of slowing the rider down to a speed which was lower than that the rider would choose when relying on normal delineation cues, thereby producing a margin of safety in terms of curve negotiation speed.

Braking in emergency situations is likely to be made considerably safer by advanced braking technologies. Baxter and Robur (2007) report a series of braking tests on current motorcycles. They conclude that, of the systems tested, the highest decelerations were achieved with a combination of an integrated braking system (which ensures an appropriate balance of braking forces on front and rear wheels) and ABS on both wheels. They also concluded that although a fully experienced, alert rider can perform as well or better as integrated systems on dry surfaces, integrated ABS systems are likely to outperform even the best riders on low friction roads and under emergency conditions as riders are able to exploit the machine’s braking capacities to the maximum without fear of loss of control or falling over.

Although several motorcycle manufacturers currently offer integrated ABS systems, they are unlikely to become general in the near future, especially for lower-priced machines. For braking associated with normal cornering, most riders are likely to have to depend on their own braking skills for some time to come.

2.3.2 Motorcyclist Views of their Skills

A recent evaluation of a mail-out campaign to promote safe cornering practices is interesting in the context of the present review for the insight it gives regarding motorcyclists’ views of their own skills (Friswell et al. 2008). The brochure being evaluated was generally well received; 56% of recipients thought it had made them more aware of the consequences of a cornering crash. However, only 11% reported that it told them something they did not already know. Fewer respondents to the questionnaire who had not received the brochure reported taking corners in the recommended manner than those who had received the brochure, suggesting it had some effect on riding behaviour.

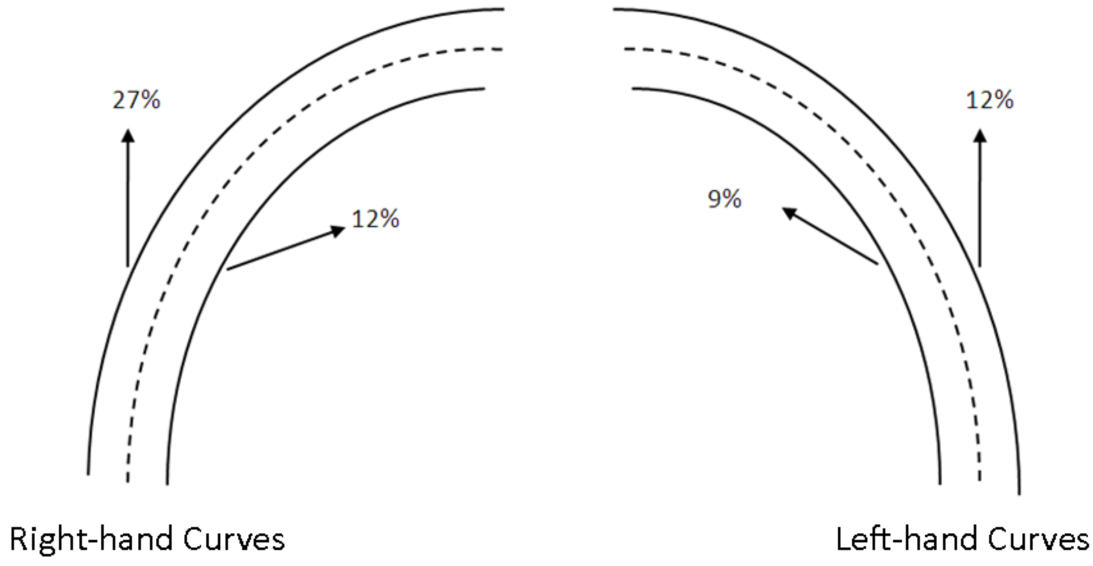
There were differences in knowledge about factors which contribute to cornering crashes. More than 50% of the respondents who had not received the brochure thought (incorrectly) that most cornering crashes occurred in wet conditions compared to 39% of the respondents who had received the brochure. More than 14% of the respondents who did not receive the brochure thought (again incorrectly) that most cornering crashes occurred at night, compared to only 8% of respondents who had received the brochure.

These results suggest that a majority of motorcyclists may underestimate the risk posed by cornering manoeuvres in good conditions.

2.4 Motorcycle Crash Patterns and Delineation

2.4.1 Crash Patterns

In a comprehensive analysis of motorcycle crashes on Victorian roads from 2001 to 2005, Styles et al. (2007) reported that approximately 20% of crashes involved running off the road on a curve.



Source: Data from RTA (2002).

Figure 2.3: Relative frequency of different types of run-off-the-road crashes on NSW high speed roads

The Roads and Traffic Authority (RTA) (2002) produced a Road Environment Safety Update detailing a procedure to target this type of crash. Although the data cited deals with all crashes of vehicles, not just motorcycles, and the findings are based on NSW crashes on high speed, undivided roads, these results possibly have general applicability. Twenty-seven percent of single vehicle run-off-the-road crashes of all severities recorded – fatal, injury and tow-away – were run-off-the-road to the left on right hand curves, and a further 12% were run-off-the-road to the right crashes on left hand curves.

Fewer run-off-the-road crashes occurred on left hand curves, with 12% involving vehicles running off to the right and 9% vehicles running off to the left. The pattern is summarised in Figure 2.3.

In the absence of specific data on motorcycle crashes at right and left hand curves, it seems probable that the pattern of motorcycle crashes will be similar to that for all vehicles, and that the most frequent category of motorcycle crashes on curves is running off to the left on right-hand curves.

The high prevalence of these crash types on curves, which make up only a small proportion of the undivided high speed network, provided the rationale for targeting these sites.

In the description of their site selection process, Mulvihill et al. (2008) identified thirteen Local Government Areas (LGAs) in Victoria with high incidences of motorcycle crashes. The Shire of Yarra Ranges stood out as having almost twice as many crashes as the next highest LGA, Baw Baw Shire. Presumably this is due to Yarra Ranges' proximity to the main population centre and its winding, hilly roads which are a great attraction for recreational riders.

Mulvihill et al. then examined loss of control crashes along the main routes in the Shire of Yarra Ranges. The Warburton-Woods Point Road stood out as having the highest number of crashes, with 43 out of the 133 motorcycle loss of control crashes, i.e. 32% of the crashes of interest. This route was selected as the site for the trials of the perceptual countermeasures they evaluated.

2.4.2 Previous Attempts to Provide Delineation for Motorcyclists

Although the importance of delineation for motorcyclists has generally been recognised, there has been little attempt to either examine in detail what improved delineation has delivered for motorcyclists, or to devise delineation which is specifically geared to motorcyclists' needs.

The search of the bibliographic data bases using the term 'motorcyclists and delineation' did not reveal any studies which fell into either of these categories.

Entering the search term 'motorcycle delineation' to the Google search engine provided reference to road safety strategy documents from three Australian States, but nothing else of immediate interest. The three references were to:

Victoria's Arrive Alive strategy (VicRoads 2010), which summarises the Victorian Motorcycle Blackspot program; many of the black spots are to receive enhanced delineation in the form of chevron alignment markers, guide posts and/or edge lines under the program.

The Queensland Motorcycle Safety Strategy 2009–2012 (Department of Transport and Main Roads 2009), which highlights improved and consistent delineation treatment over an entire route length as one of the measures to provide safe roads and a safe road environment.

The South Australian Motorcycling Safety Strategy 2005–2010 (Department for Transport, Energy and Infrastructure 2005) emphasises delineation, signing and lighting as important in achieving safe roads for motorcyclists.

2.4.3 Vision Zero and Motorcycling

In 2008, Norway opened what is claimed to be the world's first highway with comprehensive treatments to address motorcycle safety issues, following the prescriptions of Vision Zero principles. The route is approximately 14 km of RV 32 in Telemark province, close to the capital, Oslo. The treatments highlighted in press releases are guardrail fitted with a sub-rail to prevent collisions between unseated RIDERS and guardrail supports, better positioned sign supports, and more forgiving roadsides (Motorcycle.com 2008).

Lamp columns were moved away from the highway edge and behind the crash barrier where possible. The number of signposts was reduced by removing some signs and putting more signs on a common support of the 'lattix' type, a frangible support but of unknown performance when struck by a human body. Steep rock faces were given a more forgiving profile and run-off areas were created. Unsurfaced side roads were sealed at junctions with RV 32 to restrict gravel wash off (European Safer Urban Motorcycling (eSUM), no date)

No mention was made of any delineation treatments; one of the images in the eSUM document shows chevron alignment markers around a curve treated with guardrail, rather similar to treatments currently used in Australia. However, it is not known if they were there before the road was upgraded. From the available accounts of the treatments applied to the RV 32, it is not possible to say whether delineation treatments were part of the package. However, it seems clear that delineation treatments were not regarded as a newsworthy component in the package, and that the package of treatments did not include significant innovation so far as delineation was concerned.

2.5 The WYLIWYG treatment

2.5.1 The Treatment and its Technical Justification

The only treatment that appears to have emerged in recent years which is specifically designed to guide motorcyclists around curves is the 'Where you look is where you go' (WYLIWYG) treatment developed in Buckinghamshire, England.

The treatment is based on the recommended riding practice of looking for the vanishing point of the curve as a cue to how sharp the curve is and how far it extends. Riders are advised to reduce their speed on the approach to the curve to ensure they enter the curve at a speed at which they will be able to safely negotiate it. Once in the curve, they are advised to keep their eye on the vanishing point and to steer their bike towards it.

One risk that riders face in negotiating the curve is that their visual attention and glance direction will become fixated on some feature of the road scene, for example, a gate or a prominent tree, rather than the vanishing point. The continuous WYLIWYG delineation gives the eye a continuous reference, so that riders are less subject to this form of distraction.

A further benefit of the WYLIWYG treatment is that all the posts used in the treatment are a uniform height above the surface (920 mm), so that the rider has information as to whether the road rises or falls towards the vanishing point, thereby enabling better judgement of a suitable combination of line and speed for cornering.

2.5.2 Benefits of the WYLIWYG Treatment and Public Reaction

According to the Buckinghamshire County Council (BCC) leaflet describing the treatment (BCC 2005), the WYLIWYG treatment was installed at a site where there had been 3 deaths, 5 serious injuries and 2 minor injuries in the eight years prior to installation. At time of writing the BCC leaflet, between two and three years had elapsed since the installation, with no crashes or injuries recorded at the site.

The treatment has been widely reported in motorcycling and road safety publications, including Institute of Advanced Motorists newsletters (Gwent Group of Advanced Motorists, n.d.), and motorcycling websites in Australia and New Zealand (Motorcycle Riders' Association 2009).

The WYLIWYG initiative was awarded one of the three Prince Michael of Kent International Road Safety Awards in 2006. This award is highly regarded in the UK, and further increased media attention (Roadsafe 2006).

Interestingly, an internet search was unable to locate any information on applications of WYLIWYG in Buckinghamshire, or elsewhere in the UK, other than the first installation.

At time of writing, Malcolm James, the originator of the concept and person responsible for the original installation, was contacting his peers in other UK county road authorities to try to put together a snapshot of progress with installations and their outcomes. His own organisation (Devon County Council, having moved from Buckinghamshire) had plans to install WYLIWYG treatments at two sites, but no treatment had been installed at that time (Malcolm James, email, 29 July 2009).

2.5.3 Comparison with Current Delineation Practice in Victoria

Guideposts have been widely used on the Australian road system for several decades, so it is difficult to demonstrate their effectiveness by means of crash studies. One exception was a substantial reduction in crashes following an upgrade of guidepost reflectors on a major rural highway reported by Vincent (1978). However, the crash reductions in this case were mainly at night.

Chevron alignment markers (CAMs) are widely applied where the advisory speed on a curve falls substantially below the advisory speed on the approach. The effectiveness of CAMs in improving driver behaviour was demonstrated in a major experiment on a test track using cars, where their effectiveness was compared with guideposts and with edge lines of varying width (Johnston 1983).

The WYLIWYG treatment differs in subtle but possibly important respects from both of these treatments.

WYLIWYG uses guide posts at even spacing, whereas the treatment set out in the Australian Standard (AS1742.2, Standards Australia 2010) specifies spacing between the guide posts which is inversely proportional to the curve radius, i.e. the less the curve radius, the closer the guide-post spacing. The basic underlying principle is to provide continuity of guidance to drivers and riders. However, the guide post spacing is much wider than under the WYLIWYG system and the standard recommends guide posts be provided across the whole network, not just at problem curves.

The principles underlying CAMs are very similar to both guide posts and WYLIWYG in that they attempt to provide continuous guidance around the curve; like WYLIWYG, they are provided only at problem curves. The direction indicated by the chevrons can be discerned several hundred metres in advance of the curve, providing road users with effective information about the existence of a curve and its direction well before any action is taken. The spacing between the elements is again proportional to the curve radius. During fieldwork for the present study, the opportunity was taken to informally assess the performance of CAMs along the motorcycling routes inspected. On many of the small radius curves which are characteristic of these motorcycling routes, CAMs did not deliver continuous information about curvature; later CAMs in the series did not come into view until the previous CAM had already passed out of central view.

2.6 Implications for the Main Study

The literature scan has four important implications for the conduct of the study.

First, the prevalence of crashes involving running off the road to the left on right hand curves, although it applies to all vehicles, not just motorcycles, suggests that this situation should be given priority in the observational study.

Second, the account of how centrifugal force is generated during cornering suggests that the rider's speed and lateral placement are variables which have a direct impact on the safety of the cornering manoeuvre, and are therefore appropriate measures for assessing the effectiveness of the WYLIWYG treatment. The recommended procedure for negotiating curves in terms of speed and lateral placement provides a framework for establishing whether or not rider curve negotiation has improved following the installation of WYLIWYG. If the behaviour following installation becomes more like the recommended pattern, i.e. changing trajectory to widen the radius and accelerating through the curve, then behaviour may be considered to have improved.

The performance measures suggested in the project proposal are appropriate as measures of risk, i.e.:

- speed at the entry to the curve, at the apex of the curve, and on the exit from the curve – evidence of a tendency to steady speed or moderate acceleration through the curve will be interpreted as improved performance

- lateral placement, based on the distance from the edge of the road on the approach and at the exit, and on distance from the centreline at the apex of the curve; will provide an indication of whether riders’ trajectory selection moves closer to the recommended pattern or not, recognising that extremes of lateral placement in terms of encroaching on the edge of the sealed area or the travel lane in the opposite direction place the rider at risk.

Third, the explanatory leaflet from Buckinghamshire County Council describes a straightforward procedure for setting out the treatment. No difficulties were therefore expected in customising the treatment to the sites selected for the trial.

Finally, the success of WYLIWYG might be difficult to repeat in Victoria. Delineation practice in the UK makes little use of guideposts, so that providing this form of delineation at a problem site was of benefit. In contrast, guideposts are universally applied on all but the most minor of public roads in Victoria; on sharp curves, chevron alignment markers have been installed to provide additional long-range delineation. The improvement would therefore be in terms of improving on the existing delineation rather than providing delineation where no delineation was previously available, other than the naturally available cues from the environment.

3 SELECTION OF SITES AND PILOT OBSERVATIONS

3.1 Site Selection

Several routes were considered in the search for suitable sites for the trial of the WYLIWYG treatment. Routes considered had to have a reasonable number of curves, be popular motorcycling routes, and be within easy reach of Melbourne. The routes were driven by the project leader in a small car; the aim was to find sites reasonably similar to the site at which the original WYLIWYG treatment in Buckinghamshire was installed, i.e. a curve with moderate to tight radius, with a good approach sight distance, and moderate gradient. Routes considered were:

- C789 from Dromana to Red Hill
- C746 from Kinglake to St Andrews
- C724 from Healesville to Toolangi/Kinglake
- C512 from St Fillans to the junction with C511
- C508 from Marysville to Buxton
- C511 from Warburton to the junction with C512.

Most of the routes were unsuitable, as all the curves but the high-radius curves had been comprehensively treated with CAMs. The only exception was on the C511, where suitable curves were located. One of these sites was part of the site used by Mulvihill et al. (2008) in their evaluation of delineation treatments based on perceptual countermeasures. As discussed in Section 6, these treatments were not installed in such a way as to give rise to the perceptual illusion intended, and the treatments themselves were quite dilapidated when inspected, with missing and/or broken guide posts. No safety issues would be created by removing them and replacing them by conventional guide posts during the before period, then replacing them with the WYLIWYG treatment during the trial.

A detailed inspection of the site was carried out along with VicRoads staff to confirm the locations as suitable. The two treatment sites, and a number of possible control sites were chosen on that trip. The control sites were finally selected during the pilot measurement runs (see Section 3.2).

The location of the curves is shown in Figure 3.1. They form a compact group, commencing approximately 1.3 km south of the junction with the C512, and extending 5.0 km south.

Site photos of each curve before installation of the WYLIWYG treatment are shown in Figure 3.2 to Figure 3.5.

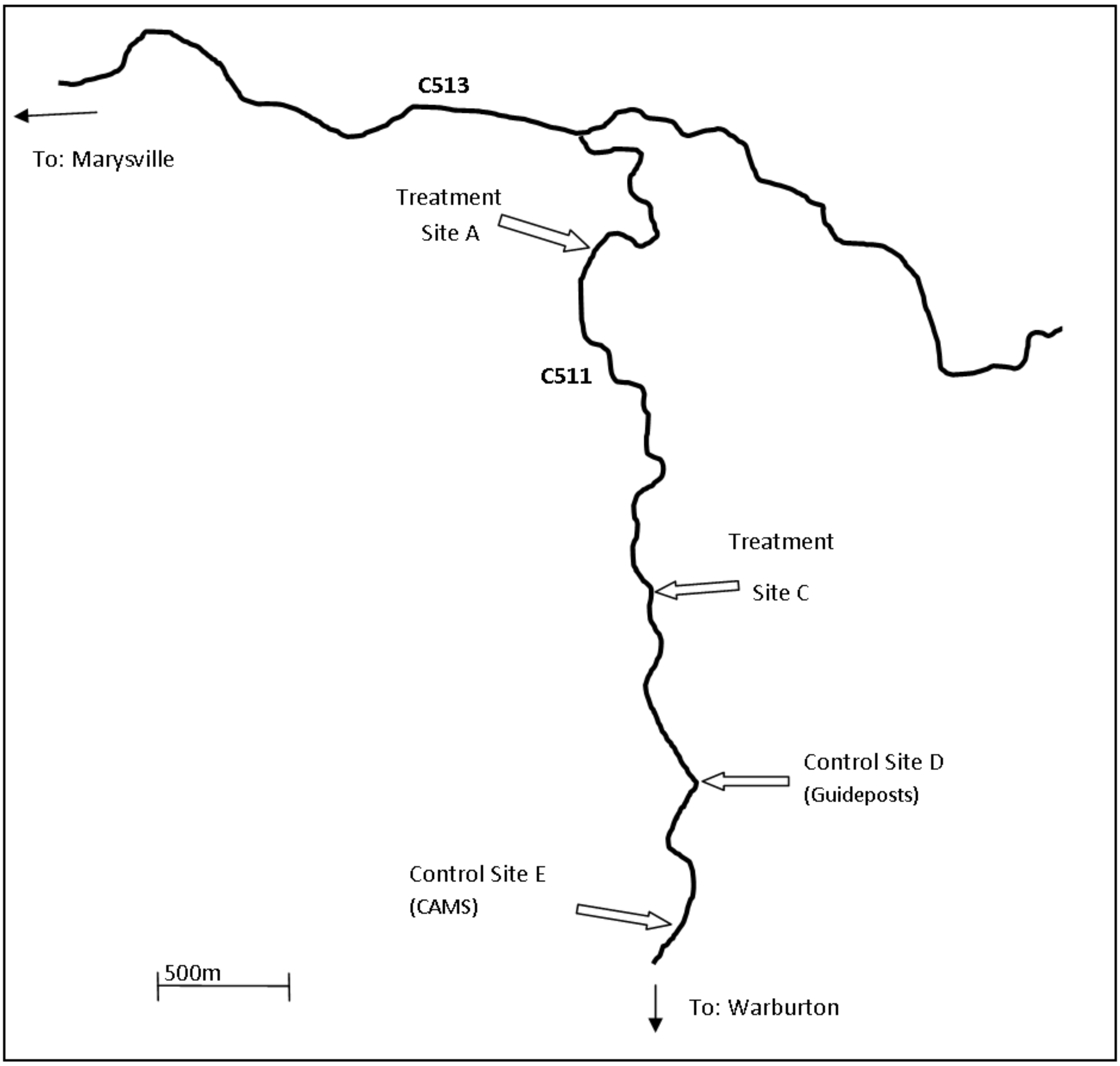


Figure 3.1: Locations of curves

Figure 3.2: Site A – Treatment site

Figure 3.3: Site C – Treatment site

Figure 3.4: Site D – Control site with guideposts

Figure 3.5: Site E – Control site with CAMs

3.2 Pilot Video Recordings

Pilot measurements were taken at the sites to test the camera mounting methods and locations. As well as two members of the ARRB research team, this step involved two personnel from the video contractor's staff, and a member of ARRB staff who rode the target motorcycle. This rider was an experienced motorcyclist who rode regularly.

Three camera locations were selected at each site, one to record behaviour on the approach, one to record behaviour at the apex of the curve and one to record behaviour as the rider exited the curve.

A suitable tree was located for each camera location; the camera was attached to the tree using a flexible metal collar which was tightened by a screw fastener. The camera was mounted slightly above head height. This provided a good view of the site, and discouraged unauthorised tampering with the camera during the trial. In some cases, the tree initially selected did not produce a satisfactory view of the site. In these cases, an alternative location was found. For each of the treatment and control sites, acceptable locations were found for all three cameras required by the project design. The trees were marked so that they could be identified quickly on subsequent trial days.

At the start of video recording, a scale marked in 100 mm segments was temporarily placed on the road surface for approximately 1 minute. When the video record was being analysed in the laboratory, the scale positions were transferred to an overlay on the video screen, allowing assessment of the lateral position of riders travelling through the site. Traffic cones were also set up temporarily by the side of the road at a known distance apart (generally 20 metres) to allow measurement of speed from the video record. These points were also transferred to the overlay.

ARRB's rider rode through the site a few times to give an idea of how well motorcycle position would be observed and recorded during the trial. A few other motorcyclists using the route were also captured on video. The image quality obtained was judged to be adequate for the main study.

From previous experience with lateral placement in this type of analysis, it was clear that the motorcycle could confidently be allocated to the correct 100 mm category.

It was expected that most motorcycle speeds through the sites would be 40 km/h (11.1 metres per second) or slower. The measurement base for speed estimation was 20 metres in all cases; i.e. a distance which will require approximately 1.8 seconds to traverse. Timing was carried out with the aid of a stop watch with 0.1 second increments. With a timing error of plus or minus 0.1 seconds; speed estimates were therefore accurate to within 0.1/1.8 = 0.0556 of the true value, i.e. to within plus or minus 6%. Since the analysis was expected to be based on the averages of several dozen speeds and there was no reason to expect that the timing errors would be biased in one direction, this was considered adequate.

4 DESIGN AND INSTALLATION OF TREATMENTS

4.1 Design

4.1.1 Design Concept

The procedures underlying the original WYLIWYG installation (Buckinghamshire County Council (BCC) 2005) are based on locating the successive vanishing points as a motorcyclist negotiates a curve.

Riders may not adequately track the vanishing point around the curve if the cues are indistinct, e.g. if vegetation obscures the true line of the curve, or if there are breaks in the cues, e.g. gaps in the tree line or gates disrupting a visual line created by hedges. Providing clear delineation cues may overcome these problems.

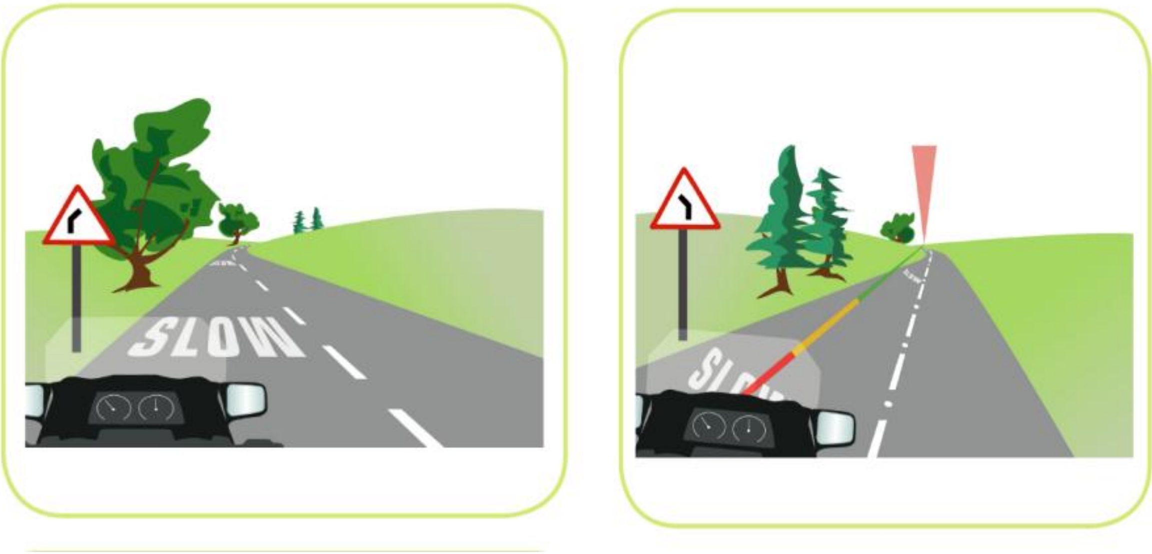
As the rider arrives at the apex of the curve, the distance between successive vanishing points increases, until a point is reached where the immediate vanishing point is no longer a helpful cue, and attention switches to another vanishing point further down the road. At this point, delineation of the curve is no longer helpful.

As the rider arrives at the apex of the curve, the distance between successive vanishing points (VP in Figure 4.1) increases, until a point is reached where the immediate vanishing point is no longer a helpful cue, and attention switches to another vanishing point further down the road. At this point, delineation of the curve is no longer helpful. This is indicated by the long distance between VP3 and VP4 in Figure 4.1; the WYLIWYG treatment should only be continued as far as VP3.

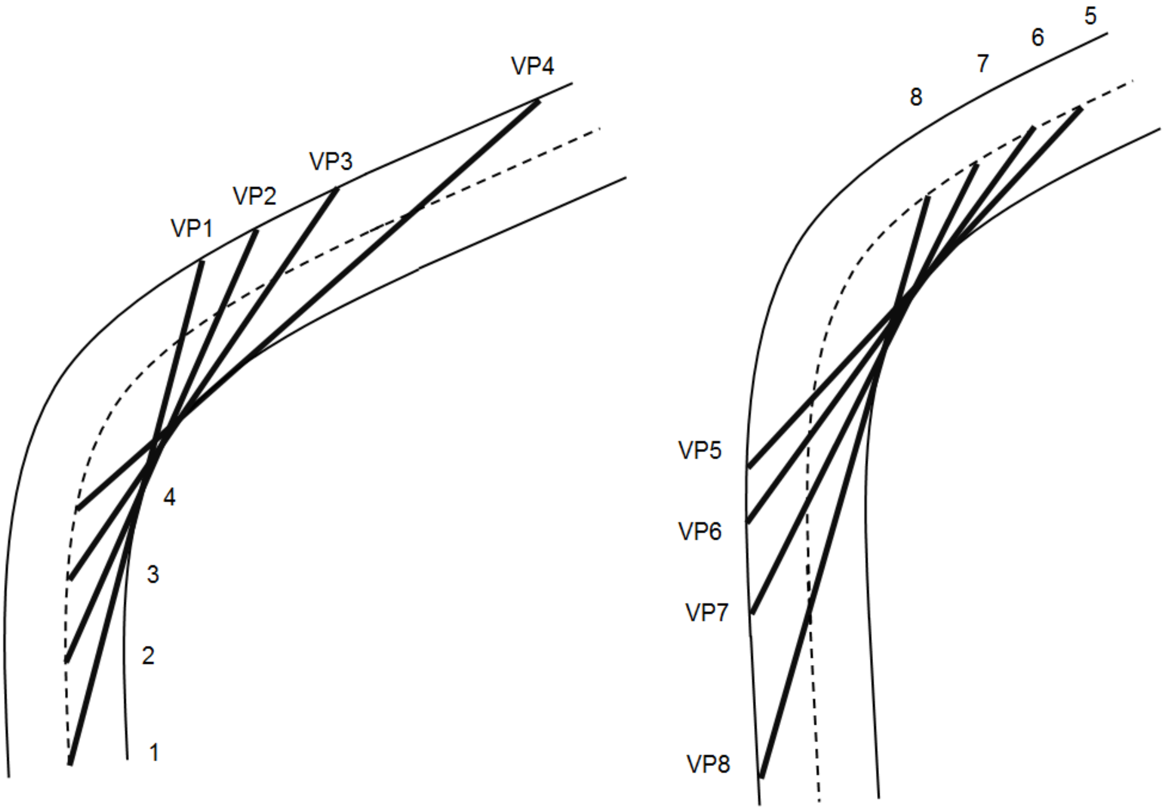
Approached from the opposite direction, similar increases in the distance between successive vanishing points occur, and the point at which delineation of the curve ceases to be helpful can be identified. In this case, it is indicated by the long gap between VP7 and VP8; the treatment should only be continued as far as VP7.

The WYLIWYG treatment consists of installing high-visibility guide posts on the outside edge of the curve at constant intervals between the two terminal points (VP7 and VP3) to provide continuous guidance around the curve.

Estimating from the photographs of the installed treatment on p.15 of a leaflet published by Buckinghamshire County Council (BCC), the posts appear to be installed around the middle part of the curve at regular intervals of approximately 1 metre (BCC 2005). They follow the outside edge of the curve on one side of the road only, appearing on the left-hand side of a right curve, and on the right-hand side of a left curve. They are positioned on the roadside around to the point at which sight distance increases as the road straightens at the end of a curve. The length of the road over which WYLIWYG extends is the distance between the point at which the vanishing distance increases during negotiation of a curve, and the vanishing point in the opposite direction when the site is approached from the opposite direction. The BCC leaflet indicates that 7 to 10 metres (it is assumed from the apex of the curve in each direction) is sufficient, giving a total treatment distance of approximately 17 metres.



Source: Buckinghamshire County Council. (2005).



Note:
Measurement points are on the centre line, vanishing points on the edge.

Figure 4.1: Successive vanishing points on the approach to a curve

Figure 4.2: The Vergemaster guide post (left) compared with a conventional Australian guide post (right)

In the Buckinghamshire trial, a proprietary brand of guidepost (the 'Vergemaster') was used (Figure 4.2). These are a rounded triangular tube with a face approximately 140 mm wide facing the traffic, designed to project 920 mm above ground level. They are boldly patterned in black and white, and carry 100 mm x 180 mm panels made of Class 2 reflective material on the surfaces facing the traffic, red in one direction and white in the other.

4.1.2 Setting-out Procedure

The setting-out procedure for the two trial sites followed the BCC leaflet (BCC 2005). The approach to each curve was viewed from the driver's seat of a stationary car positioned close to the road centre line, while an assistant walked along the edge of the road on the outside of the curve, directed by voice commands from the observer in the car. The vanishing point was determined at the starting point of the procedure and marked with a painted spot applied at the edge of the road. The vehicle was then moved forward ten metres, and the new vanishing point established. This procedure was repeated until the distance between successive vanishing points began to increase considerably, at which point the vanishing point was considered to be the terminal point for the treatment and marked carefully on the road surface.

The same procedure was then carried out, approaching the curve from the opposite direction, and the final vanishing point marked.

Tyre marks at the trial sites indicated that vehicles pull off onto the verge at these sites. Trial manoeuvres using a Subaru Outback station wagon, (considered representative of current Australian passenger vehicle dimensions), indicated that a spacing of 8 m between posts would allow vehicles sufficient room to pull-off and re-enter the road. This spacing was adopted at both treatment sites.

4.2 Safety Precautions

Prior to the 'before' behavioural measurements and as required by the VicRoads project brief, a safety audit of the two treatment sites was conducted by a registered safety auditor with experience of motorcycling audits (Cardno Victoria Pty Ltd). The purpose of this first audit was to ensure that ARRB and VicRoads were aware of the risks that were present at the sites, and that these risks were no greater than would be expected on typical curves in mountainous country. No issues were identified by the audit.

Following the installation, and before the commencement of the 'after' behavioural measurements, a second audit was carried out by the same team that conducted the first audit. The purpose of this audit was to ensure that the WYLIWYG treatment did not introduce any new hazards to the situation and that it did not appear to increase the overall level of risk to riders and their passengers. Once more, no issues of concern were identified.

4.3 Installation

Drawings provided by the manufacturers indicate that the Vergemaster post should be placed in a hole and backfilled to the ground level indicated on the post (Glasdon, no date). The Glasdon web site indicates that the exact requirements should be assessed for each site, including the use of quick-setting concrete for back filling. In view of the high rates of theft or vandalism experienced with novel traffic control items in the past, it was decided to back-fill with concrete as far as practicable. Because of variations in ground level due to the slope of the batter and table drains, backfilling with concrete was stopped at some posts before the backfill was complete in order to avoid creating exposed areas of concrete which would be potentially hazardous to motorcyclists who were thrown from their bikes.

The WYLIWYG installation at Site A is shown in Figure 4.3, and the installation at Site C is shown in Figure 4.4. The treatment is shown as it would be viewed by northbound and southbound riders in both cases.

Figure 4.3: Site A following WYLIWYG installation; top scene is as seen by northbound riders, bottom scene is as seen by southbound riders.

Figure 4.4: Site C following WYLIWYG installation; top scene is as seen by northbound riders, bottom scene is as seen by southbound riders.

5 STUDY OF RIDER BEHAVIOUR – METHOD

The study involved installation of the WYLIWYG treatment at two sites (Sites A and C), and comparison of rider behaviour at these sites with behaviour at two untreated sites (Sites D and E). Rider behaviour was recorded at all sites before the WYLIWYG treatment was installed, and again after installation.

Three measurement locations were selected at each site, one near what was judged to be the apex of the curve, one on the approach to the curve, and one on the exit from the curve. The distance between locations varied according to site characteristics, but was generally between 50 and 100 m.

5.1 Video Recording Procedure

One camera position was selected to provide coverage for each of the three locations at the four sites, making 12 camera locations in total. The cameras were attached to trees by means of an adjustable metal collar, tightened by a screw fastener (Figure 5.1).

Figure 5.1: Installation of a camera for the study

All sites were viewed through telephoto lenses and cameras were mounted on trees slightly above head height to give the optimum view and to discourage unauthorised tampering with the camera during the trial. Since suitable trees were haphazardly located at each site, a process of trial and error was necessary to locate the most suitable camera positions. The availability of a suitable tree determined on which side of the road the camera was located. In some cases, the tree initially selected did not produce a satisfactory view of the site. In these cases, an alternative location was found. For all locations at the treatment and control sites, acceptable camera positions were found.

Camera locations selected on the first day were marked with paint, and used on all subsequent occasions, giving the same general view. However, it was not possible to align views exactly on subsequent days, requiring recalibration of the data capture set-up on each occasion recordings were made.

On arrival at the first site, the field team proceeded to the first measurement location. The video camera was set up to give the required view of the location. A folding scale, marked in black and white sections 100 mm wide, was laid on the road surface at right angle to the centre line. It was laid from the edge of the sealed surface inwards at the entry and exit locations, and from the centre line outwards in the case of the central locations. Traffic cones were set up 10 m upstream and 10 m downstream of the marked scale to mark the start and finish of the speed measuring zone.

The camera was allowed to run for 1–2 minutes with the cones and scale in place, which allowed calibration of the measurements during data capture. The cones and scale were then removed, and the camera left to run for the rest of the day.

Cameras were set up between 8.30 and 10.30 am, when there were few motorcycles on the road. The cameras were recovered for the evening between 5.00–6.00 pm, by which time motorcycle numbers had reduced.

5.2 Data Capture Procedure

Video records were downloaded from the cameras onto dedicated stand-alone hard disk drives. The images were projected onto a standard 17 inch computer screen. At the start of the analysis for each day's recording session at each location, a transparent overlay was taped to the monitor screen. The video tape was stopped to leave an image where the traffic cones and marked scale were visible on-screen.

A marker pen and ruler were then used to transfer the measurement framework to the transparent overlay. The outlines of the sealed surface and the centre line were copied onto the transparency. The cone locations were marked, and lines drawn from these points to meet the main road at right angles to the edge of the road. Where this was difficult to judge, the tape was advanced until a four-wheeled vehicle passed through the site (preferably a utility or a rigid truck), which was assumed to travel parallel to the edge of the road, and the appropriate line judged from the direction of the truck's rear axle. The 100 mm gradations on the scale, placed half-way down the speed measuring zone, were transferred to the screen and extrapolated across the width of the screen.

For each motorcycle passing through the location the following data items were recorded:

- direction of travel
- time of arrival
- travel time through the speed measuring zone
- lateral placement within the lane.

Direction of travel and arrival time were read directly from the screen. Travel time was measured to the closest 0.1 seconds, using a stopwatch. Lateral placement was measured using the on-screen scale.

In addition, all other vehicles passing through the site during the observation period were recorded. The data items recorded were direction of travel, vehicle type and time of arrival.

All data items were recorded manually on a pre-prepared data sheet, then subsequently transferred to an Excel file and verified.

5.3 Field Work

Before data were collected over the period 29 and 30 January 2011; data for the after period was collected on 5 and 6 March 2011.

6 STUDY OF RIDER BEHAVIOUR – RESULTS

The results have been analysed separately for right-hand curves (i.e. for northbound riders at Site A, and for southbound riders at Sites C, D and E) and for left-hand curves (i.e. for southbound riders at Site A and for northbound riders at Sites C, D and E). The results of the speed measurements are presented in Section 6.1 and the results of the lateral placement measurements are presented in Section 6.2. These speeds and lateral placements are evaluated in Section 6.3 in terms of the 'best practice' framework, outlined in Section 2.3. Checks for the prevalence of high risk behaviours are reported in Section 6.4. Details of the results, the number or riders and statistical testing are presented in Appendix A. Between 62 and 211 riders were recorded travelling in each direction at the different curves.

The recommended procedure for negotiating curves described in Section 2.3 requires that most of the slowing down for the curve should be done before entering the curve. Sharp decelerations in the curve are indicative of poor technique or a mistake in reading the curve. The recommended technique also requires that riders should adopt a trajectory that tends to increase the radius of the curve. For right-hand curves, this requires moving closer to edge on the approach, closer to the centre at the apex of the curve then closer to the edge again on the exit. For left hand curves, the opposite is required, i.e. moving towards the centre on the approach, moving towards the edge of the road at the apex, and moving back towards the centre on the exit.

If WYLIWYG were improving rider performance then, following the installation of WYLIWYG it would be expected that:

- Riders would be travelling at a lower speed at the first measurement location than they were before installation.
- Changes in rider speeds between the first measurement location and the middle measurement location would fall in the range of slight deceleration to acceleration.
- Riders' speeds would increase between the middle measurement location and the last measurement location.
- On right-hand curves, riders would tend to move closer to the edge of the road at the first measurement location, move closer to the centre of the road and the middle measurement location, and move closer to the edge of the road at the last measurement location.
- On left-hand curves, riders would tend to move closer to the centre of the road at the first measurement location, move closer to the edge of the road at the middle measurement location, and move back to the centre of the road at the last measurement location.

This framework has been adopted for the analysis in Section 6.1 to Section 6.3.

The curvatures for Figure 6.1 to Figure 6.4 were approximated from their outlines as they appeared on Google Earth. The width of the road was doubled on the diagrams in order to make them legible.

6.1 Speed

The speeds at which riders negotiated right-hand curves are shown in Figure 6.2 and the speeds at which they negotiated left-hand curves are shown in Figure 6.3.

6.1.1 Right-hand Curves

Site A

Before installation, there was a large drop in speeds between the first measurement location and the central location, followed by an even larger increse in speeds at the last location. Following installation, speeds increased between the first measurement location to the middle location, and again between the middle location and last location.

After installation, speeds were lower at the first measurement location and at the last measurement location, but higher at the middle measurement location than the low speed measured at that location in the before period.

Site C

Before installation, there was a reduction in speed between the first measurement location and the middle measurement location, followed by an even larger reduction at the last measurement location. After installation, speed increased considerably between the first measurement location and the middle location, and increased again between the middle location and the last.

After installation, speeds were considerably lower at the first measurement location, similar at the middle location and higher at the last location.

Site D

Before installation, there was a large drop in speeds between the first measurement location and the middle measurement location, followed by an increase at the last location.

After installation, the pattern was similar and the speeds similar, apart from lower speeds at the last measurement location.

Site E

Before installation, speeds increased between the first measurement location and the middle measurement location, but fell slightly at the last measurement location. After installation, there was little difference among the speeds at the three measurement locations. Speeds were generally higher than they were before instrallation.

6.1.2 Left-hand Curves

Site A

Before installation, speeds increased from the first measurement location to the middle location, and increased again slightly at the last measuring point. After installation speeds varied by only a small amount across the three measurement points, with speeds slightly faster at the middle measurement location than at the other two.

After installation, speeds were faster at the first location and the middle location than before installation, but almost the same at the last location.

Site C

Before installation, speeds fell slightly from the first measurement location to the middle measurement location, then rose slightly at the third measurement location. After instrallation speeds changed little between the first and second measurement points, but dropped by a large margin at the last measurement location.

Site D

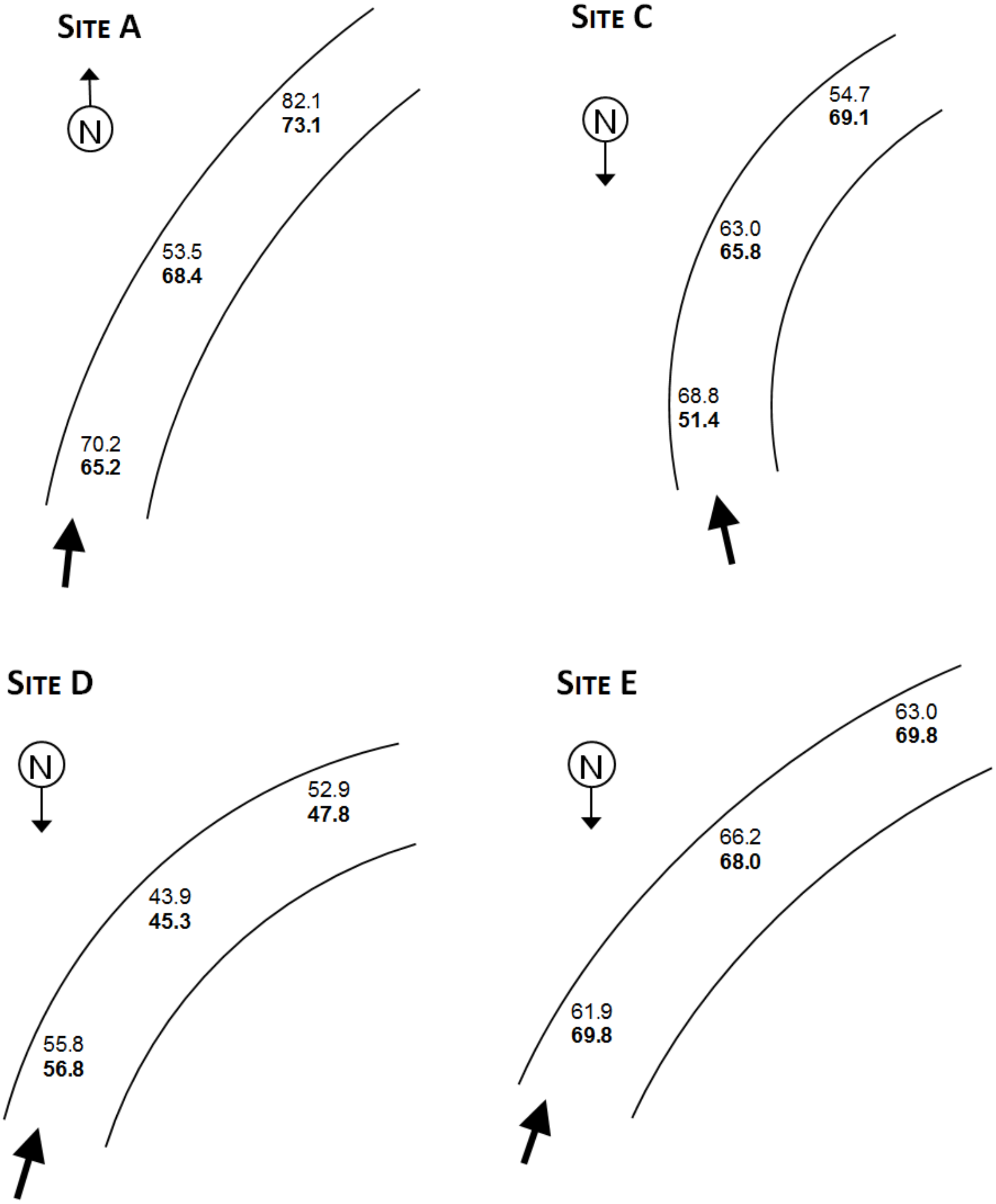
Before installation at the treatment sites, speeds fell by a large margin between the first and middle locations, then rose again at the last measurement location. After installation, the same pattern was observed, save that the increase between the middle and last locations was very small.

In the after period, speeds were similar to speeds before installation, except that speeds were lower at the last measurement location.

Site E

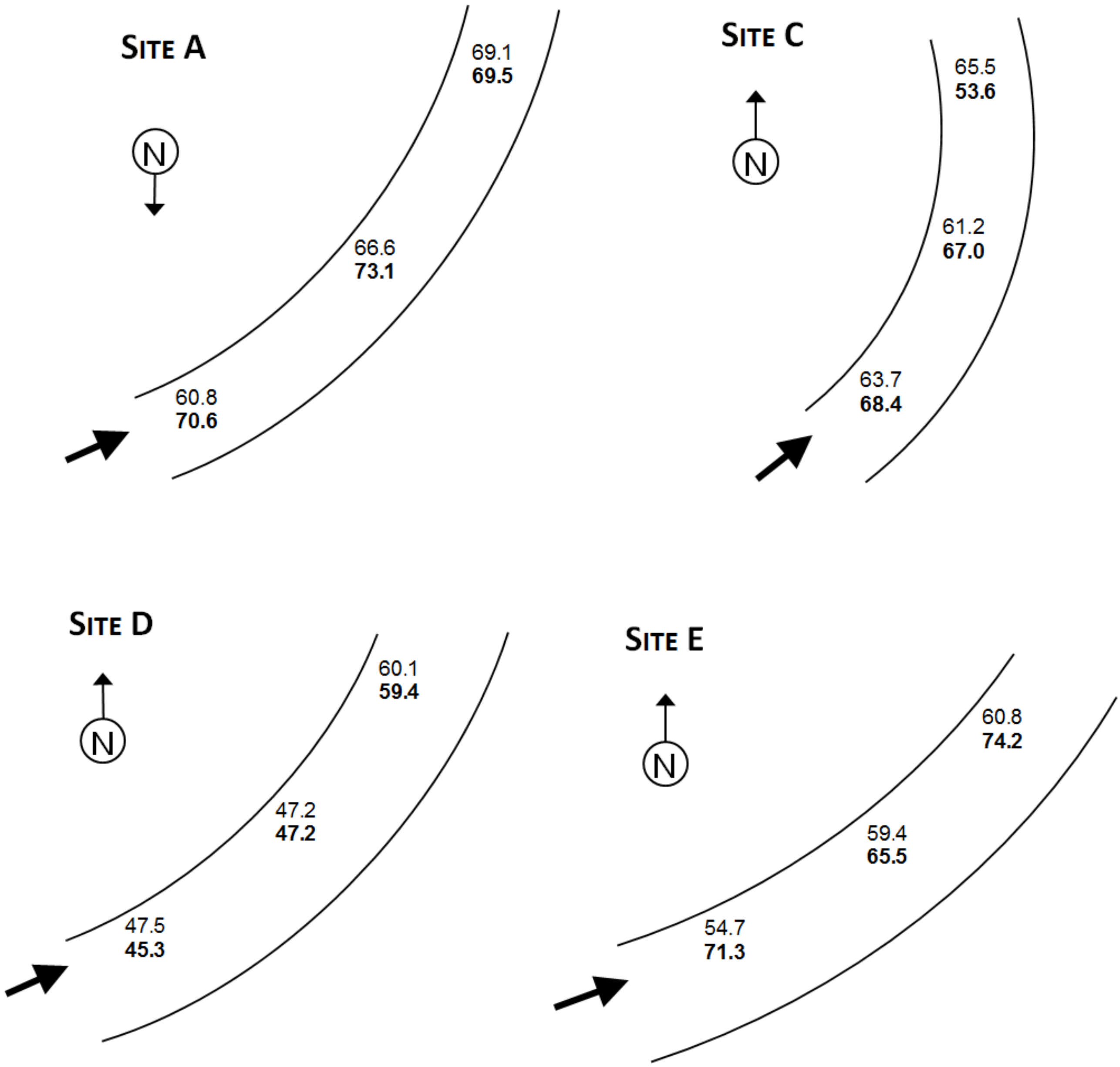
In the before period, speeds increased at the middle measurement location compared to the first measurement location, but reduced slightly at the last measurement location. In the after period, there was little variation in speeds across the three measurement locations.

Speeds were faster at all locations in the after period.



Note:
Speeds in the before period are shown in normal type; speeds in the after period are shown in bold type.

Figure 6.1: Mean speeds at measurement locations on right-hand curves



Note:
Speeds in the before period are shown in normal type; speeds in the after period are shown in bold type.

Figure 6.2: Mean speeds at measurement locations on left-hand curves

6.2 Lateral Placement

The lateral placements of riders at the three measurement locations as they negotiated right-hand curves are shown in Figure 6.3 and the corresponding lateral placements for left-hand curves are shown in Figure 6.4.

6.2.1 Lateral Placement at Right-hand Curves

Site A

After installation, riders' paths were displaced slightly towards the centre of the road, away from the WYLIWYG treatment. At both the first and last locations riders' paths moved away from the edge of the road.

Site C

After installation, the riders were nearer the edge of the road when they entered the curve, at about the same distance from the edge in the centre of the curve, and further from the edge at the last measurement location.

Site D

The path followed in the after period was closer to the edge at the first measurement point, similar for the middle measurement point, and further from the edge at the last measurement point.

Site E

In the after period, the lateral placement was closer to the edge at the first measurement point, similar for the middle measurement point, and closer to the edge at the last measurement point.

6.2.2 Lateral Placement at Left-hand Curves

Site A

After installation, riders' paths were displaced slightly towards the edge of the road; note that the effect of WYLIWYG on all riders appears to have been to have shifted their path away from the WYLIWYG treatment.

Site C

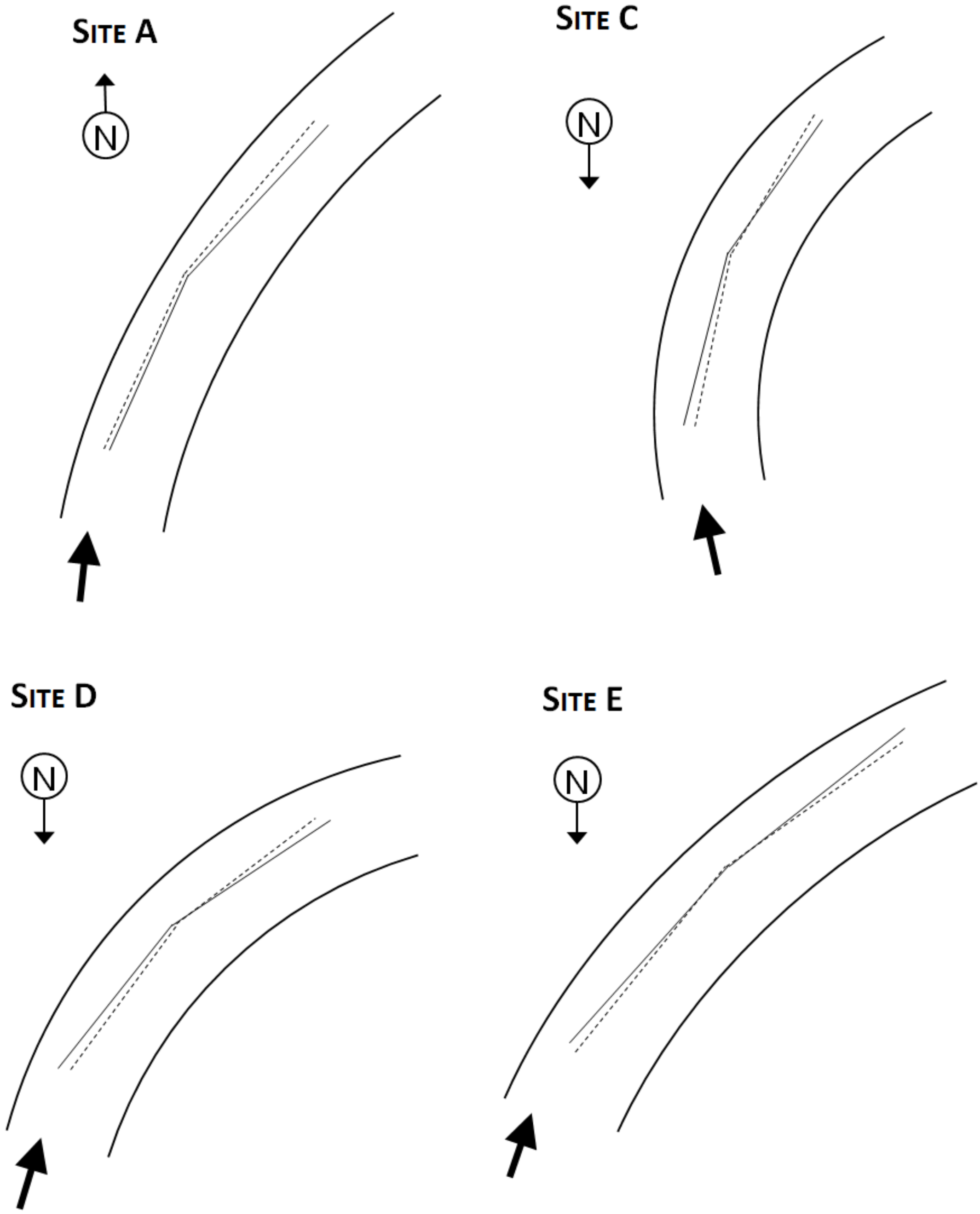
After installation, riders' paths moved towards the centre of the road at the first measurement location, and towards the edge of the road at the middle and last measurement locations.

Site D

In the after period, there was little change in the lateral placement at any of the measurement locations.

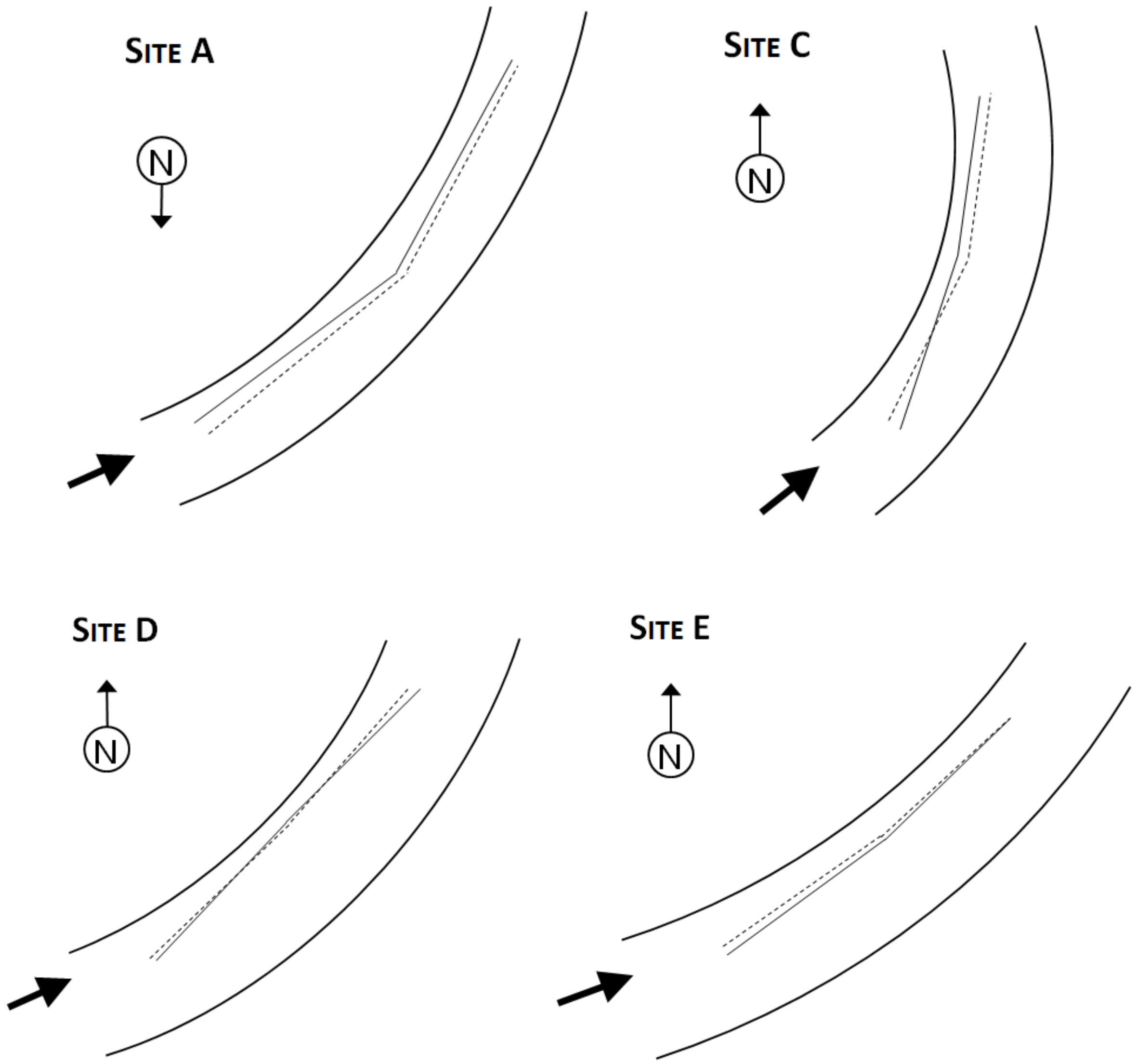
Site E

Riders' paths were further from the edge at the first measurement location, but little changed at the other measurement locations.



Note:
Path followed in the before period is shown as the dotted line; path followed in the after period is shown as a solid line.

Figure 6.3: Lateral placement at measurement locations on right-hand curves



Note:
Path followed in the before period is shown as the dotted line; path followed in the after period is shown as a solid line.

Figure 6.4: Lateral placement at measurement locations on left-hand curves

6.3 Assessment of Effects on Rider Safety

The results of the speed and lane change measurements are summarised in Table 6.1. It should be read in conjunction with Figure 6.1 to Figure 6.4. Assessments are based on the extent to which riders' curve negotiation changed in the after period to be more similar to the idealised strategy discussed in Section 6.1.

6.3.1 Treatment Sites

The WYLIWYG treatment was installed at Site A and Site C, as an outside treatment of a right-hand bend.

At Site A:

- When approached as a right hand curve, the speed profile improved in the recommended direction, but there was no improvement in lateral placement.
- When approached as a left hand curve, there was no evidence of improvement on speed or lateral placement.

At Site C:

- When approached as a right-hand curve, there was a considerable improvement in the speed profile; in particular, the entry speed was much lower, indicating that the WYLIWYG treatment may have been particularly effective in alerting riders to the curve; however, there was no evidence of a beneficial effect on lateral placement.
- When approached as a left hand curve, the pattern of speeds moved away from the optimal, and there was no beneficial effect on lateral placement.

The treatment therefore appears to have resulted in patterns of speeds and accelerations that are closer to the recommended procedures at right-hand curves, but to have no beneficial effects on lateral placements at these curves. The treatment appears to have had no beneficial effects on either the pattern of speeds or lateral acceleration at left-hand curves.

6.3.2 Control Sites

Sites D and E were control sites.

At Site D:

- Whether approached as a right-hand curve or a left-hand curve, there was little change in either speed or lateral placement following the installation of WYLIWYG at the other sites.

At Site E:

- When approached as a right-hand curve, there were changes in both speed and lateral acceleration profiles in the direction of the recommended procedures.
- When approached as a left-hand curve, there were large changes in speed for the after period, but the changes were not in the direction of the recommended procedures; there was little change in lateral placement.

The reasons for the improved curve negotiation performance when approached as a right-hand curve in the after period are not clear, nor are the reasons for the large increases in speed when approached as a left-hand curve.

Table 6.1: Changes in speed and lateral placement at treatment and control sites and effects on safety

Site	Curve	Speed(km/h)	1st location	2nd location	3rd location	Comment	Assessment
A	Right hand	Speed (km/h)	-5.0*	+15.1*	-9.0*	Speeds followed recommended pattern more closely, and varied less between sites; placement moved to the right away from the WYLIWYG treatment	Improvement in speed profiles; slight increase in radius
		Placement (m)	0.2*	0.6*	0.9*		
	Left hand	Speed (km/h)	+9.8*	+6.5*	+0.4	Less variation in speeds, but no improvement on the good pattern which was evident before; placement moved to left, away from the WYLIWYG treatment	No improvement in the pattern of speeds; neutral with respect to lateral placement
		Placement (m)	0.5*	0.2	0.2*		
C	Right hand	Speed (km/h)	+17.2*	+2.8*	+14.4*	Speeds followed recommended pattern, and entry speed much lower; no consistent effect on placement	Greatly improved speed profile; neutral with respect to lateral placement
		Placement (m)	0.6*	0.1	0.5*		
	Left hand	Speed (km/h)	+4.7*	+5.8*	-11.9*	Higher speeds at the start and middle locations, but large speed reduction at the last position; opposite of recommended approach; no consistent trend in placement	Speed pattern moved away from the optimal; neutral with respect to lateral placement.
		Placement (m)	0.6*	0.3*	0.5*		
D	Right hand	Speed (km/h)	+1.1	+1.4	-5.1*	Speed and placement similar before and after	Little change – good control site
		Placement (m)	0.1	0.1	0.2		
	Left hand	Speed (km/h)	+0.8	0.0	-0.7	Speed and placement similar before and after	Little change – good control site
		Placement (m)	0.2	0.0	0.1*		
E	Right hand	Speed (km/h)	+7.9*	+1.8	+6.8*	Speeds faster in after period, steady across the three locations; lateral placement changed in the recommended direction (closer to the edge at the first and last measurement locations, little change at the centre location).	Improvement in speed and lateral placement
		Placement (m)	0.2*	0.1*	0.3*		
	Left hand	Speed (km/h)	+16.5*	+6.1*	+13.4*	Faster speeds at the first and middle locations, followed by a large drop at the third location. A small change in lateral placement in the wrong direction.	Speed profile changed in the wrong way; little change in lateral placement.
		Placement (m)	0.2	0.2	0.0		

Note:

Asterisks indicate statistically significant differences. These data should be read in conjunction with Figure 6.2 to Figure 6.4. Assessments are based on the extent to which riders' curve negotiation changed to be more similar to an idealised strategy. Increases in speed are prefixed by a plus sign, reductions in speed are prefixed by a minus sign.

The likely impacts on safety are not completely clear, but on balance may perhaps indicate a move to safer travel. At right hand curves, the speed profiles moved closer to the recommended procedure in both cases, and a drop in speeds at the entry to the curve was particularly evident at Site C. There was a slight increase in the radius followed by riders at one of the curves.

At left-hand curves, there was no change in speed profiles or lateral placement to indicate that riding had moved closer to the recommended procedures.

6.4 High Risk Riding Behaviours

One possible area of concern is whether the improved delineation resulted in some riders increasing speed or lateral placement by a sufficient amount to place themselves at risk. As the discussion in Sections 6.1 – 6.3 shows, the changes in mean speed and lateral placement did not suggest deterioration in safety. However, it is reasonable to assume that it is the riders who travel fastest or closest to the edge of the road who are most at risk of crashing. Examination of the performance of the riders at the upper-end of the distributions for these variables could therefore possibly provide a better targeted indication of whether or not risk was changing.

Table 6.2: 95th percentiles for speed and lateral placement for travel in both directions at all measurement locations

Site	Location	Before/after	Speed (km/h)	Lateral placement (metres from the edge of the seal)
Right hand curves				
Site A	South	Before	90.0	0.60
		After	80.0	0.40
	Middle	Before	67.4	2.25
		After	80.0	2.85
	North	Before	120.0	1.20
		After	90.0	2.00
Site C	South	Before	80.0	1.40
		After	80.0	0.60
	Middle	Before	80.0	2.70
		After	80.0	2.67
	North	Before	80.5	0.48
		After	60.3	0.85
Site D	South	Before	65.4	0.60
		After	60.0	0.36
	Middle	Before	54.2	2.60
		After	51.4	2.68
	North	Before	67.4	0.80
		After	65.4	0.96

Site	Location	Before/after	Speed (km/h)	Lateral placement (metres from the edge of the seal)
Site E	South	Before	80.0	1.00
		After	90.0	0.84
	Middle	Before	80.0	2.98
		After	80.0	3.00
	North	Before	80.0	1.22
		After	86.5	0.60
Left-hand curves				
Site A	South	Before	90.0	2.60
		After	90.0	2.70
	Middle	Before	90.0	0.24
		After	90.0	0.51
	North	Before	79.6	2.64
		After	90.0	2.47
Site C	South	Before	90.0	2.50
		After	90.0	2.90
	Middle	Before	80.0	0.57
		After	72.0	0.40
	North	Before	80.0	2.99
		After	80.0	2.55
Site D	South	Before	65.4	3.00
		After	60.0	3.00
	Middle	Before	55.4	0.51
		After	56.3	0.53
	North	Before	55.4	2.90
		After	80.0	3.00
Site E	South	Before	72.0	2.90
		After	72.0	3.00
	Middle	Before	90.0	0.60
		After	80.0	0.90
	North	Before	80.0	2.50
		After	80.0	2.40

The 95th percentile values for speed and lateral placement for riders travelling in both directions at each of the measurement locations are shown in Table 6.2. The 95th percentile is the speed or lateral placement that was exceeded by 5% of riders at each of the locations. It may be regarded as an indicator of the typical speed of the fastest riders or typical placement of the riders furthest from the centre line. It needs to be understood, however, that the fastest 5% of riders are not necessarily the same riders as the 5% with the most extreme lateral placement. In this context, the

95th percentiles should be regarded as direct indicators of each particular risk – travelling too fast, crossing the centre line, or running too wide.

One complication is that appropriate lateral placement varies according to whether the curve is a right-hand curve or a left-hand curve, In the case of a right-hand curve, the recommended procedure is to move closer to the edge at the entrance to the curve, to move closer to the centreline at the apex of the curve and to move back closer to the edge of the road on the exit. Since all measurements are expressed in terms of distance from the edge of the road, at the entrance and exit it is appropriate to consider the 5th percentile lateral displacement and at the apex of the curve, the 95th percentile lateral displacement. In both cases, the percentile is the cut-off point for the 5% of riders behaving in the riskiest fashion.

In the case of a left-hand curve, the recommended procedure is the opposite, moving towards the centre of the road at the start of the curve, moving to the edge of the road at the apex, then back to the centre on the exit. Assessing the behaviour of the riskiest 5% of riders therefore requires examining the 95th percentile lateral placement at the start of the curve, the 5th percentile at the apex and the 95th percentile again at the end.

For the sake of convenience, all sets of measurement in this discussion are treated as 95th percentiles.

Inspection of the table shows the following:

- For the right-hand curves:
  - Speeds were generally lower in the after period, with only one increase in speed at a treatment site (10 km/h – Site A middle location) and two increases at the control sites (both Site E, first and last locations).
  - In terms of lateral placement, the 95th percentile at the first measurement point of Site A moved close to the edge and was relatively low; however notice that the 95th percentile for Site D in the before period was even lower.
- For the left-hand curves:
  - Speeds were generally lower in the after period, with only one increase in speed at a treatment site (10 km/h – Site A last location) and one increase at the control sites (Site D, last location).
  - Ninety-fifth percentile lateral placement increased at one treatment site location (Site C) to high levels (2.90 metres), but this was less than the 95th percentile lateral placement for the before measurements at the same site, and less than several of the before and after 95th percentiles for the control sites.

The general pattern of the 95th percentile measurements does not suggest any increase in risk arising from the treatment.

7 STUDY OF RIDER BEHAVIOUR – DISCUSSION

7.1 Effect of WYLIWYG on Rider Behaviour

WYLIWYG appears to have had some positive effects on rider behaviour. At right-hand curves, speed profiles changed in the direction of recommended practice, and there was a slight change in lateral placement in the direction of the recommended procedure. There appeared to be no beneficial effects at left-hand curves, and the speed profile at one of them appears to have moved away from the recommended pattern.

In Section 2.4 evidence was reviewed that showed that the majority of crashes on curves occurred at right-hand curves and although these data did not apply specifically to motorcycles, it seemed likely that this would be the case for motorcycles as well. Such beneficial effects as were detected therefore apply to the most hazardous curve direction.

These positive changes need to be seen in the context of other changes, e.g. overall increases in speed at both right hand curves, and a movement away from the recommended speed profile at one of the left-hand curves. On the evidence of the present study, it is not certain that the positive effects outweigh the negative effects.

7.2 Limitations of the Current Study

This study is subject to two major limitations, as outlined in the following sections.

7.2.1 Site Selection

As explained in Section 3.2, the only sites available on the routes selected differed from the site in Buckinghamshire for which the WYLIWYG treatment was designed. The sites chosen were on a winding road running through mountainous country, rather than the isolated curve with long tangential approaches as was the case with the original site in Buckinghamshire.

A further limitation was that the entire length of the route had already been treated with guide posts, which are standard treatments on curves in Australia, in contrast to the UK where guide posts are used very sparingly. In many cases, the guide posts had been supplemented by chevron alignment markers.

Both these factors would tend to reduce the impact of WYLIWYG.

7.2.2 Data Capture and Measurement

The cameras used in the study were generally unobtrusive and appear unlikely to have affected rider behaviour to any great degree.[1]

Data capture was done by human observers, which was slow, laborious and of limited accuracy. Time to travel between measurement points was measured using a stop watch, accurate to within 0.1 seconds at best. Lateral placement and lean angle were measured directly from the screen and were of limited accuracy.

[1] They were not however totally unobtrusive. A camera was stolen by a group of four-wheel drivers during a recording session which was not used in the study, recorded by a companion camera on the opposite side of the road which apparently was not noticed.

7.3 Implications for the Provision of Delineation along Motorcycling Routes

The results from the present study, though promising, were far from conclusive. Further work is needed to determine whether or not WYLIWYG offers sufficient advantages over the current delineation treatments to be worth pursuing in Victoria.

Even if the current version of WYLIWYG continued to show promise, cost is likely to remain a major stumbling block. Not only are the imported Vergemaster guideposts expensive in themselves, but the requirement to embed them in concrete results in high installation costs. These high costs are exacerbated by the fact that many candidate sites are in remote locations.

An extruded plastic guidepost of approximately similar dimensions to the Vergemaster product which could be driven into the ground would greatly reduce installation costs, and might also reduce the costs of the guideposts as well. Unfortunately, initial inquiries placed with a leading Australian manufacturer have indicated that this is not an option that could readily be pursued (email from Tanya Tallarida, Marketing Assistant, EzyDrive, 31st January 2012).

It is uncertain whether the WYLIWYG treatment is justified under Australian conditions, where guideposts are part of the normal treatment of all curves. However, three points are worth considering:

- Despite the widespread provision of guideposts, many motorcyclists crash on curves. It is not known to what extent these crashes result from misperception of the curve, and to what extent they are due to a decision to test the limits of the machine and rider or other factors. Experience with WYLIWYG in the UK suggests that, at least under some circumstances, improved delineation can improve motorcyclist safety on curves. It would therefore seem to be worth persisting with this line of research, whilst recognising that it will be difficult to show definite effects from upgrading delineation rather than providing delineation where none previously existed.
- Many curves on motorcycling routes in Victoria are treated using chevron alignment markers. These were originally intended as a long-range delineation treatment to warn road users approaching a curve along a straight of the presence of the curve and to give an indication of its direction, severity and gradient. This information would enable road users to enter the curve at an appropriate speed and with accurate expectations about its curvature and gradient. However, on motorcycling routes the chevron alignment markers are frequently used to provide short range delineation. The most important feature of short range delineation is continuity of guidance around the curve, something that chevron alignment markers do not do well on tight curves. The spacing between successive markers means there is often a gap between a marker going out of view and the next one coming into view. While there is no evidence that this is a safety issue, this arrangement does not give continuity of guidance and is therefore not ideal.
- As can be seen from Figure 4.2, the Vergemaster guideposts are more conspicuous than conventional guideposts. It may therefore be worth considering using Vergemaster or other more conspicuous guideposts at selected points on motorcycling routes to indicate a potentially hazardous curve (as chevron alignment markers are currently being used) while providing continuity of guidance around the curve (which chevron alignment markers do not always manage to achieve).

7.4 Implications for Future Research

This study indicates very clearly the difficulties in collecting and interpreting data on rider curve negotiation. To obtain a comprehensive view, it is necessary to consider both speeds and lateral placement in a dynamic context as the rider moves around the curve. The implied radius measure proved to be unreliable, balancing out the speed and distance results at one treatment site, but giving inconsistent results at the other site. The reasons for this are not clear.

With current measurement tools, there does not appear to be much scope for reducing the number of observation points or the amount of work in capturing data from the video record. However, there may be scope for improving the accuracy of some of the measurements. A time stamp on the video record with an interval of 0.01 s might increase the accuracy of the timings in the study. Software which projects an accurate geometric grid onto the road surface, based on calibration measures for reference, would enable more accurate placement of reference lines and gradation points for the lateral placement measures.

In the present study, the number of observations at each site was more than sufficient to provide rigorous tests for ‘before-after’ comparisons. Future work could potentially relax the requirements for the number of riders at each site, and concentrate on covering a wider range of sites.

Any future studies of rider behaviour in response to changes in delineation are likely to require a broadly similar level of resource allocation, unless suitable analysis software becomes available. Future research could concentrate on answering questions such as:

- Does a treatment such as WYLIWYG consistently result in riders moving across the road away from it, as was the case at Site A?
- Does a treatment such as WYLIWYG consistently result in more consistent speeds through a site, as was the case at Site A?

An alternative approach would be to apply a WYLIWYG-style treatment more broadly, and to monitor crash history. This would be a direct approach which avoids the problems of measuring whether behavioural changes are a valid predictor of crash outcomes in this instance. Offsetting this advantage is the need for a large study which would have to run for a number of years before there was any prospect of detecting a statistically significant reduction in crashes.

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APPENDIX A THE RESULTS IN DETAIL

A.1 Speed

The speeds in the diagrams in Appendix A are expressed in metres per second, the original measurements taken from the field data. To convert to km/h, the measure used in the main body of the report, the speeds in meters/second should be multiplied by 3.6 to give the speed in km/h.

Speeds at Site A in the before and after periods are shown in Figure A 1 and Figure A 2 for northbound and southbound riders respectively. Numbers of motorcycles, standard deviations of speeds and the results of statistical testing are shown in Table A 1.

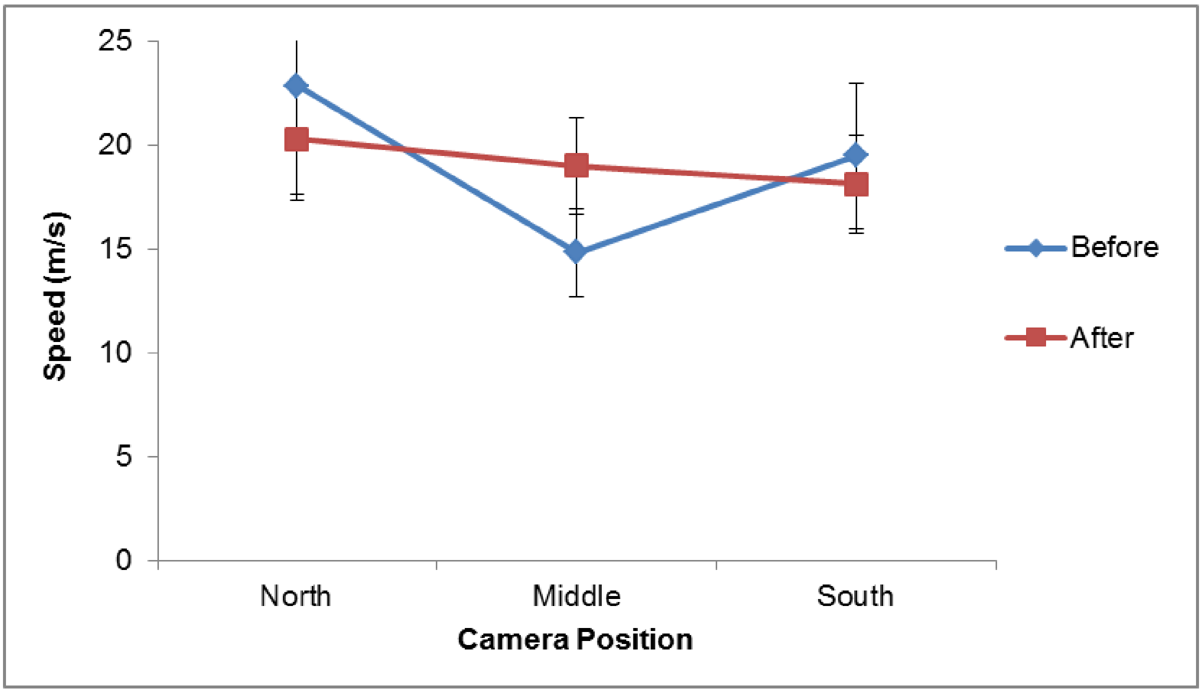

Figure A 1: Mean speed (with standard deviation) at Site A – northbound

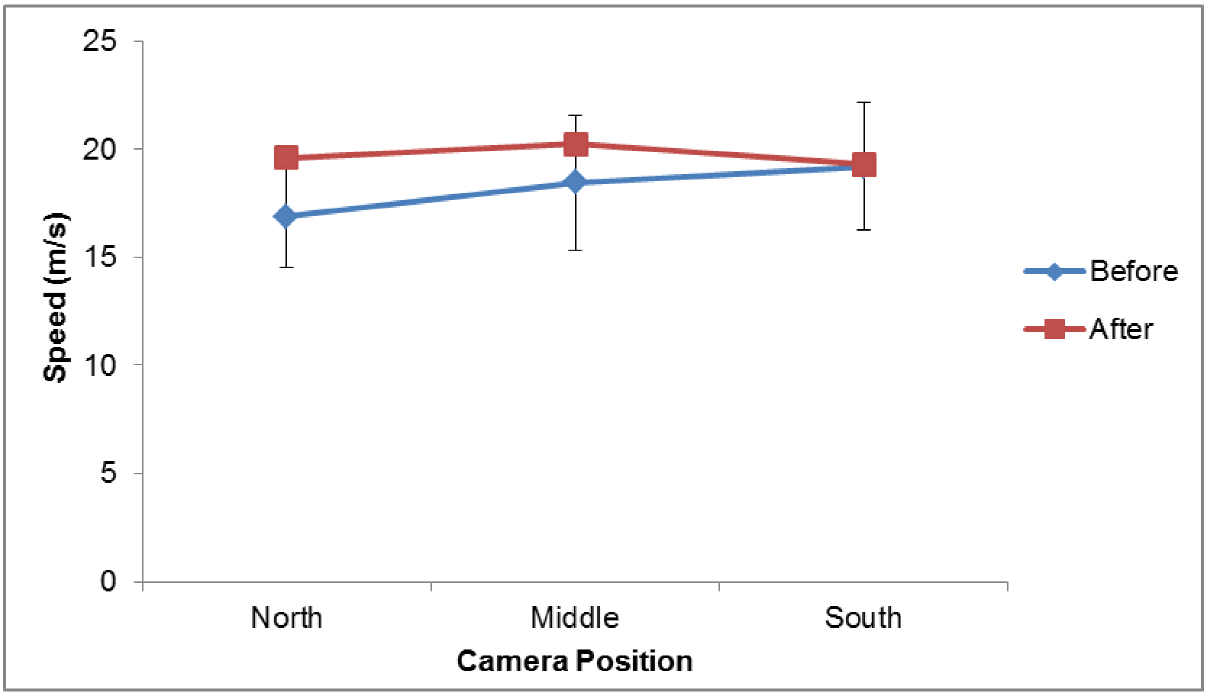

Figure A 2: Mean speed (and standard deviation) at Site A – southbound

It can be seen that northbound traffic reduced speed after the installation of the treatment, by an average of 1.4 m/s at the south location (the first encountered by the northbound riders), and by 2.5 m/s at the north location. However at the middle location mean speed increased by 4.2 m/s. Southbound riders increased speed by 2.7 m/s at the north location (the first they passed through), by 1.8 m/s at the middle location, and travelled at almost the same speed at the south location.

Table A 1: Speeds at Site A (treatment site)

Northbound					
Location	**Before/After**	**Number of motorcycles**	**Mean speed (metres/second)**	**Standard deviation**	**t**
South	Before	123	19.5	3.5	4.078vs
	After	191	18.1	2.4	
Middle	Before	73	14.8	2.1	-13.189vs
	After	188	19.0	2.3	
North	Before	81	22.8	5.5	3.978s
	After	183	20.3	2.6	
Southbound					
Location	**Before/After**	**Number of motorcycles**	**Mean speed (metres/second)**	**Standard deviation**	**t**
North	Before	120	16.9	2.4	-6.438s
	After	85	19.6	3.4	
Middle	Before	117	18.5	2.9	-4.111vs
	After	88	20.3	3.2	
South	Before	68	19.2	3.0	-0.185v
	After	82	19.3	3.9	

Note: All t-tests are conducted to the 95% confidence level. v= equal variances assumed. s= significant difference in the means.

Speeds at Site C in the before and after periods are shown in Figure A 3 and Figure A 4, and numbers of motorcycles, standard deviations of speeds and the results of statistical testing are shown in Table A 2.

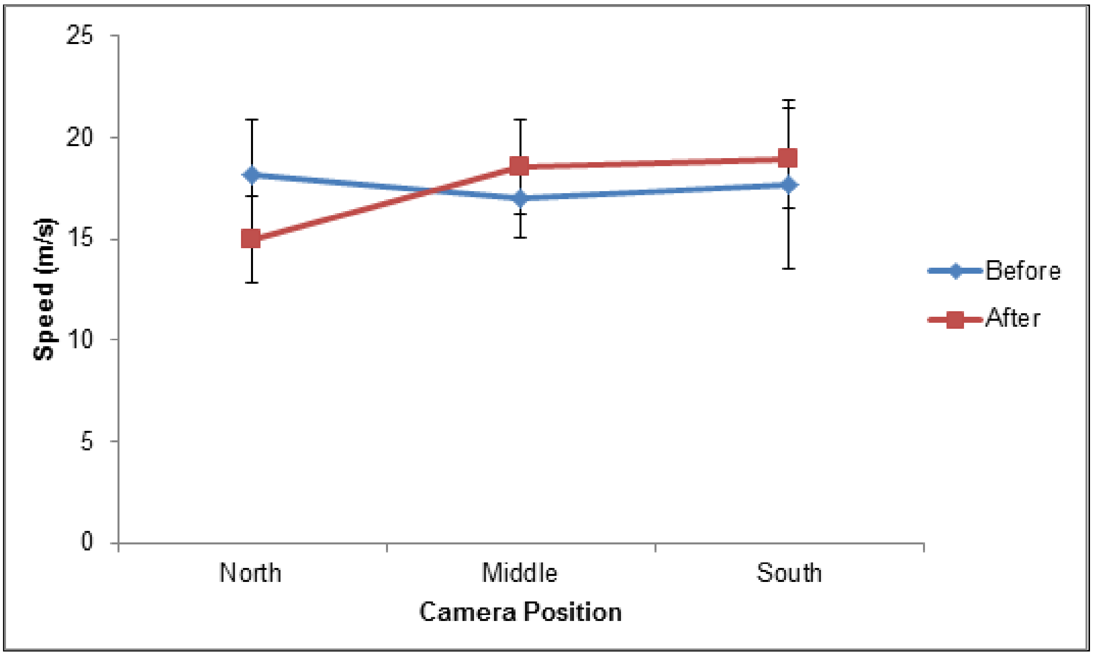

Figure A 3: Mean speed (and standard deviation) site C – northbound

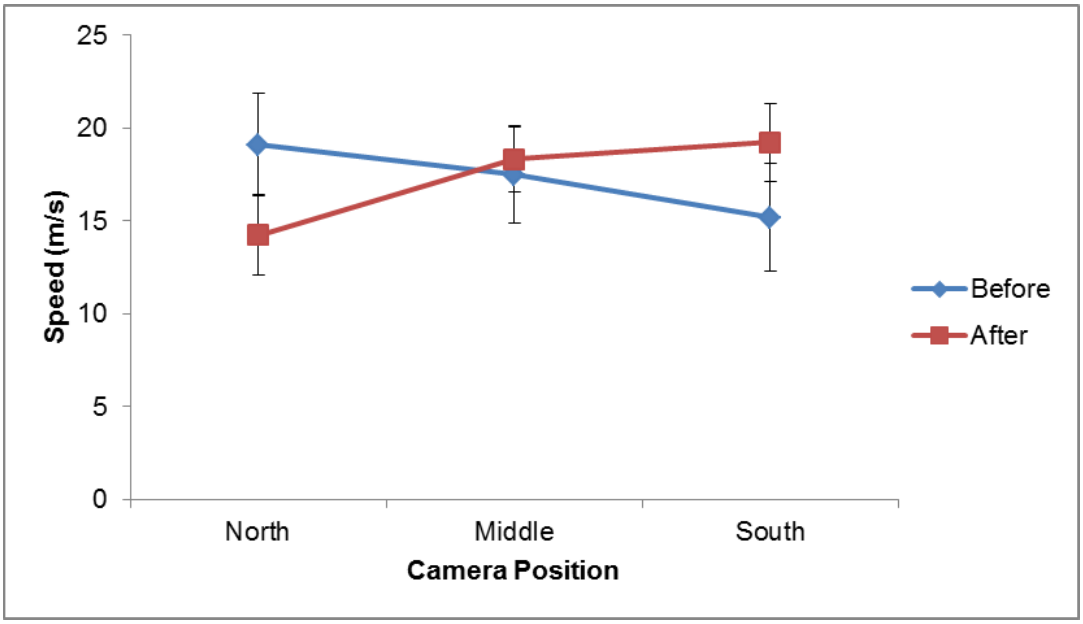

Figure A 4: Mean speed (and standard deviation) site C – southbound

Table A 2: Speeds at Site C (treatment site)

Northbound					
Location	**Before/After**	**Number of motorcycles**	**Mean speed (metres/second)**	**Standard deviation**	**t**
South	Before	132	17.7	4.2	-3.263s
	After	195	19.0	2.4	
Middle	Before	111	17.0	2.0	-5.915vs
	After	194	18.6	2.3	
North	Before	101	18.2	2.7	10.385s
	After	200	14.9	2.1	
Southbound					
Location	**Before/After**	**Number of motorcycles**	**Mean speed (metres/second)**	**Standard deviation**	**t**
North	Before	78	19.1	2.7	12.730s
	After	98	14.3	2.2	
Middle	Before	71	17.5	2.6	-2.338s
	After	84	18.3	1.8	
South	Before	78	15.2	2.9	-10.201vs
	After	84	19.2	2.1	

All t-tests are conducted to the 95% confidence level. v= equal variances assumed. s= significant difference in the means.

In this case, northbound riders increased their speeds at the south (first-encountered) and middle locations, but decreased speed by 4.7 m/s at the north location. Southbound riders reduced their speed at the north location by 4.8 m/s, but increased speed slightly at the middle location (0.8 m/s) and increased speed considerably at the south location (4 m/s).

The speed and lateral placement data for Site D (the control site with standard guideposts only) are shown in Figure A 5 and Figure A 6, and motorcycle numbers, standard deviations of speeds and results of statistical testing are shown in Table A 3.

For both northbound and southbound riders, speeds changed very little at any of the locations. The largest changes were a 0.8 m/s decrease northbound at the south location and a 1.4 m/s reduction southbound at the south location.

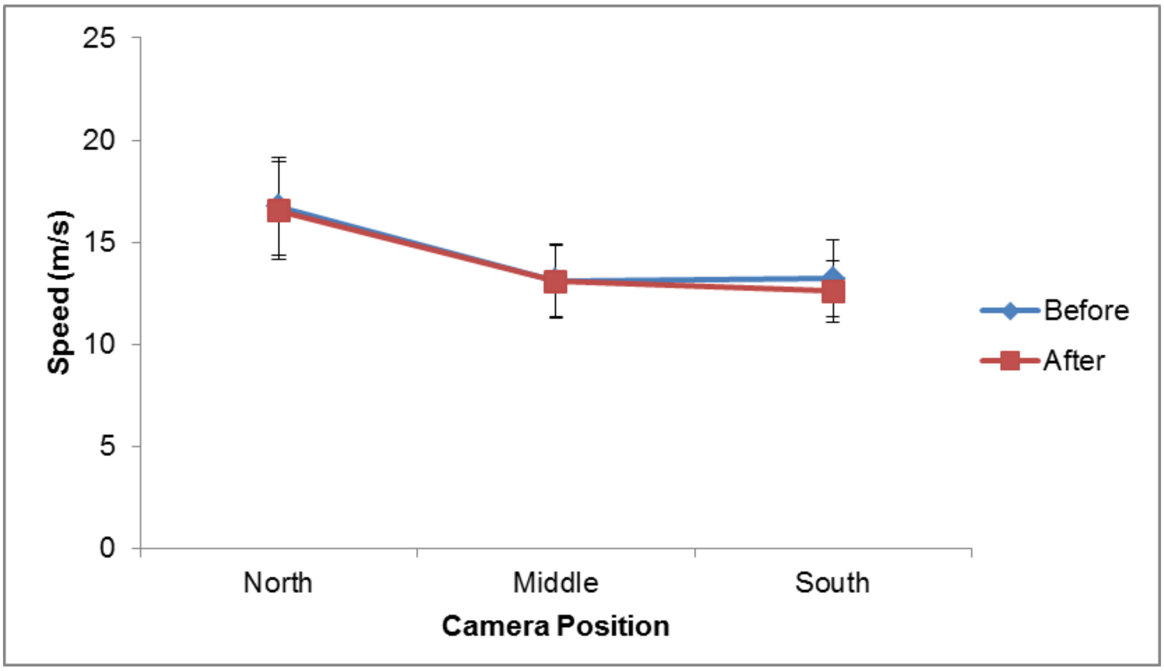

Figure A 5: Mean speed (and standard deviation) site D – northbound

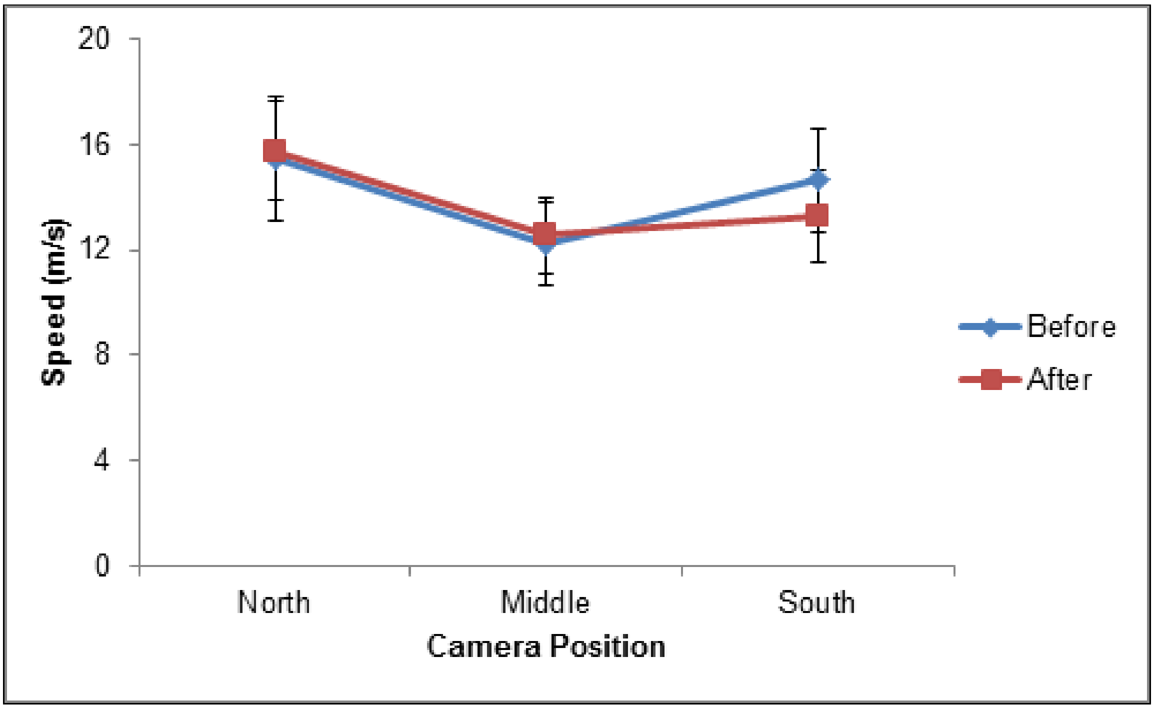

Figure A 6: Mean speed (and standard deviation) site D – southbound

Table A 3: Speeds at Site D (control site with guidepost delineation)

Location	Before/After	Number of motorcycles	Mean speed (metres/second)	Standard deviation	t
Northbound					
South	Before	117	13.2	1.9	3.068[s]
	After	201	12.6	1.5	
Middle	Before	115	13.1	1.8	0.062[v]
	After	192	13.1	1.7	
North	Before	112	16.7	2.4	0.752[v]
	After	192	16.5	2.4	
Southbound					
Location	**Before/After**	**Number of motorcycles**	**Mean speed (metres/second)**	**Standard deviation**	**t**
North	Before	73	15.5	2.3	-0.816[v]
	After	78	15.8	1.9	
Middle	Before	65	12.2	1.6	-1.339[v]
	After	84	12.6	1.5	
South	Before	66	14.7	1.9	4.567[vs]
	After	85	13.3	1.7	

Note: All t-tests are conducted to the 95% confidence level. [v]= equal variances assumed. [s]= significant difference in the means.

The speed and lateral placement data for Site E are shown in Figure A 7 and Figure A 8 , and motorcycle numbers, standard deviations of speeds and results of statistical testing are shown in Table A 4.

In the 'after' period, all riders at all Site E locations rode faster than they did in the 'before' period.

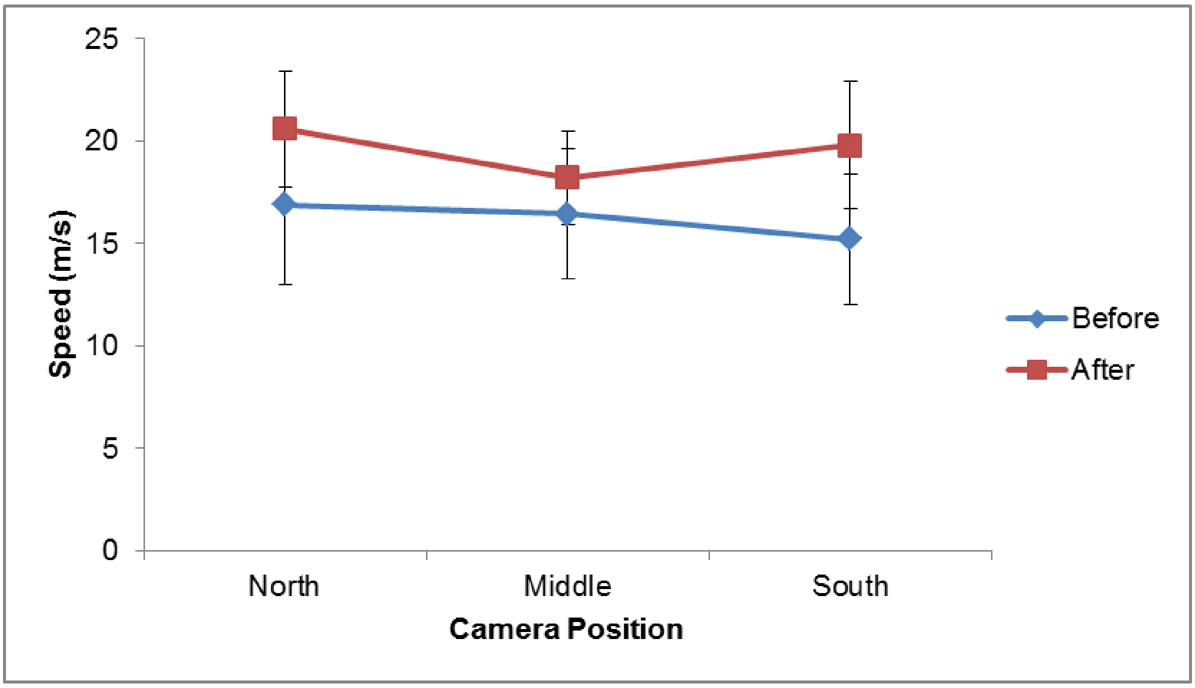

Figure A 7: Speeds at Site E (control site with chevron alignment marker delineation) – northbound

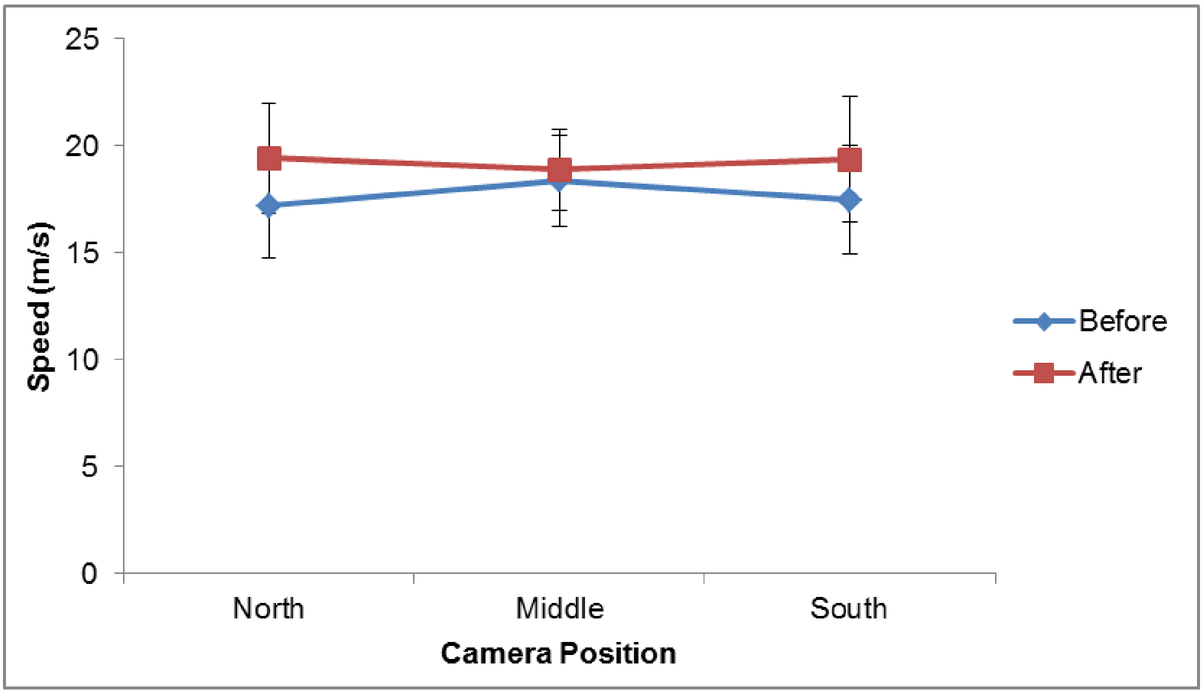

Figure A 8: Speeds at Site E (control site with chevron alignment marker delineation) – southbound

Table A 4: Speeds at Site E (control site with chevron alignment marker delineation)

Northbound					
Location	**Before/After**	**Number of motorcycles**	**Mean speed (metres/second)**	**Standard deviation**	**t**
South	Before	118	15.2	3.2	-12.828[vs]
	After	211	19.8	3.1	
Middle	Before	126	16.5	3.2	-5.446[s]
	After	199	18.2	2.3	
North	Before	107	16.9	3.9	-8.609[s]
	After	193	20.6	2.8	
Southbound					
Location	**Before/After**	**Number of motorcycles**	**Mean speed (metres/second)**	**Standard deviation**	**t**
North	Before	69	17.2	2.4	-5.523[vs]
	After	86	19.4	2.6	
Middle	Before	63	18.4	2.1	-1.585[v]
	After	87	18.9	1.9	
South	Before	62	17.5	2.5	-4.102[vs]
	After	84	19.4	2.9	

Note: All t-tests are conducted to the 95% confidence level. [v]= equal variances assumed. [s]= significant difference in the means.

A.2 Lateral Placement

Lateral placement at Site A is shown in Figure A 9 and Figure A 10. In all cases, the distance is the distance from the edge of the sealed surface. Standard deviations of placements and results of statistical testing are shown in Table A 5.

Northbound traffic moved away from the edge, closer to the centre line in the after period. There is very little change at the south location (the first encountered by northbound riders), but larger changes at the middle and north locations. Southbound traffic tended to move towards the edge line in the after period, away from the centre line. The effect is small in comparison to the changes for the northbound traffic. Note that in both cases the movement is away from the delineators.

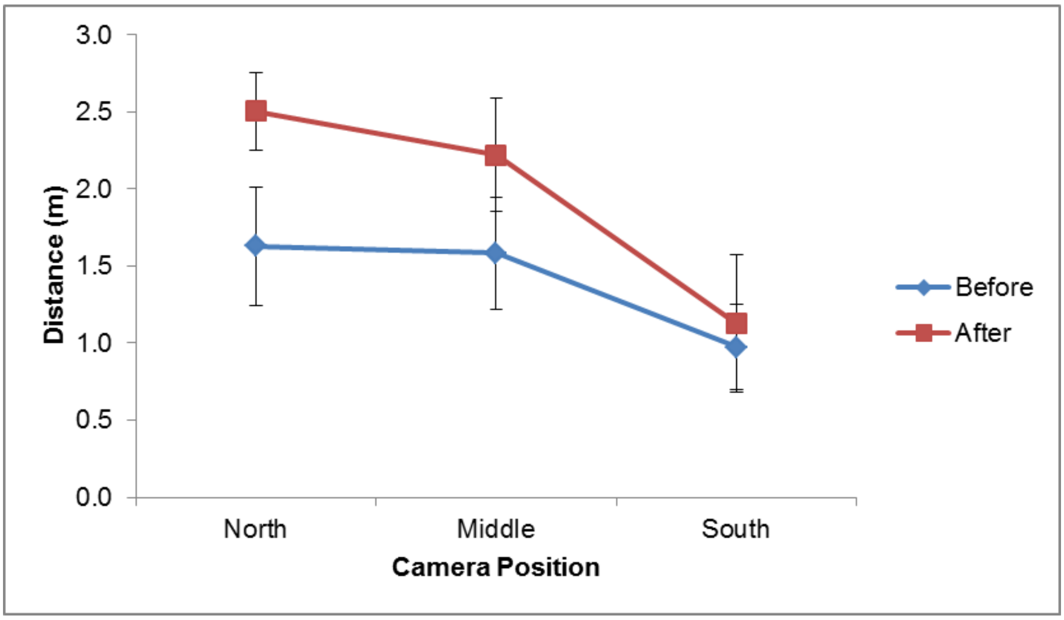

Figure A 9: Lateral placement at Site A (treatment site) before and after the installation of WYLIWYG – northbound

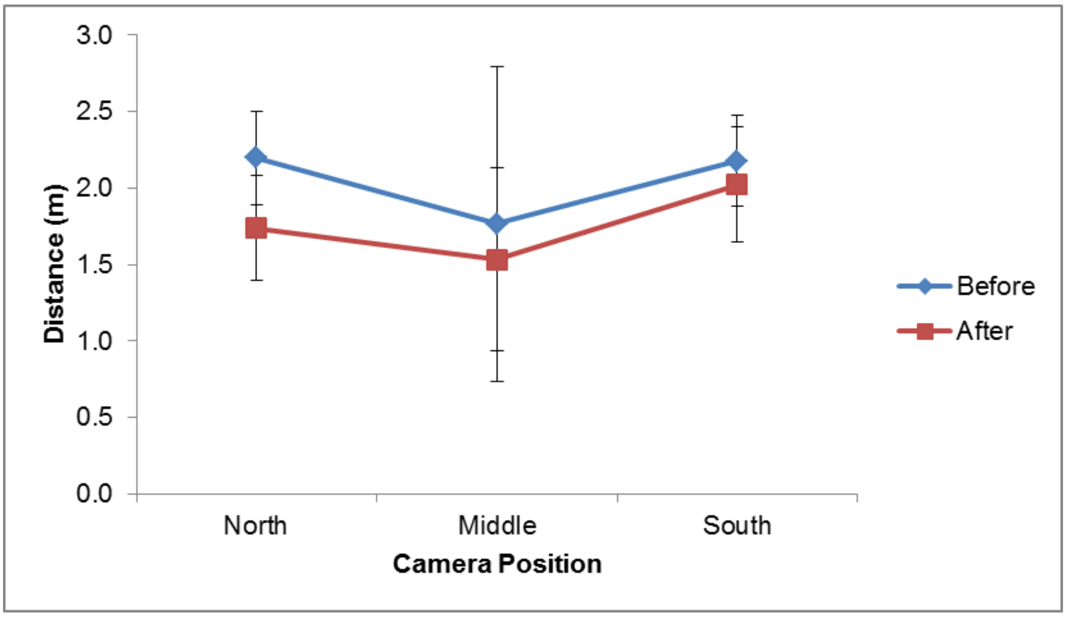

Figure A 10: Lateral placement at Site A (treatment site) before and after the installation of WYLIWYG – southbound

Table A 5: Lateral placement at Site A (treatment site) before and after the installation of WYLIWYG

Northbound				
Location	**Before/After**	**Lateral placement (metres from the edge of the seal)**	**Standard deviation**	**t**
South	Before	0.97	0.28	-3.716s
	After	1.13	0.44	
Middle	Before	1.58	0.36	-12.585vs
	After	2.22	0.37	
North	Before	1.63	0.38	-18.800s
	After	2.50	0.25	
Southbound				
Location	**Before/After**	**Lateral placement (metres from the edge of the seal)**	**Standard deviation**	**t**
North	Before	2.20	0.31	10.080vs
	After	1.74	0.34	
Middle	Before	1.77	1.03	2.051s
	After	1.53	0.60	
South	Before	2.18	0.30	2.704vs
	After	2.02	0.38	

Note: All t-tests are conducted to the 95% confidence level. v= equal variances assumed. s= significant difference in the means.

Lateral placement at Site C is shown in Figure A 11 and Figure A 12, and standard deviations and the results of statistical testing are shown in Table A 6.

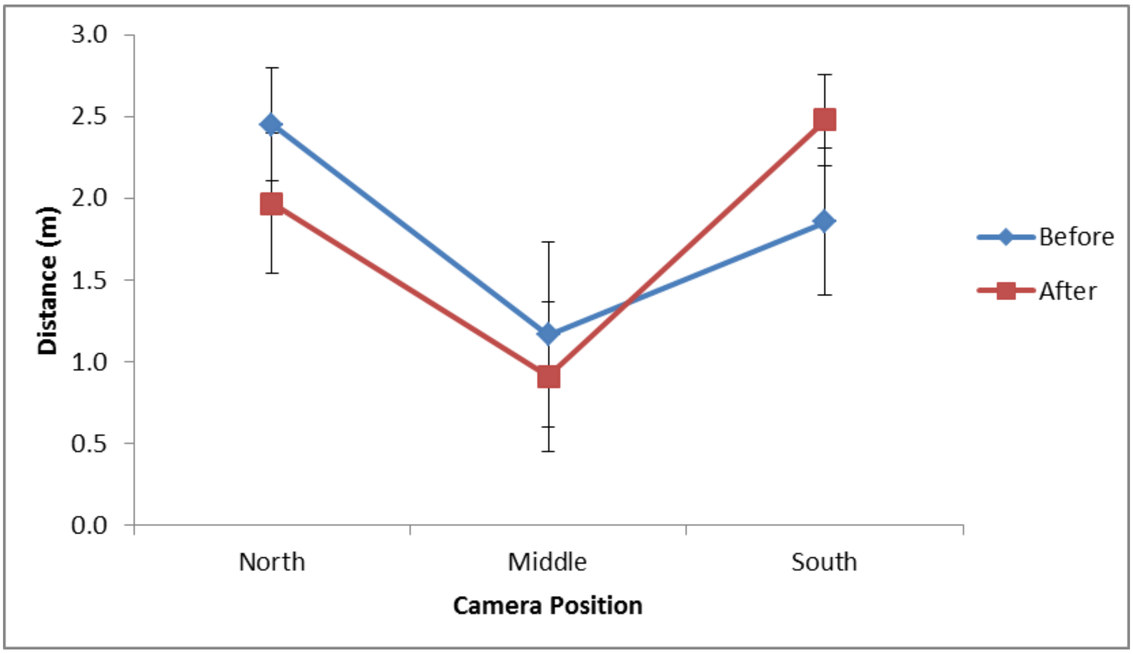

Figure A 11: Lateral placement at Site C (treatment site) – northbound

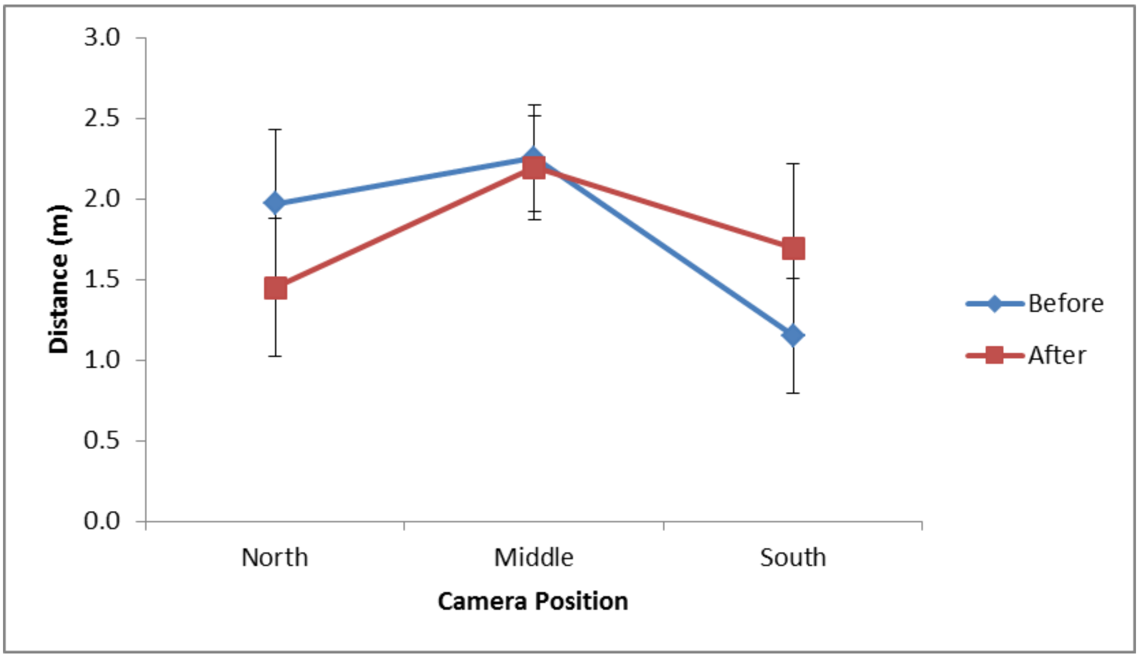

Figure A 12: Lateral placement at Site C (treatment site) – southbound

Table A 6: Lateral placement at Site C (treatment site)

Location	Before/After	Lateral placement (metres from the edge of the seal)	Standard deviation	t
Northbound				
South	Before	1.85	0.45	-14.231^{s}
	After	2.48	0.28	
Middle	Before	1.16	0.57	5.590^{vs}
	After	0.86	0.37	
North	Before	2.45	0.34	10.656^{s}
	After	1.96	0.43	
Southbound				
Location	**Before/After**	**Lateral placement (metres from the edge of the seal)**	**Standard deviation**	**t**
North	Before	1.97	0.48	9.059^{vs}
	After	1.39	0.38	
Middle	Before	2.25	0.33	0.985^{v}
	After	2.20	0.33	
South	Before	1.15	0.36	-7.655^{s}
	After	1.68	0.52	

Note: All t-tests are conducted to the 95% confidence level. ^{v}= equal variances assumed. ^{s}= significant difference in the means.

Northbound riders moved closer to the centre line at the south location, and away from the centre line at the middle and north locations. Southbound riders moved away from the centre line at the north location and towards the centre line at the south locations, but hardly changed at the middle location.

Lateral placement at Site D (the control site with standard guideposts) is shown in Figure A 13 and Figure A 14, and standard deviations and the results of statistical testing are shown in Table A 7. Little change was evident at any of the measurement locations.

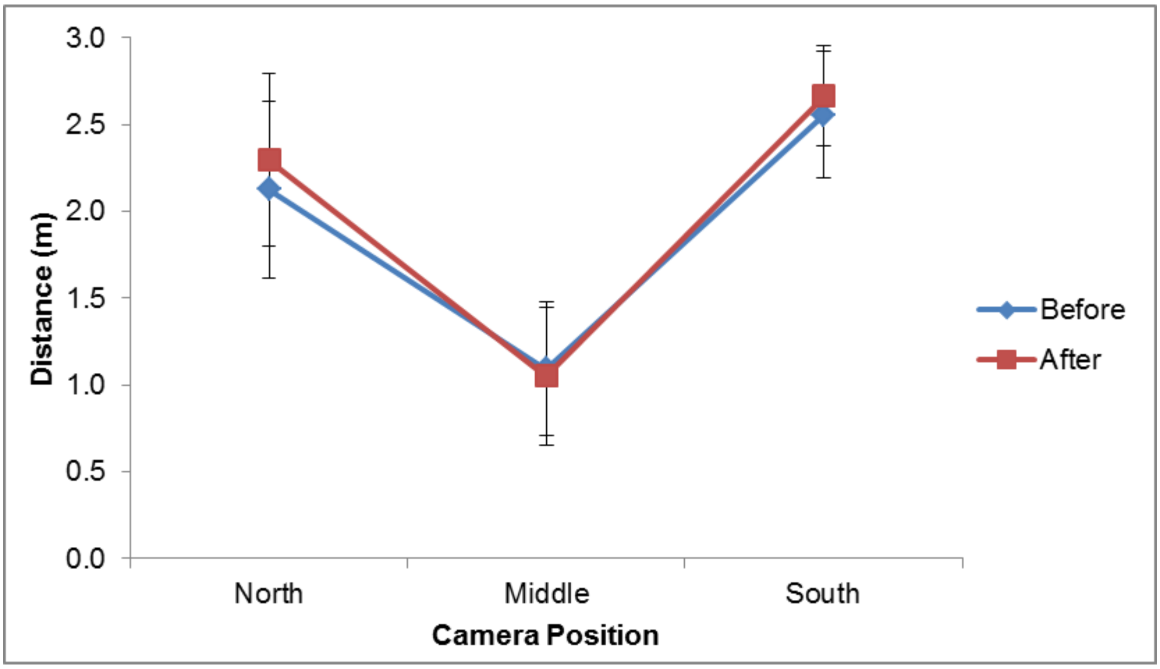

Figure A 13: Lateral placement at Site D (control site with guidepost delineation) – northbound

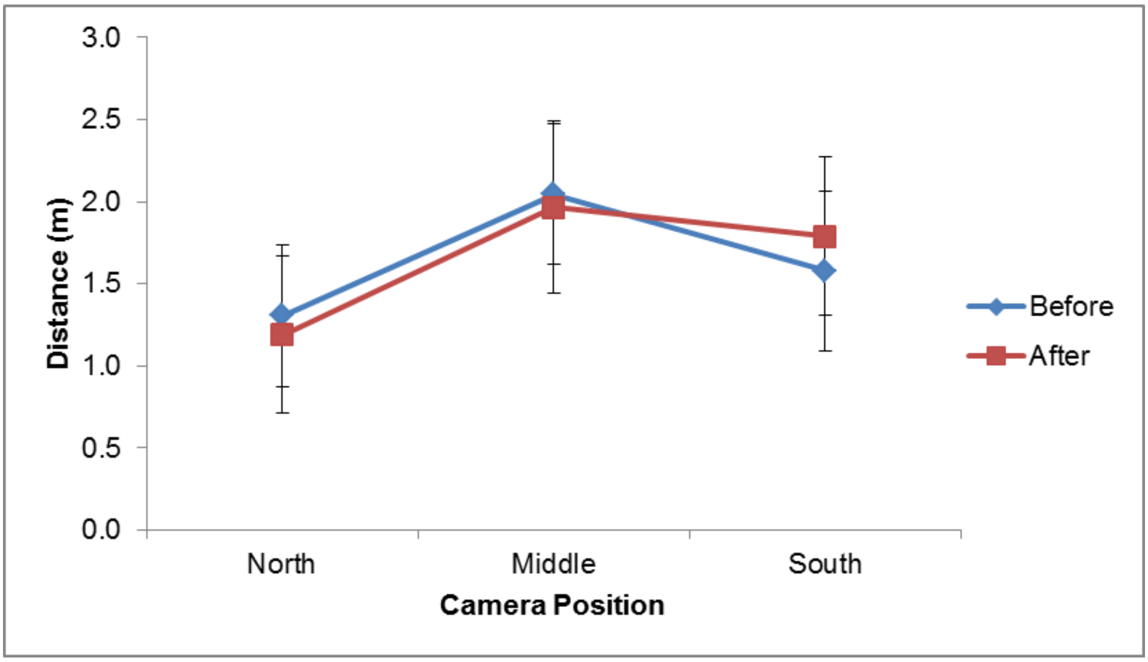

Figure A 14: Lateral placement at Site D (control site with guidepost delineation) – southbound

Table A 7: Lateral placement at Site D (control site with guidepost delineation)

Northbound				
Location	**Before/After**	**Lateral placement (metres from the edge of the seal)**	**Standard deviation**	**t**
South	Before	2.56	0.36	-2.932[vs]

	After	2.67	0.29	
Middle	Before	1.09	0.39	0.936^{v}
	After	1.05	0.40	
North	Before	2.13	0.51	-2.836^{vs}
	After	2.30	0.50	
Southbound				
Location	**Before/After**	**Lateral placement (metres from the edge of the seal)**	**Standard deviation**	**t**
North	Before	1.31	0.43	1.581^{v}
	After	1.19	0.48	
Middle	Before	2.05	0.43	0.995^{v}
	After	1.97	0.52	
South	Before	1.58	0.49	-2.621^{vs}
	After	1.79	0.48	

Note: All t-tests are conducted to the 95% confidence level. ^{v}= equal variances assumed. ^{s}= significant difference in the means.

Lateral placement at Site E (the control site with CAMs) is shown in Figure A 15 and Figure A 16, and the standard deviations and results of the statistical testing are shown in Table A 8.

Northbound riders moved towards the centre line at the south and middle locations but did not change at the north location. Southbound riders did not change position at the middle location but moved away from the centre at the north and south locations, but changes were small in all cases.

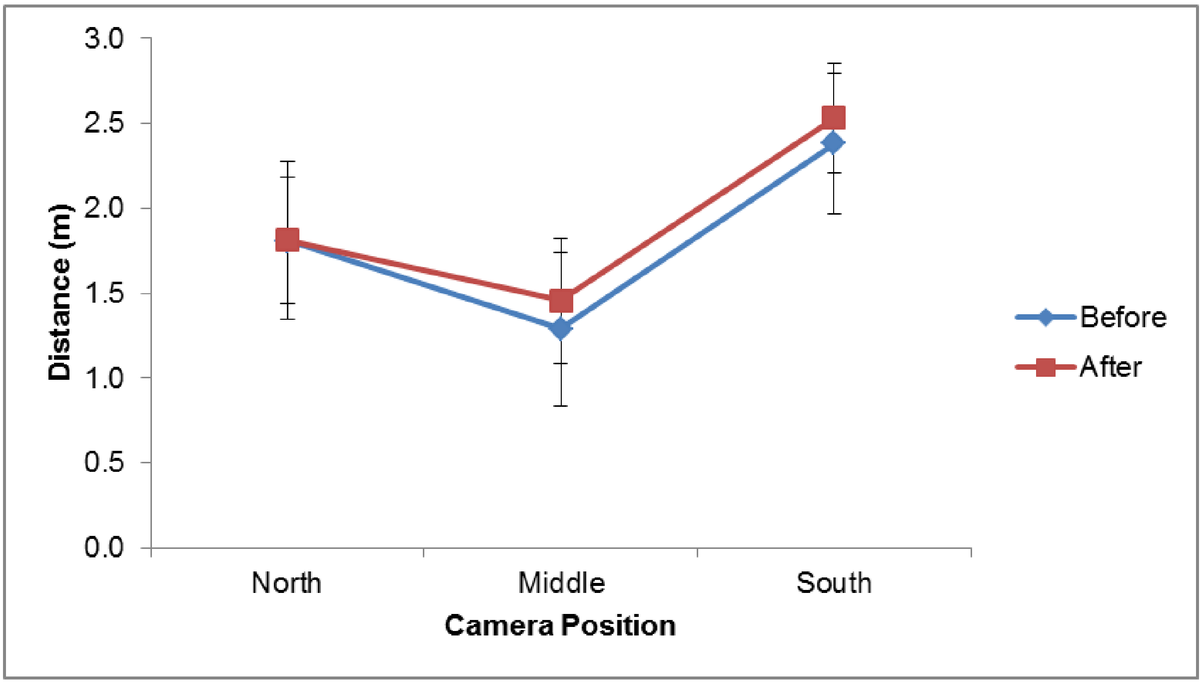

Figure A 15: Lateral placement at Site E (control site with chevron alignment marker delineation) – northbound

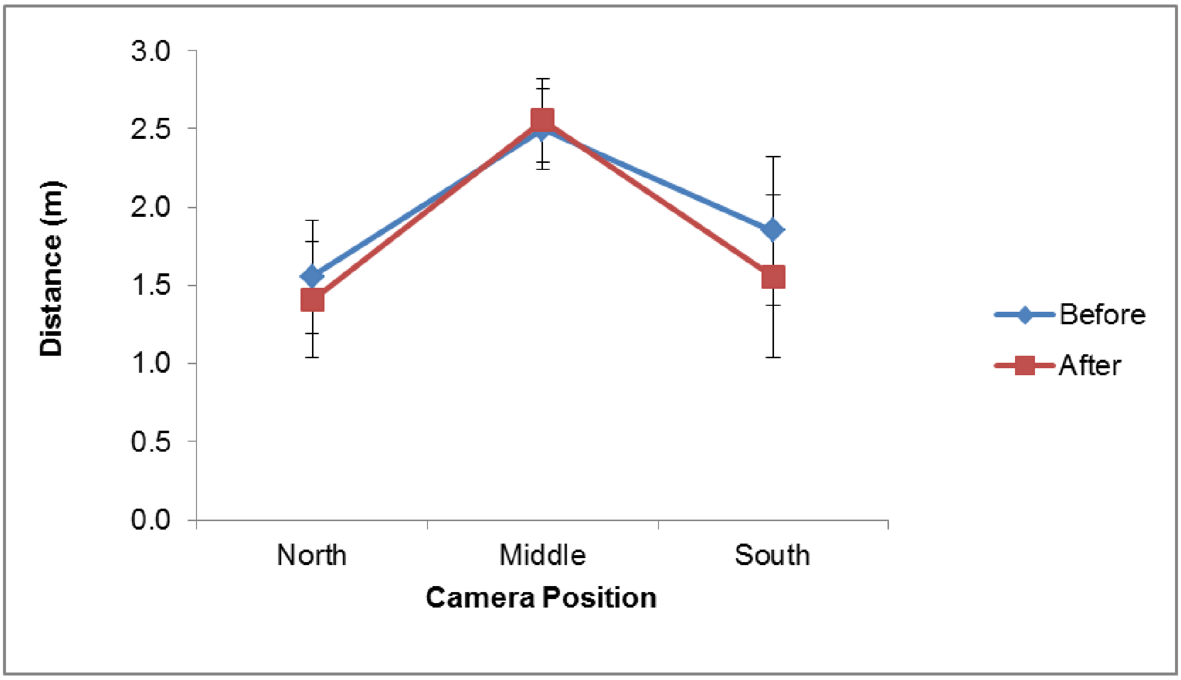

Figure A 16: Lateral placement at Site E (control site with chevron alignment marker delineation) – southbound

Table A 8: Lateral placement at Site E (control site with chevron alignment marker delineation)

Location	Before/After	Lateral placement (metres from the edge of the seal)	Standard deviation	t
Northbound				
South	Before	2.38	0.41	-3.437s
	After	2.53	0.32	
Middle	Before	1.29	0.45	-3.640vs
	After	1.46	0.36	
North	Before	1.81	0.37	-0.023
	After	1.81	0.46	
Southbound				
Location	**Before/After**	**Lateral placement (metres from the edge of the seal)**	**Standard deviation**	**t**
North	Before	1.56	0.36	2.552vs
	After	1.40	0.37	
Middle	Before	2.50	0.26	-1.248v
	After	2.55	0.27	
South	Before	1.85	0.47	3.492vs
	After	1.56	0.52	

Note: All t-tests are conducted to the 95% confidence level. [v]= equal variances assumed. [s]= significant difference in the means.