



**TRANSPORTATION ASSOCIATION
OF CANADA**

**COLOURED BICYCLE LANES
SIMULATOR TESTING**

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1.0 INTRODUCTION

Boulevard Transportation Group was retained by the Transportation Association of Canada (TAC) to undertake a study of coloured bike lanes testing in conflict areas. To facilitate this study, Boulevard retained the services of the University of Calgary Driving Simulator (UCDS), which is operated out of the Cognitive Ergonomics Research Laboratory (CERL) at the University of Calgary. This report provides a summary of the University of Calgary work with an interpretation of the results from a traffic engineering perspective. Based on the UCDS results and traffic engineering considerations, a recommendation regarding coloured bike lanes in conflict areas is made.

2.0 STUDY DESIGN PARAMETERS

The project steering committee (PSC) identified four bike marking treatment options for testing in conflict zones. For this study, the specific conflict zones considered were those where cyclists have the right of way but where this may not be understood by motorists or even cyclists. (E.g., where a right-turn lane is added and a bike lane is carried straight through between the right turn lane and the through-lane. Conflicts can arise between cyclists and right-turning motorists in this case since their paths cross.) The four bike markings tested in the study were the following: 1) solid blue marking between dashed white; 2) dashed blue stripes between dashed white; 3) dashed white markings only (current TAC-recommended design); and 4) a series of bicycle sharrows (bicycle stencil plus chevron arrows) in succession. See **Figure 1** for the tested marking types, and **Figure 2** for the sharrow design. The sharrow design is that recommended in the *TAC Design and Application of Bike Pavement Markings Research Report*. See Appendix 1 for bicycle pavement marking specifications.

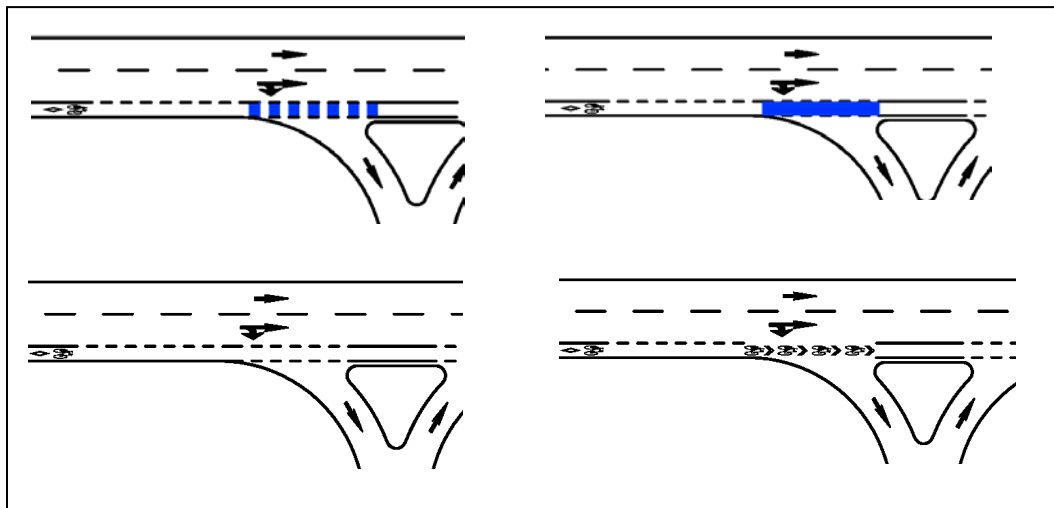


Figure 1: The Four Test Bike Markings: Blue Dashed, Blue Solid, White Dashed, and Sharrows

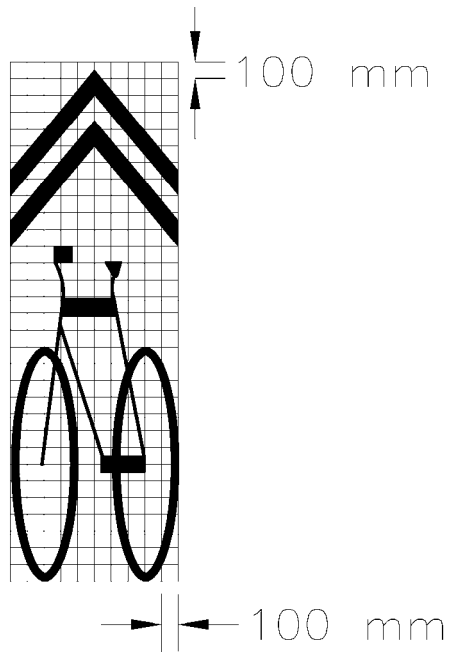


Figure 2: Sharrow Stencil Marking

Source: *TAC Design and Application of Bike Pavement Markings Research Report*

The purpose of this study was to investigate if the treatments have any effect on driver-cyclist conflicts in conflict zones, to assess if there are any driving behavioural differences in the presence of one type of coloured marking versus another, and to establish comprehension of the different marking types.

3.0 UCDS STUDY

This section provides a overview of the driving simulator and the UCDS study report. Details of the UCDS study methodology, results, and conclusions can be found in the attached report, “Driving Simulation Study of Bicycle Lane Markings: Draft Report”, CERL, 2008.

3.1 Driver Simulator

The driving simulator consists of the following attributes.

- an car frame and interior (a four-door Saturn sedan)
- projection video screens providing 180 degrees of vision
- side and rearview mirrors that simulate what a driver would see
- head-mounted eye-movement recorder
- video recorders, computer station and server bank to record data fields



University of Calgary Driver Simulator

3.2 Testing Procedure

The study itself consisted of testing 30 test participants, balanced across age (18-24, 25-54, 55-80) and gender categories. All participants were required to have valid drivers licences and meet vision acuity requirements. Participant characteristics were compiled (such as miles driven per year, cycling frequency, collision history, vision acuity etc), and participants were tested for simulator sickness with a preliminary five minute practice drive. The participants then drove through three experimental drives, and were then tested in regards to marking comprehension and marking preference after the drive was completed.

3.2.1 The Experimental Drives

The first of the three experimental drives was seven minutes and exposed the participants to each of the four bike marking treatments without any other traffic or events. Drives two and three were twelve minute drives and incorporated other vehicular traffic along with a conflict incident between the test driver and a cyclist at the conflict zone. Drives two and three were used for data collection and analysis. Specific measures recorded were driver speed, standard deviation of lane position (SDLP),

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and behaviour at the cyclist/motorist conflict event for the sharrows treatment and blue dashed treatment only (accelerate and pass in front, break and pass behind, or collision).

3.2.2 Comprehension Testing

Following the test drive, each test participant was asked comprehension questions regarding the bicycle lane treatment options. Firstly, four pictures were shown (one of each treatment) from the driver's viewpoint (i.e. picture is from the view a driver would have in the drive lane) and asked "what do these lane markings mean to a driver", followed by "what should a driver do when seeing such lane markings". Then, each participant was shown four pictures (one of each treatment) from the cyclist's viewpoint (i.e. picture is from the view a cyclist would have in the cycle lane), where they were asked "what do these lane markings mean to a cyclist" followed by "what should a cyclist do when seeing such lane markings". If the participant identified the marking as a bicycle lane marking, then they were also asked "who has the right-of-way".

The results were compiled by the U of C team, and were marked as correct (2), partially correct (1), or incorrect (0). An answer was considered correct if a respondent indicated that the coloured area was a bike lane or cyclist area and that drivers need to watch out for / yield to cyclists. Note that correct identification of who has the right-of-way was not essential for an answer to be designated as correct. (The right-of-way results were not analyzed by the UofC team.) The UofC team then assessed comprehension by grouping correct and partially correct together and assuming the total as "correct".

3.2.3 Marking Preference

Test subjects were asked two questions regarding their preference for coloured lane markings. The first question was as to their preference from all four markings. The second question was as to their preference of either the blue dashed or the sharrows markings.

3.3 Test Findings

3.3.1 Demographics

In addition to the balancing of test participants across three age categories (18-24, 25-54, 55-80) and by gender, the following demographic breakdown of test subject characteristics was obtained.

In terms of driving characteristics, driver frequency varied by age category with the youngest driving the most annually on average, followed by the middle age category and older age category. The

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younger age category was found to have slightly higher collision and violation rates than the middle and older age categories.

In terms of cycling characteristics, the majority of test participants were bicycle-owners (77 percent). In terms of frequency, most classified themselves as infrequent cyclists (71 percent), followed by commuter cyclists (18 percent) and recreational cyclists (11 percent). The middle age category had the highest average cycling distance per month, followed by the younger age and then the older age group.

3.3.2 Test Drive Performance

The test drive performance results were as follows. Neither driver speed nor driver SDLP were found to be significantly affected by the different bicycle lane treatments.

For the conflict events (for blue dashed and sharrow markings), no significant difference was found between the treatments, although there was a higher percentage of drivers that yielded to the cyclist in the presence of the dashed blue as compared to the sharrows, for both the right-turn diverge event and the left-merge event.

3.3.3 Comprehension Results

The comprehension results were considered correct if the response was deemed to be either correct or partially correct, and incorrect otherwise. The results of the first comprehension question from the driver's view perspective were that the sharrow treatment had the highest comprehension (97 percent), followed by white dashed (69 percent), blue dashed (67 percent), and solid blue (60 percent). For the second comprehension question, where participants were asked the marking meaning from a cyclist's view perspective, the order was found to be sharrows (96 percent), blue dashed (82 percent), blue solid (75 percent) and white dashed (71 percent). Therefore the sharrows were found to have the highest level of comprehension, based on the UofC's methodology of combining correct and partially correct answers into the correct category.

Results were also provided from the UofC broken down by the three categories of correct, partially correct, and incorrect for the first comprehension question (asked from the driver's perspective). These results were:

- Sharrows- correct 25, partially correct 5, incorrect 0
- Blue Solid- correct 11, partially correct 13, incorrect 6
- Blue Dashed- correct 11, partially correct 15, incorrect 4

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- White Dashed- correct 16, partially correct 7, incorrect 7

As such, even when the results are broken down by three categories instead of two, the results still indicate that sharrows have the highest comprehension, followed by white dashed, blue dashed, and blue solid. Note that the UofC did not statistically analyze results in this format.

3.3.4 Preference Results

For the preference of all four lane treatment options, a majority (16 of 30) preferred the sharrows, followed by white dashed (7 of 30), blue dashed (5 of 30) and blue solid (2 of 30). For the preference between blue dashed or sharrows, 21 out of 30 preferred the sharrows and 9 of 30 preferred the blue dashed marking.

3.4 UCDS Team Conclusions and Recommendations

The UCDS team made the following conclusions:

- driver speed and lane positioning was not affected by treatment or by driver age
- no difference was found regarding bicycle-vehicle conflicts between blue dashed and sharrow treatments.
- lower levels of marking comprehension were found for older drivers (though not significant), which is typical
- the sharrows had the highest level of comprehension and highest preference; in the UCDS team opinion, it is the best treatment option

From these conclusions, the USDC team recommends that further evaluation of the sharrows should be considered, with the removal of arrows and possibly colour being considered.

4.0 TRAFFIC ENGINEERING CONSIDERATIONS

4.1 Materials Considerations

There are materials considerations for these markings. This includes material type (paint, thermoplastic markings, coloured or stamped asphalt) and the associated factors such as constructability, maintenance, durability, visibility, and traction performance, and the resulting cost. These are important issues to consider in assessing the suitability of a coloured lanes installation. Some issues that were not tested which could potentially be tested in a simulator include traction and visibility in different light and weather conditions. Another issue is that of colour; for this test, only blue and white were tested, as blue was originally identified as the preferred colour for potential use in cyclist-

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motorist conflict zones based on research conducted for the development of the *TAC Design and Application of Bike Pavement Markings Research Report*. The cost of applying the various treatments varies according to materials (thermoplastic or paint), application (building and using stencils) and jurisdiction (weather, local road marking convention). Issues of the shade of blue, durability and conformity should be researched before the coloured measures are adopted.

4.2 Interpretation of UCDS Results

4.2.1 Driver Testing

The results indicate no major differences between the performance of the four bike lane treatment options, in terms of driver lane positioning or in terms of behaviour at the conflict zone with a cyclist event. From the measures that were assessed for this analysis, there is no compelling driver performance based rationale for selecting one treatment over another.

Eye movement data was also collected as part of this research. However, because of project budget limitations and the time and cost intensive nature of analyzing eye movements, this data was left unanalyzed. Analysis of this data may identify which treatments are more noticed by drivers (in terms of number of times the device was looked at and the duration of looks), which could provide greater insight into which treatments increase a drivers awareness of the conflict-zone bike lane, as well as which treatments divert drivers attention away from the rest of the driving task. It is possible, however, that the eye movement data will not provide any particularly beneficial insight at all (this concern was expressed by the UCDS team).

4.2.2 General Comprehension Results Considerations

The comprehension testing was undertaken with a still photo of the marking after the test. While this testing information is quite useful in garnering driver comprehension, it does not necessarily reflect what the real-world comprehension of (and behaviour to) a marking would be for a newly-exposed driver. To test this during the driving task is more difficult, however, as drivers are concentrating on the driving task.

The City of Calgary had, at the time of this testing, a relative lack of on-street bike lanes, and instead has historically focused on the development of an extensive off-street bicycle pathway network. (They are increasingly used, but only a couple of installations existed throughout the city as of the testing in 2007). As such there are some benefits and drawbacks to the interpretation of the results. As a positive factor, the results may be indicative of a typical jurisdiction that does not have bike lanes, and as such

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indicate comprehension of the treatments for a non-bike lane acclimated area, which could be a benefit in terms of education (for areas with and without many bike lanes alike). On the other hand, if this testing had been undertaken in an area where bike lanes are more prevalent the comprehension of the non-sharrow treatments may have been greater due simply to familiarity with painted bike lanes. Since the performance results were similar for all treatments, other treatment options may perhaps still be viable, in particular in considering that coloured lanes should be used in conjunction with bike lanes and are most likely to be considered for use in areas where on-street bike lanes already exist. As such, marking comprehension, and perhaps preference, may be altered through familiarity and driver and cyclist education.

4.2.3 Specific Comprehension Results Considerations

In terms of correct comprehension, all options were interpreted correctly by some test subjects. The sharrows were interpreted correctly most frequently, followed by the blue dashed, white dashed, and solid blue. The blue solid had the highest frequency of incorrect interpretation, followed by the dashed blue.

In terms of some of the specific comprehension answers received, the sharrows and the white dashed markings had the least adverse type of partially correct or incorrect interpretations. The sharrows marking was, however, much more likely to be associated as a cyclist lane whereas the white dashed was often not interpreted as anything special at all.

Dashed Blue

The dashed blue marking was sometimes misinterpreted as a blue crosswalk, which could potentially imperil pedestrians by placing them in an unsafe environment (as their presence would be unexpected to drivers and their speed performance). Although this might result in cautious behaviour from a driver, it was also interpreted by some as a dismount-and-cross location from the cyclist's perspective.

Sharrows

Of some concern is the comprehension of the sharrows, from the cyclist's perspective, being interpreted in several cases as a "directive" for cyclists, as in cyclists must ride along the sharrows. This is not strictly speaking correct, as cyclists wishing to turn right or left may make lane changes into the main vehicle lanes. The other three paint marking options did not elicit this type of "directive" interpretation. This is perhaps not surprising, as directional arrows are often used in drive lanes to indicate allowable movements at an intersection (and should be accompanied with turning movement

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regulatory signage). This type of miscomprehension may perhaps be minimized or eliminated should the bicycle stencils be employed without the arrows.

An issue that should also be considered for the sharrows is the stencil spacing, which was not addressed in this testing.

Solid Blue

The solid blue marking was sometimes misconstrued as a “safe zone”. This is not necessarily an issue of concern if interpreted as such by drivers, as if they do they will likely respect the conflict zones and any cyclists therein. This is, however, somewhat of a concern from the cyclist perspective, as it may give a cyclist a false sense of security.

The solid blue was also at times associated with a “can’t cross” directive, which is definitely of concern as that is not the intended message, and could in interpreted as such unduly impact a driver’s behaviour, at least in the right-turn diverging movement. (Such a message may be quite desirable, however, for different applications such as colour for reserved bus lanes.)

White Dashed

The white dashed marking was the least likely to elicit any unexpected behavioural assumptions. In one case a respondent felt it indicated a safe zone, otherwise it did not elicit the “crosswalk”, “do not drive across”, or “must ride bike straight through” answers that the other treatments did (dashed blue, solid blue, and sharrows respectively).

The still photo used for comprehension may introduce some issues of scale (regarding the bike lane width). In particular the white dashed may be interpreted as a car lane, as it is not completely obvious that it is narrower than the drive lane (i.e. a car in the drive lane may have given the picture questionnaire a better sense of scale). This may have influenced some of the incorrect responses for the white dashed lane, in particular in consideration of the potential unfamiliarity with on-street bike lanes in general in the City of Calgary.

5.0 CONCLUSION

The following conclusions are made regarding the bicycle lane marking simulator testing:

- No significant differences in conflict yield behaviour or incidence between the sharrows and blue dashed options.

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- Driver speed and standard deviation of lane position were not found to be affected by treatment type.
- Sharrows are the best at eliciting some level of correct comprehension.
- All of the treatment options were found to have some level of correct comprehension in at least half of test subjects
- The three “new” options (blue dashed, solid blue, and sharrows) were each associated with some additional directive or purpose that is not intended; the blue dashed as a crosswalk, the solid blue as a do not cross barrier or “safe” zone, and sharrows as a mandatory cyclist positioning. Of these misconceptions, those associated with the blue options are potentially more detrimental in terms of safety ramifications or driver/cyclist uncertainty (e.g. a pedestrian placing themselves in the conflict zone on what they think is a crosswalk is a greater safety issue than a cyclist misconstruing sharrows to mean travel directly forward over the sharrows only.
- The white dashed was not associated with undue adverse operations, but was also least likely to elicit special recognition as a bike lane from drivers.
- The sharrow misconception regarding directive to cyclists may potentially be minimized or eliminated by omitting the use of the directional arrows for the cyclists, and instead using the bike stencil only.
- Sharrows were the preferred treatment type by the test subjects.

In considering treatment suitability, in areas where cyclist/motorist conflicts are not a major concern, white dashed markings are adequate since the comprehension is adequate and not adverse in nature, and minimizes undue materials and maintenance costs. For areas where conflicts may be of greater concern, the sharrow treatment is the preferred option (of the four tested) for raising awareness of the bike lane through the conflict area as the treatment that has the greatest percentage of correct interpretation with a minimum of adverse interpretations whilst having no significant difference in driver performance measures.

Of the blue options, the dashed blue is preferable to the solid blue as it indicates to drivers that it is permissible to drive across in a clearer manner than solid blue. It also had higher comprehension and preference rates than solid blue. The blue marking options would, however, be more prudently employed with an extensive education campaign. That is not to say that the sharrow treatment shouldn't be launched with an education campaign as well, just that it is more critical for the blue dashed or solid since the meaning is less intuitive, and because of the adverse interpretations by some respondents that could pose undue safety and operational consequences.

Application:

The measure used should extend through the conflict zone whether at an intersection or elsewhere. Conflict zones are defined as areas where cyclists have the right of way but where this may not be understood by motorists or even cyclists. (E.g., where a right-turn lane is added and a bike lane is carried straight through between the right turn lane and the through-lane. Conflicts can arise between cyclists and right-turning motorists in this case since their paths cross.) Another example is on and off ramps. These markings must not, however, be used to demarcate conflict zones across high-speed roadway ramps (roadways >70km/h), as the high speed differential between cyclists and motorists introduce a significant conflict potential and motorists do not typically expect to yield to cyclists in these locations. (See the *TAC Design and Application of Bike Pavement Markings Research Report* for further discussion on this issue.)

There may be other conflict zones that would benefit from this measure that are not prescribed in this report. Consideration of what would be a conflict zone in these other circumstances should be done by a qualified professional using industry standard safety or conflict analysis techniques.

6.0 RECOMMENDATIONS

As a pre-existing TAC approved measure, it is recommended that the option for marking a bicycle lane through a conflict zone with white dashed bicycle lane markings be retained. In areas where the practitioner deems that a bicycle lane carried through a conflict zone warrants increased visibility and/or demarcation, the following is recommended:

- if there is no requirement for lane markings then a succession of sharrow markings may optionally be used
- if there is a requirement for lane markings then a succession of bicycle stencils may optionally be placed between the dashed bicycle lane markings.

Figures 3, 4, and 5 show examples of the white dashed bicycle marking option, the sharrow marking option, and the white dashed marking with bicycle stencils marking option carried through a conflict zone respectively. All pavement markings for these scenarios are to be designed as per the *TAC Design and Application of Bike Pavement Markings Research Report*.

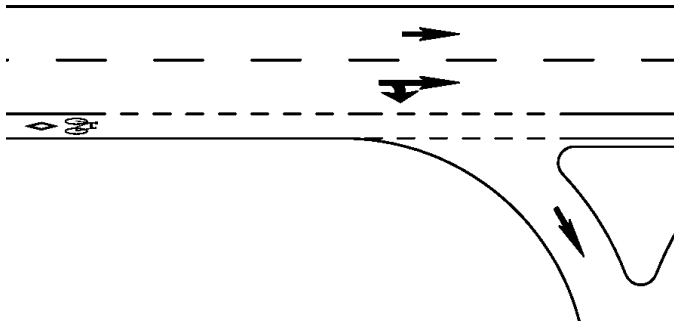


Figure 3: Example of White Dashed Bicycle Markings Carried Through a Conflict Zone

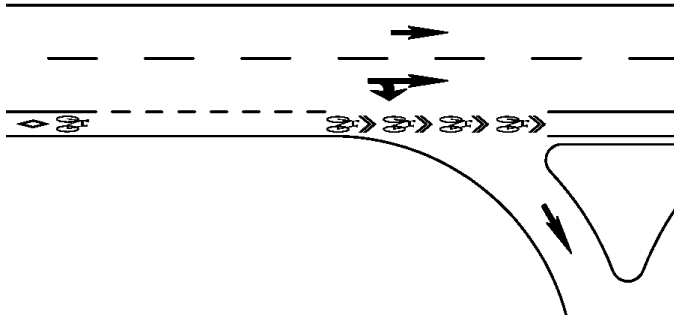


Figure 4: Example of Sharrow Markings Carried Through a Conflict Zone

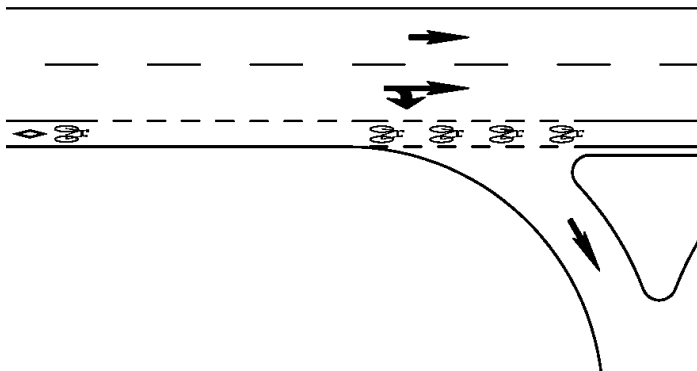


Figure 5: Example of White Dashed Bicycle Markings Plus Bicycle Stencils Carried Through a Conflict Zone

APPENDIX 1

TAC Bicycle Lane Markings

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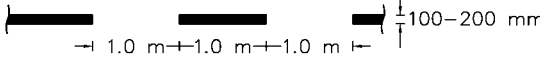

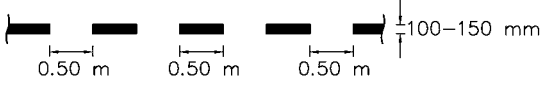
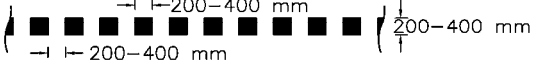

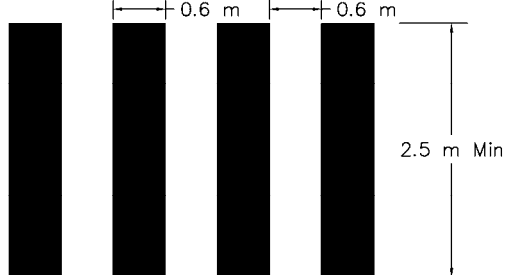
NAME OF LINE		DIMENSIONS
LONGITUDINAL	BICYCLE LANE (SOLID, WHITE)	
	BICYCLE LANE (DASHED, WHITE)	
	CONTRA-FLOW LANE (YELLOW)	
	GUIDING LINES (WHITE)	
TRANSVERSE	ELEPHANT'S FEET BICYCLE CROSSING (WHITE)	
	CROSSWALK (WHITE)	
	ZEBRA CROSSWALK (WHITE)	

Figure A-1: Bicycle Pavement Markings

Source: TAC Design and Application of Bike Pavement Markings Research Report