Before and After Evaluation of “Rush Hour” Sharrow Pavement Markings along College Street

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Cycling Infrastructure & Programs
Transportation Services
City of Toronto

TORONTO

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1. Introduction

In May 2010, the City of Toronto installed a new application of shared-lane pavement markings, referred to as "rush hour" sharrows. This treatment involves installing sharrows in the curb lane as per the City's draft guidelines in locations where parking is permitted at all times of the day except "rush hour." With the rush hour sharrow application, parked cars cover the sharrow markings for parts of the day, but during the periods when parking is prohibited, the sharrows are visible to motorists and cyclists. Sharrows are being used in this way to improve cycling conditions during the busiest times of the day. In general, "rush hour" sharrows are intended for use along downtown streetcar routes where there are moderate to high cycling volumes, but where there is not enough space to provide full-time sharrows or bike lanes without impacting streetcar service and parking.

Figure 1. Rush hour sharrows on College Street (at Shaw Street)

The Transportation Association of Canada's *Bikeway Traffic Control Guidelines for Canada* includes sharrows, but there are no specifications for part-time use.[1] Part-time bicycle facilities have been used elsewhere, including simple bicycle stencils on Pender Street in Vancouver[2], and 'floating' bicycle lanes (marked with unique lane striping, but no bicycle symbols) used in San Francisco.[3] In London, UK, "advisory" bicycle lanes are used to advise, but not require, motorists to stay out of the curb area. The lanes are marked with a dashed line, are often coloured, and include bicycle symbols. As with "rush hour" sharrows, motorists can park in these other types of part-time cycling facilities. The presence of part-time parking is recognized by Transport for London as the greatest drawback of the advisory lanes, and is the primary

[1] Transportation Association of Canada. (2012). Bikeway Traffic Control Guidelines for Canada, Second Edition. Canada.

[2] Advocacy for Respect for Cyclists. (2003). Comparison of College and Pender Streets. Toronto. Accessed online July 7, 2009 at http://respect.to/wiki/pmwiki.php?n=Library.ComparisonOfCollegeAndPenderStreets

[3] Salaberry, M. (2004). Floating Bike Lanes. San Francisco Department of Parking and Traffic. San Francisco. Accessed online July 7, 2009 at http://www.sfmta.com/cms/uploadedfiles/dpt/bike/report%20on%20floating%20bike%20lane%2012_11_06.pdf

reason they are not used elsewhere in northern Europe.[4] "Rush hour" sharrows are a "made-in-Toronto" solution that is expected to be more legible to cyclists and motorists in our city than the designs used elsewhere.

During consultation on the project's design and implementation, members of the cycling community and City staff expressed a desire to evaluate the effectiveness of this new sharrow application before considering its use on other streets in Toronto. As a result, a "before-and-after" evaluation was undertaken for the College Street installation, with videotape analysis and an online survey of cyclists. The City has conducted evaluations of typical sharrow applications in different contexts (e.g. two-lane versus four-lane roads), but this is Toronto's first "before-and-after" sharrow study. The evaluation provides an assessment of two "firsts" for Toronto: "rush hour" sharrows, and single-file (centre of the lane) sharrows.

The following report begins with an overview of the College Street context and design, followed by an outline of the methods used for video analysis and the survey of cyclists. The results are then presented and discussed, with a focus on gauging the effectiveness of the design and cyclists' attitudes towards the new sharrow applications. Lessons learned are then presented as recommendations for the future application of sharrows on City streets.

What is a "sharrow"?

Sharrows are a "shared lane pavement marking" that consists of two white chevrons and a bicycle symbol.

The purpose of sharrows is to encourage drivers and cyclists to take lane positions that promote safer lane sharing.

There are two types of sharrow applications: The side-by-side application is intended for use on lanes which are wide enough for side-by-side cyclist/driver operation, but not wide enough for bike lanes; The single file application is intended for use on lanes which are too narrow for cyclists and drivers to operate side-by-side (less than 4.0 m wide).

[4] Transport for London. (2005). Chapter 4: Links – cycle lanes, cycle tracks and other cycle facilities. London Cycling Design Standards. London, UK. pp. 66-69. Accessed in December 7, 2009 at http://www.tfl.gov.uk/businessandpartners/publications/2766.aspx

2. Context & Design

2.1. College Street

The "rush hour" sharrow treatment was piloted along a 2.3 km gap in the College Street bike lanes, from Lansdowne Avenue to Manning Avenue in the city's downtown west end (Figure 2). This section of College Street is a four lane arterial road with streetcar operation and parking (permitted during off-peak hours). There are mixed land uses fronting the street, with a predominance of independent commercial shops, bars and restaurants at street level, and an increase in residential frontage as you head west.

The "rush hour" treatment was selected for this section of College Street due to the high volume of cyclists using the route (east of the study area, approaching Spadina Avenue, on a typical weekday approximately 4,700 cyclists used College Street in a 12 hour period, with peak hour peak direction volumes of 300-400 cyclists during the rush hours, as per September 2010 count), coupled with the inability to install bicycle lanes. Between Manning Avenue and Brock Avenue, the curb lane is narrow at 3.4 m wide and cannot accommodate a bicycle lane without removing on-street parking *and* shifting motorists onto the existing streetcar tracks (which would slow the public transit service). At Brock Avenue the roadway widens and the curb lane can accommodate bicycle lanes, but doing so would require *either*, a) allowing parking 24-hours a day (which would move all motorized traffic onto the streetcar tracks), or b) removing the parking all together (to avoid impacting streetcar service). Neither option was considered feasible at the time of implementation.

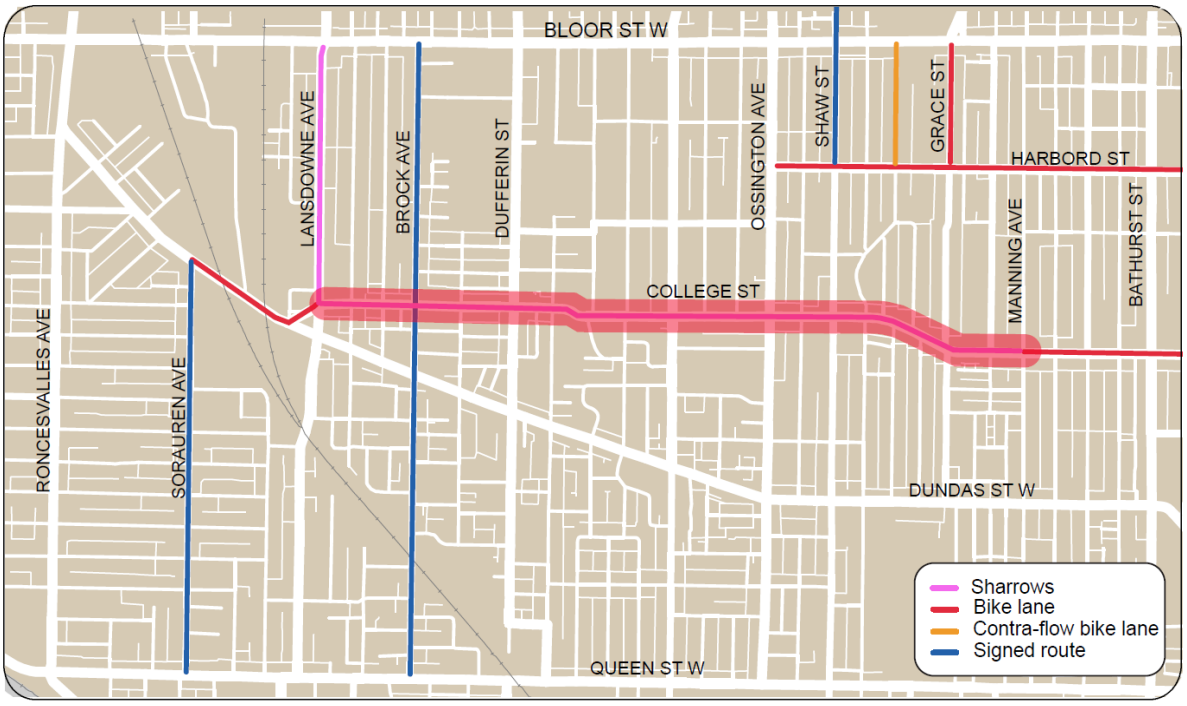


Figure 2. Project area and bikeway network context (2010)

2.2. Single-file operation sharrows – Manning to Brock

The curb lane on College Street, between Manning Avenue and Brock Avenue (2.0 km), is generally 3.4 m wide, too narrow for motorists and cyclists to comfortably travel side-by-side. The other main east-west arterials across downtown Toronto are similar to this section of College Street, as they also have narrow curb lanes and streetcar service.

Because of the narrow lane width, the "rush hour" sharrows were placed as close to the centre of the lane as possible to encourage cyclists to "take the lane" (ride in the centre of the traffic lane), but at a distance where they would be covered by parked vehicles during the periods when parking is permitted (Figure 3). To achieve this, the sharrow stencils were installed at approximately 1.6 m from the curb. At this placement, approximately 20 cm of the sharrow may be visible when a car is parked on top (depending on vehicle width); however, moving the stencil closer to the curb would detract from the intended "take the lane" message.

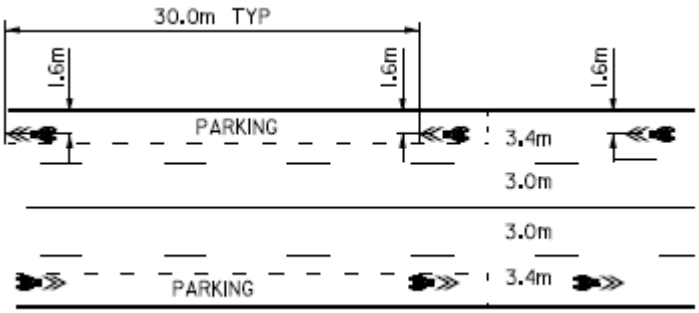


Figure 3. Single-file rush hour sharrows (Manning Avenue to Brock Avenue)

In both sections of College Street, the sharrows were installed at a lateral spacing of 25 to 30 m at mid-block, with reduced spacing near intersections, as per the draft Toronto guidelines.

Between Manning and Brock, the sharrows provide a cycling facility only during the hours when on-street parking is prohibited (Monday to Friday between 7:00 to 9:00 a.m. eastbound, and 4:00 to 6:00 p.m. westbound).

Figure 4. The Manning-Brock section of College Street, viewed from Location 1, before and after the installation of sharrows.

2.3.Side-by-side operation sharrows – Brock to Lansdowne

The curb lane in the short section of College Street between Brock Avenue and Lansdowne Avenue (300 m) is greater than 4 m wide, providing enough room for cyclists and motorists to travel side-by-side comfortably and safely. Before the sharrows were installed, the curb lane was not striped; instead, the concrete streetcar bed served to delineate the curb and centre lanes. Because of the poor definition of space on the roadway, drivers would occasionally attempt to "double up" in the curb lane, either driving two cars to the lane in rush hour, or driving adjacent to parked cars during non-rush hours. This situation could cause cyclists to be squeezed adjacent to the curb or parked cars, making riding conditions uncomfortable.

The original proposal for this section included "dual sharrows" (Figure 5). With this design, one row of sharrows was to be installed 1 m from the curb, with a second row 3.5 m from the curb. As with the single-file rush hour sharrows, the row of sharrows adjacent to the curb was to provide a cycling facility during peak hours, and be covered by parked cars during off-peak hours. The second row of sharrows 3.5 m from the curb was to be visible at all times to indicate a safe cycling path outside of the door zone of parked vehicles during off-peak hours. The two rows of sharrows were to be off-set, to support the cyclists' intuitive preference to ride as close to the right hand curb as practicable at different times of the day.

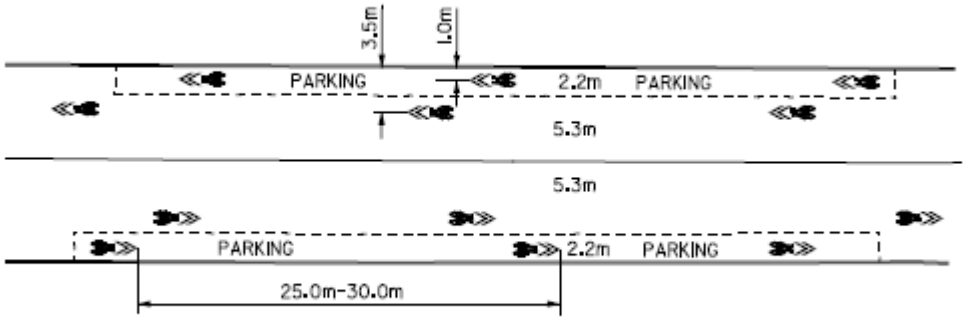


Figure 5. Original design for side-by-side operation sharrows (Brock Avenue to Lansdowne Avenue)

Following consultation with City Traffic Operations staff, the design was simplified to reduce installation and maintenance costs. The final design included one row of sharrows placed 1 m from the curb, visible during peak hours only (Monday to Friday, 7:00 to 10:00 a.m. eastbound, and 3:30 to 6:30 p.m. westbound). In addition, the curb lane was striped at 4.1 m to delineate an off-peak cycling area approximately as wide as a bike lane (1.9 m) between parked cars and the centre travel lane (Figure 6). Since the striping was placed outside the streetcar bed, it effectively narrowed the curb lane.

Although there was room to provide a wider curb lane to create more space for cyclists in the off-peak condition, doing so would have created a space large enough for drivers to continue "doubling-up." By limiting the width of the curb lane to 4.1 m, drivers are discouraged from travelling in the space between parked cars and the centre travel lane during off-peak periods, leaving it free for cyclists.

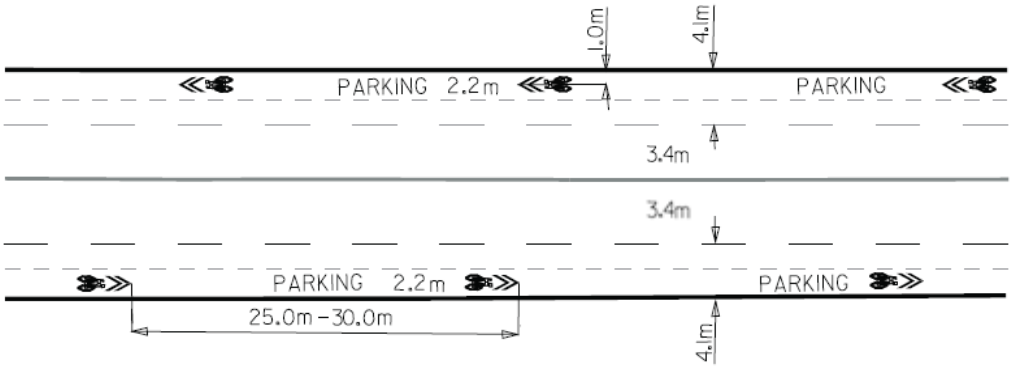


Figure 6. Final design for side-by-side operation sharrows (Brock Avenue to Lansdowne Avenue)

Figure 7. The Brock-Lansdowne section of College Street, viewed from Location 2, before and after the installation of sharrows.

2.4.Parking – Design and Enforcement

During consultation, members of the cycling community raised concerns that if cars are allowed to park on top of bicycle markings on rush hour sharrow routes that motorists will feel emboldened to park in bicycle lanes where the same bicycle stencil is used. To address this concern there were proposals to use coloured stencils, mark the parking spots, and add other instructional text to the pavement markings, or cancel the project.

Staff concluded that rush hour sharrows are a potentially valuable addition to the Bikeway Network and decided to proceed with a pilot project to test their use on streets with high cycling volumes where bike lanes are not currently feasible. After considering the proposed design alterations, staff determined it is desirable to start with the simplest design and change it if necessary after evaluating its' effectiveness.

Since parking and stopping is regulated by signs on the street (Figure 8) – not by pavement markings – staff determined it was more appropriate to address illegal parking in bicycle lanes by working with Toronto Police. The Toronto Police Parking Enforcement Unit agreed to

coordinate an enforcement campaign for the no-stopping prohibitions in bike lanes and on the section of College Street where sharrows were installed. An educational leaflet was developed for the enforcement campaign, which outlined the hazards of obstructing a bike lane and listed the associated fines (Appendix B).

Figure 8. Regulatory Signs for Parking and Stopping

The enforcement campaign was meant to coincide with the installation of sharrows on College Street, but due to the lack of officers available before, during, and after the G20 Summit in June 2010, the campaign was delayed until the last week of July. In total, parking enforcement officers issued 81 tickets for no-stopping along the College Street bike lanes and sharrows, and 31 educational leaflets (distributed only along the bike lane). Parking Enforcement staff have now expressed a desire to formalize the bike lane enforcement campaign and conduct it multiple times a year.

2.5. Education

Educational materials were distributed to coincide with the rush hour sharrow installation. These materials included a news release, web update, stories in City of Toronto publications, and standard text and images sent for posting on external websites, blogs and e-newsletters. The City also launched a sharrow advertising campaign online in September 2010 (Appendix C).

3. Methods

Videotape analysis and an online survey of cyclists were used to conduct a "before-and-after" evaluation of the rush hour sharrows on College Street. The purpose of this evaluation was to:

- examine whether or not rush hour sharrows improve cyclists' positioning in the lane and the road sharing behaviour of motorists, and
- identify potential improvements to the design, if necessary.

The survey component was also used to assess how successful the City's communications efforts have been in educating cyclists about the purpose of sharrows.

Both the survey and the videotape components of the evaluation were divided into two groups to capture conditions along the different sections on the College Street. The first group is for the section of College Street between Manning Avenue and Brock Avenue where single-file operation sharrows were used in the 3.4 m curb lane. The second group is for the section of College Street between Brock Avenue and Lansdowne Avenue where the side-by-side operation sharrows were used in the 4.1 m curb lane.

For all components of the evaluation the focus was on cycling conditions during "rush hour," when parking is prohibited and the sharrows are visible. For the Manning-Brock section, parking is prohibited Monday to Friday between 7:00 to 9:00 a.m. eastbound, and 4:00 to 6:00 p.m. westbound. For the Brock-Lansdowne section, parking is prohibited Monday to Friday, 7:00 to 10:00 a.m. eastbound, and 3:30 to 6:30 p.m. westbound. Videotaping was conducted from 7:00 a.m. to 9:00 a.m. at both east-bound locations, and from 4:00 p.m. to 6:00 p.m. at both west-bound locations. These intervals captured the peak periods for both bicycle and motor vehicle traffic.

The survey included a section for participants to provide feedback on their experience cycling on College Street during off-peak hours (when parking is permitted). This part of the survey aimed at assessing whether cyclists noticed the sharrows, if they were confused by motorists parking on the sharrows, and to collect feedback on the placement of sharrows around intersections. However, too few survey participants completed this portion of the survey to generate meaningful results. As a result, the off-peak portion of the survey is not discussed in the remainder of this report.

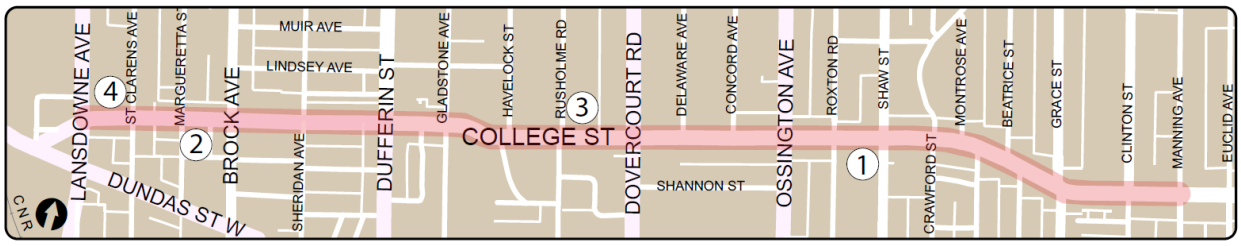
3.1. Video

Digital video recordings were used to document the position of cyclists and motorists in the road in relation to each other and the curb. Measurements were marked on the pavement at 10 cm intervals, and traffic in the direction of peak travel was video-recorded using a digital camcorder on a tripod, staffed by 9one field person (Figure 9).

Figure 9. Still shot from video

3.1.1. Locations

Four locations were selected to capture east- and west-bound traffic in the two sections of College Street where rush hour sharrows were installed (single file from Manning to Brock and side-by-side from Brock to Lansdowne). The video cameras were located along a straight-away near the end of the sharrow route. The intention was to use the same locations (give or take a few metres) for the before and after video data collection (Figure 10). Unfortunately, Location 1 had to be moved about 50 m east for the after video because of construction.



Location 1, capturing eastbound traffic in the AM, at 795 College St (moved to 783 College Street for "after")
Location 2, capturing eastbound traffic in the AM, at 1225 College St
Location 3, capturing westbound traffic in the PM ,at 972 College St (moved just west for "after")
Location 4, capturing westbound traffic in the PM, at 1270 College St (moved to 1272 for "after")

Figure 10. Video Locations

3.1.2. Sample

The "before" video was collected during the week of April 19th, 2010. Sharrows were installed during the week of May 17th, 2010, and the "after" video was collected from June 15th to 22nd, 2010 following a one-month adjustment period. In total, 32 hours of video were collected at the four locations (four hours per location, both before and after), capturing 2,122 cyclists before and 2,464 cyclists after the installation of sharrows.

3.1.3. Observations

Observations were made from the videotapes to measure the sharrows' effectiveness in promoting correct cyclist positioning in the lane, as well as lane utilisation and road-sharing behaviour by motorists.
Recorded observations included:

Cyclist location & direction:

- in street, with traffic
- in street, facing traffic (wrong way)
- sidewalk, with traffic
- sidewalk, facing traffic (wrong way)

Measurements (Figure 11):

- cyclist to moving motor vehicle (A)
- cyclist to curb (B)

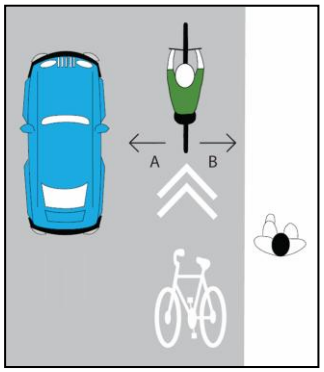


Figure 11. Video Measurements

Vehicular context (only for cyclists riding in street):

- Car beside (no vehicle in adjacent lane)
- Car beside (vehicle in adjacent lane)
- Car behind (no vehicle in adjacent lane)
- Car behind (vehicle in adjacent lane)
- Car behind and beside (no vehicle in adjacent lane)
- Car behind and beside (vehicle in adjacent lane)
- No car in lane (no vehicle in adjacent lane)
- No car in lane (vehicle in adjacent lane)

Motor vehicle traffic volume in the direction of observation was also recorded for each traffic lane.

Visible conflicts and other extenuating circumstances that might have affected the data were noted as well.

3.2. Survey

An online survey was developed to collect feedback from cyclists on their experience riding on College Street (from Lansdowne Avenue to Manning Avenue) during rush hour, before and after the sharrows were installed. The survey was live from April 19th to May 3rd, 2010 for the "before" component, and June 14th to July 9th for the "after" component. The after survey was originally scheduled to end on June 28th, but was extended to increase the number of completed surveys. The survey was approved by the City of Toronto's Corporate Access & Privacy Office and maintained online by Web Management Services.

3.2.1. Sample

Only cyclists who rode along College Street (for two or more blocks between Lansdowne to Manning) during rush hour as part of their daily commute were invited to participate. All participants had to be 18 years of age or older, and had to be expecting to continue riding this section of College Street during the survey time period.

City Cycling staff and the Toronto Coalition for Active Transportation solicited cyclists to participate in the survey through a variety of means, including on-street flyer distribution, e-newsletters and websites of local cycling groups and the City's Cycling Infrastructure & Programs unit, local cycling blogs, and Facebook. Interested individuals were asked to send an email to the City of Toronto's cycling staff, and were sent an electronic kit with instructions for how to participate in the survey. Each individual was assigned to one of the two groups, depending on which section of College Street was included in their daily commute (Lansdowne-Brock/single file sharrows or Brock-Manning/side-by-side sharrows).

Two hundred and twelve individuals signed up to participate in the survey, but only 55 before-and-after survey pairs were usable – 38 for the single file (Manning-Brock) group and 17 for the

side-by-side (Brock-Lansdowne) group. The reasons for this low rate are discussed below, in section 3.3

3.2.2. Content

To evaluate the rush hour sharrow design, the online survey of cyclists included questions regarding:

- demographics
- level of experience
- cycling facility preference
- details of their reported bicycle ride (date, time, location, direction and weather)
- level of comfort while cycling
- perceived lane positioning
- perceived sense of motorists "sharing the road"
- recall of illegally stopped/parked vehicles
- exposure to sharrows in the media
- recognition of the sharrow pavement markings
- interpretation of the sharrows
- feedback on the placement of the sharrows (from the curb, longitudinal spacing, spacing at and through intersections)

The intention was to conduct a factor comparison, for example, by looking at the relationship between demographic factors and cyclists' reported level of comfort riding on College Street before and after the sharrows were installed. Because of the small sample size, factor comparison was not possible, but descriptive statistics are provided later in the report.

3.3. Limitations

As mentioned, 212 individuals signed up to participate in the survey. However, only 88 completed both the before and after surveys. Of these, 18 survey pairs had to be discarded because the sharrows in the Lansdowne-Brock section of College Street, which had been incorrectly installed, could not be corrected until four days into the "after" survey. Survey responses for several participants were also discarded because the bicycle trips they reported on did not occur during rush hour, or they reported on one rush hour and one non-rush hour bicycle trip, making a before and after comparison impossible.

The sample for the survey is not only quite small (55 usable survey pairs), it is also not representative of the local cyclist population. There is a predominance of experienced cyclists, and females are over-represented. For these reasons, the survey results cannot be used to make generalizations about Toronto's cyclist population. Nevertheless, the responses do provide valuable feedback on the effectiveness of the two types of sharrow installations, from the cyclist's perspective.

For the video component of the evaluation, three unexpected situations arose, and likely affected the study results:

In the single file (Manning to Brock) section, construction activity at the site where the east-bound "before" observations location had been recorded meant that the camera had to be placed roughly 50 metres further east for the "after" observations. The new location was close to a signalised intersection with a transit stop on the near approach, and traffic queues often extended

beyond the observation point. Many cyclists were observed passing the stopped motorists ("queue-jumping") in the narrow space between the motor vehicles and the curb, so the cyclist-to-curb distance tended to be low. The bike-to-car measurements, which were intended to provide an indication of the effect of sharrows on the amount of clearance motorists provided while overtaking cyclists, were also affected. (Cyclists were observed passing stopped vehicles much more closely than the distance provided by most motorists when passing moving cyclists.)

Also, in the side-by-side (Brock to Lansdowne) section, where no lane striping existed before the study, sharrows and new lane striping were added at the same time. It is impossible to isolate the independent effects of these two changes on the behaviour of cyclists and motorists.

Finally, the timing of the video taping was somewhat unfortunate, as the "after" video collection occurred during the World Cup Soccer tournament and during preparations for the G20 Summit. Although only a handful of observations were affected by World Cup celebrations that spilled into the street, a significantly lower than average number of cyclists were captured during the final (June 22nd) videotaping session at location 2, as people avoided the downtown area during G20 Summit preparations.

4. Results

4.1. Video

4.1.1. Cyclist Direction and Location

One of the goals of installing sharrows is to encourage cyclists to ride on the street (versus on the sidewalk) and with traffic (as opposed to facing traffic). On College Street, the vast majority of cyclists rode in the street and with traffic both before and after the sharrows were installed. Overall, the share of cyclists riding in the street and in traffic did increase from 96% to 98% after the installation, with an associated 2% decrease in cyclists riding on the sidewalk (Figure 12). The increase was most notable for cyclists riding westbound in the section of College Street where single file sharrows were installed (Manning to Brock).

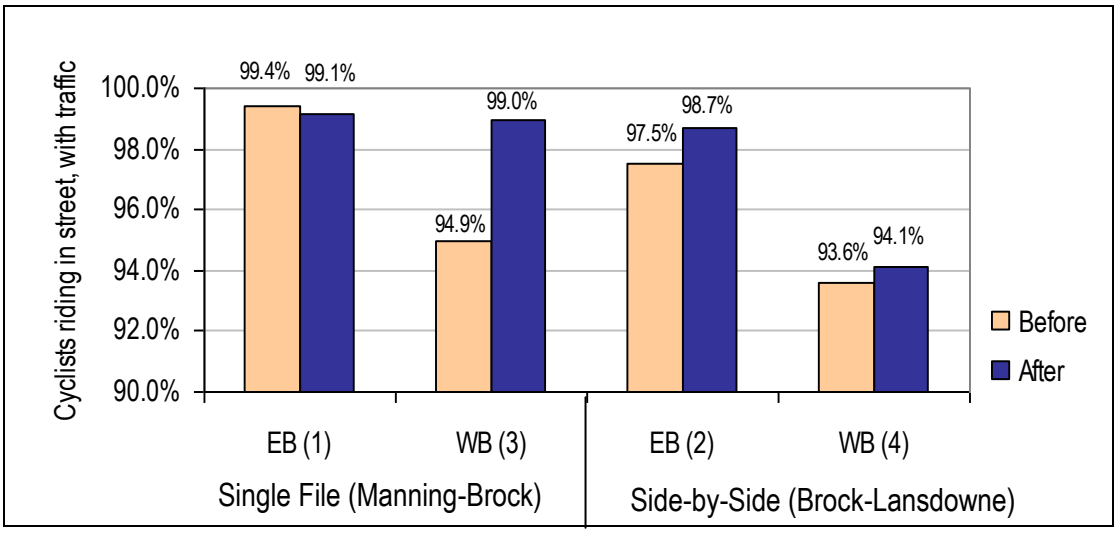


Figure 12. Percentage of cyclists riding in street with traffic

4.1.2. Cyclist Lane Positioning

To avoid debris and other hazards, CAN-BIKE guides recommend cyclists ride approximately one metre from the curb where there is room to ride side-by-side with motorized vehicles.[5] In narrow lanes (such as the Manning-Brock section of College Street), cyclists are encouraged to "take the lane" by riding farther from the curb, to discourage motorists from attempting to pass without changing lanes. Many cyclists find this uncomfortable, and ride less that 1 metre from the curb in traffic. One of the goals of this study was to measure the effectiveness of sharrows in promoting safer lane positioning by cyclists.

In both sections of College Street (with narrow and with wide curb lanes), west-bound cyclists rode an average of 30 cm further from the curb after the sharrows were installed (Figure 13).

[5] CAN-BIKE is a program of the Canadian Cycling Association that provides a nationally standardized set of courses on all aspects of utilitarian and recreational cycling. The idea of using lane positioning as a way to communicate with drivers is one of the central concepts of the "effective cycling" approach taught by CAN-BIKE. For more information, visit http://www.canbike.net/.

For east-bound cyclists, in the side-by-side section the average distance from the curb increased by less than 4 cm, a change that is not statistically significant. In the single file section, the average distance from the curb *decreased*, but, as described in section 3.3, it appears that other factors affected cyclists' lane positioning during the "after" observations at this location.

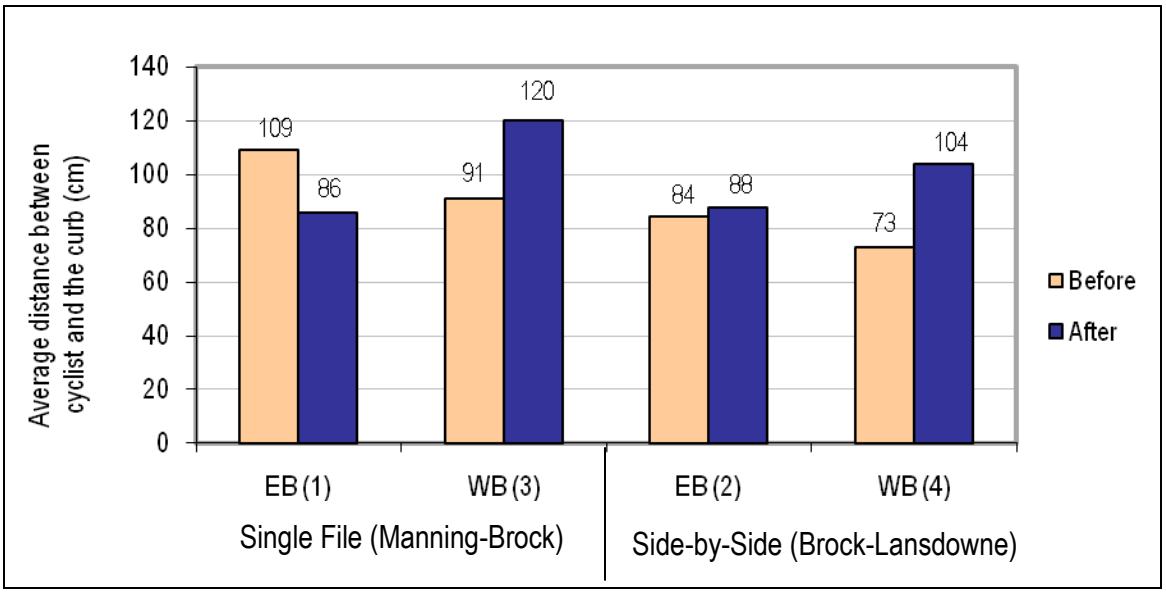


Figure 13. Average distance between cyclist and curb

Another measure that shows an improvement in cyclist lane positioning is the percentage of cyclists riding "an effective distance from the curb" (at least 100 cm), which increased from 32% to 42% overall. Similarly, the percentage of cyclists riding "too close to the curb" (less than 75 cm) decreased, from 44% to 37% overall (Table 1). When the observations from location 1 are omitted (for reasons explained above, in section 3.3), these changes become even more pronounced: cyclists riding "too close" fell from 52% to 31%, and cyclists riding at "an effective distance" rose from 23% to 46%. At location 3, where single file sharrows were installed to encourage cyclists to "take the lane" by riding near the centre of the lane, the percentage of cyclists riding at least 150 cm from the curb increased from 7% to 24%. (This number fell at location 1, but, as discussed, other factors appear to have contributed to inconsistent results at that location.)

Table 1. Percentage of cyclists riding <75 cm, >100 cm and >150 cm from the curb

	% of cyclists riding <75 cm from the curb			% of cyclists riding >100 cm from the curb			% of cyclists riding >150 cm from the curb		
	Before	After	Change	Before	After	Change	Before	After	Change
Single File (Manning-Brock)									
EB (1)	22	49	+27	54	29	-25	16	9	-7
WB (3)	38	22	-16	32	56	+24	7	24	+18
Side-by-Side (Brock-Lansdowne)									
EB (2)	54	44	-10	21	32	+11	-	-	-
WB (4)	66	37	-29	13	40	+27	-	-	-

4.1.3. Vehicular Context

Vehicular context refers to the location of a motor vehicle in relation to the cyclist – for example, behind, beside in the same lane, or beside in the adjacent lane. Vehicular context can be expected to have an effect on cyclists' lane positioning. For example, when riding in narrow lanes with faster-moving motor-vehicles, some cyclists may choose to ride closer to the curb than they would when riding "alone," so as not to get in the way of overtaking motorists. Other cyclists might choose to ride farther from the curb, in the hope of sending a clear message that drivers need to change lanes in order to overtake. To the extent that a cyclist's position can influence the behaviour of drivers attempting to overtake, lane positioning can therefore affect vehicular context.

The frequency of different vehicular contexts was examined, as well as the average distance between cyclists and the curb in different contexts, and the average distance between cyclists and passing motor vehicles. The overall distribution of motor vehicles per lane was also examined, to determine if sharrows have any independent effect on motorists' choice of lane (that is, independent of the effect caused by the presence of cyclists).

4.1.3.1. *Frequency of motorists and cyclists travelling in the same lane*

The majority of cyclists at all four locations were observed riding "alone" in the curb lane (*i.e.*, not having to share the lane with a motor vehicle) both before and after sharrows were installed, but a marked increase was observed following the installation (Figure 14). The percentage of cyclists passed by cars in the same lane decreased at all four locations, but the change was most pronounced at Location 4, the west-bound section with wide curb lane. Notably, the percentage of cyclists travelling alone in the lane increased after the sharrows were installed even where motor vehicle traffic volume increased (Location 1).

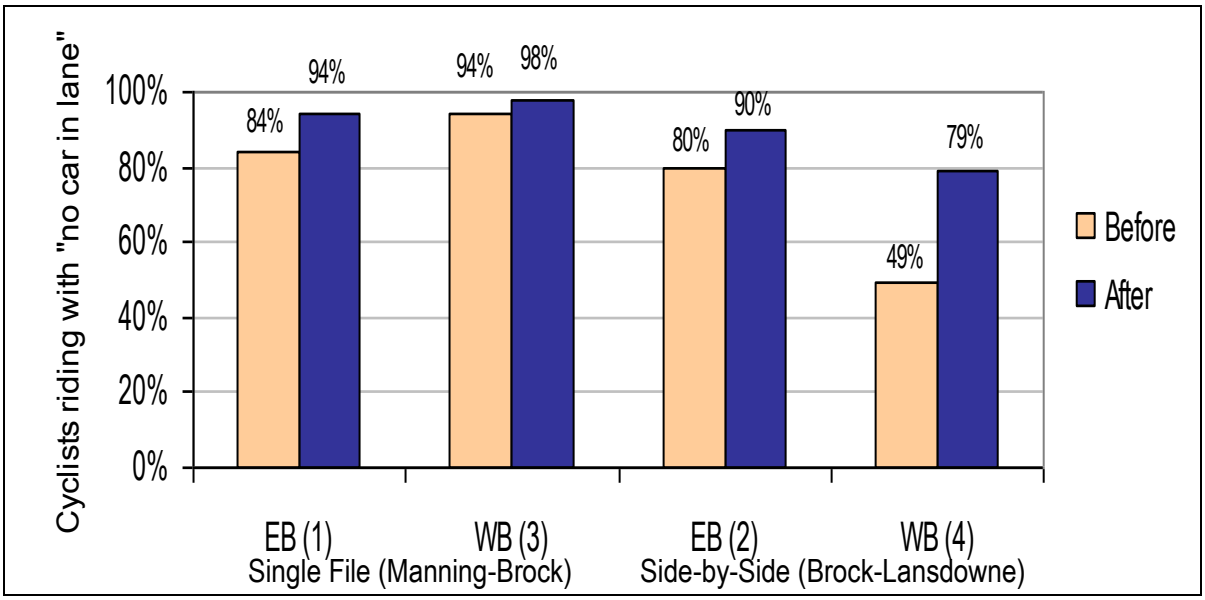


Figure 14. Percentage of cyclists riding with no car behind or beside (in the same lane)

4.1.3.2. *Distance between cyclists and the curb while being passed by motorists*

At all four locations, cyclists being passed by a motorist rode closer to the curb, on average, than is recommended by CAN-BIKE, both before and after the installation of sharrows. In the side-by-side sharrow section (Brock-Lansdowne), westbound cyclists being passed by a motorist rode an average of 10 cm further from the curb after the sharrows were installed, while the lane positioning of eastbound cyclists barely changed (Figure 15). In the single-file sharrow section (Manning-Brock), too few cyclists were observed being passed by a motor vehicle in the curb lane to provide statistically reliable findings.

4.1.3.3. *Distance between cyclists and passing motorists*

In most cases where motorists were observed passing cyclists within the curb lane, there were either too few observations to yield statistically significant findings on any change in passing distance, or the change was to small to be regarded as statistically significant. The exception is at location 2, where the average passing distance decreased by 28 cm after sharrows were installed. This may have been a result of the simultaneous installation of lane delineation markings, as mentioned in section 3.3, which effectively narrowed the curb lane. Despite the lack of any conclusive findings on the effect of sharrows, motorists at all four locations did provide a comfortable amount of space (averaging between 138 cm and 180 cm) when passing cyclists, both before and after the implementation of sharrows (Figure 15).

4.1.3.4. *Distance between cyclists and the curb when travelling alone in the lane*

As noted above (section 4.1.3.1), the percentage of cyclists travelling alone in the lane increased by about 10% after the sharrows were installed, to between 79% and 98%, depending on the location. For westbound cyclists, the average distance from the curb increased by almost 30 cm after sharrows were installed, in both the single file and side-by-side sections. The average position of eastbound cyclists in the side-by-side sharrow section barely changed (Figure 16). In the single file section, eastbound cyclists were 24 cm *closer* to the curb, on average, in the "after" observations. As mentioned in section 3.3, other factors at location 1 probably affected the cyclists' lane positioning more significantly than the presence of sharrows.

Note that, for all of the cyclist-to-curb measurements, cyclists riding side-by-side or overtaking other cyclists were excluded from the calculations.

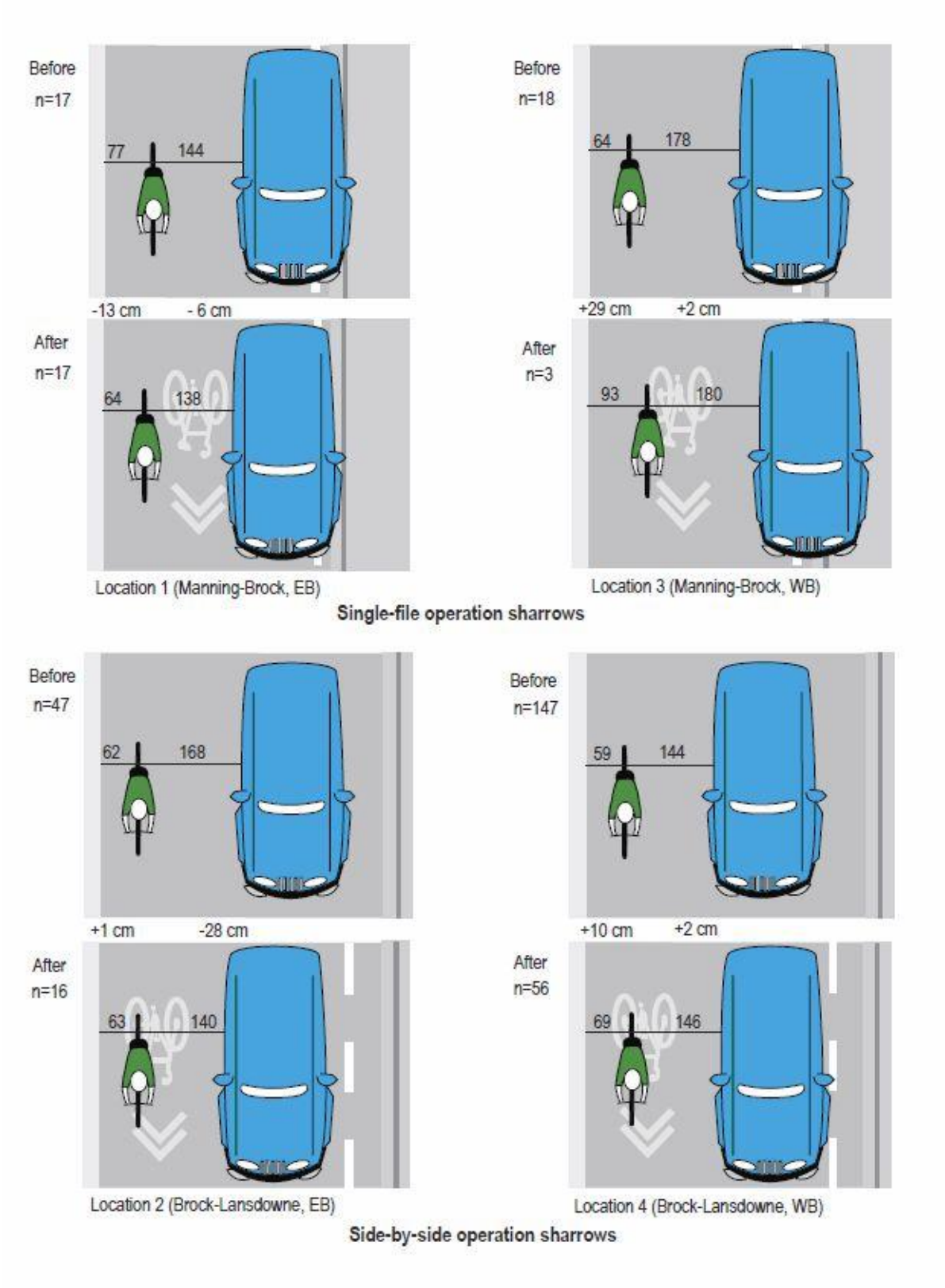


Figure 15. Cyclists' average distance from the curb and passing motorists

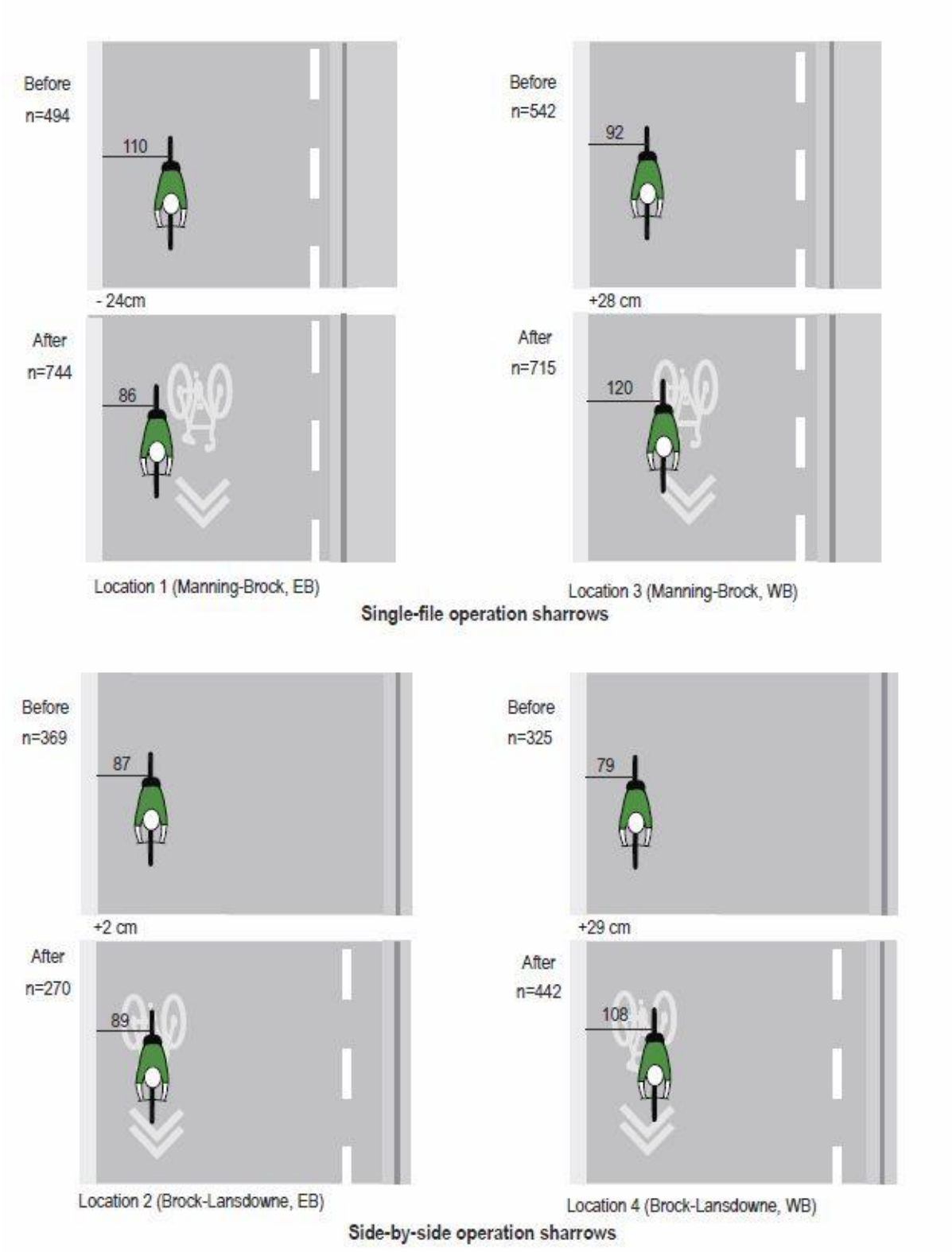


Figure 16. Cyclists' average distance from the curb when travelling alone in the lane

4.1.3.5. *Motorists' Lane Utilisation*

Although it was not part of the original study design, the decision was made to examine the distribution of motor vehicles by lane (*i.e.*, curb lane vs median lane) for *all* motorists – that is, not only those who were overtaking cyclists – before and after the installation of sharrows. Streetcars (which cannot changing lanes), and also motorcycles and scooters (which are not considered likely to influence cyclists' lane positioning to the extent that cars and trucks do) were not included in the analysis.

A significant decrease in motorists' use of the curb lane was observed after installation of sharrows, with a proportional increase in use of the median lane (Table 2). This suggests that the presence of sharrows can have an effect on motorists' lane choices that is independent from the effect that cyclists presence may have.

In the Brock-Manning section, where the curb lanes are not wide enough for cars and bikes to comfortably share the lane, over 30% of motorists were observed driving in the curb lane before sharrows were installed. This fell to approximately 20% after the installation of sharrow markings. In the Brock-Lansdowne section, where sharing the curb lane with cyclists is more comfortable, the proportion of drivers using the curb lane fell from about 55% to just over 40%. These changes are clearly related to the observed increase in the frequency of cyclists riding "alone" in the lane, as reported in section 4.1.3.1. The effect was most pronounced at Location 3, which also saw the most significant decrease in sidewalk cycling.

Table 2. Lane Utilisation by Motor Vehicles*

	Before Sharrows		After Sharrows	
Single File Sharrow Treatment	Curb	Median	Curb	Median
1) Manning-Brock East-Bound	34.0%	66.0%	24.5%	75.5%
3) Manning-Brock West-Bound	26.4%	73.6%	11.8%	88.2%
Single-file averages	31.1%	68.9%	19.9%	80.1%
Side-by-Side Sharrow Treatment				
2) Brock-Lansdowne East-Bound	53.6%	46.4%	39.7%	60.3%
4) Brock-Lansdowne West-Bound	57.1%	42.9%	41.2%	58.8%
Side-by-side averages	54.9%	45.1%	40.7%	59.3%
East-bound averages:	44.1%	55.9%	30.4%	69.6%
West-bound averages:	43.6%	56.4%	33.6%	66.4%
Overall averages:	43.8%	56.2%	32.2%	67.8%

* Does not include Streetcars, Motorcycles, and Scooters

The number of motor vehicles using the curb lane declined after the installation of sharrows, even where the total volume of motor-vehicles increased (location 1). At almost every location,

the volume of bicycle traffic increased after sharrows were installed.[6] Notably, in the single file sharrow sections, bicycles out-numbered motor vehicles in the curb lane after the sharrows were installed (Figure 17).

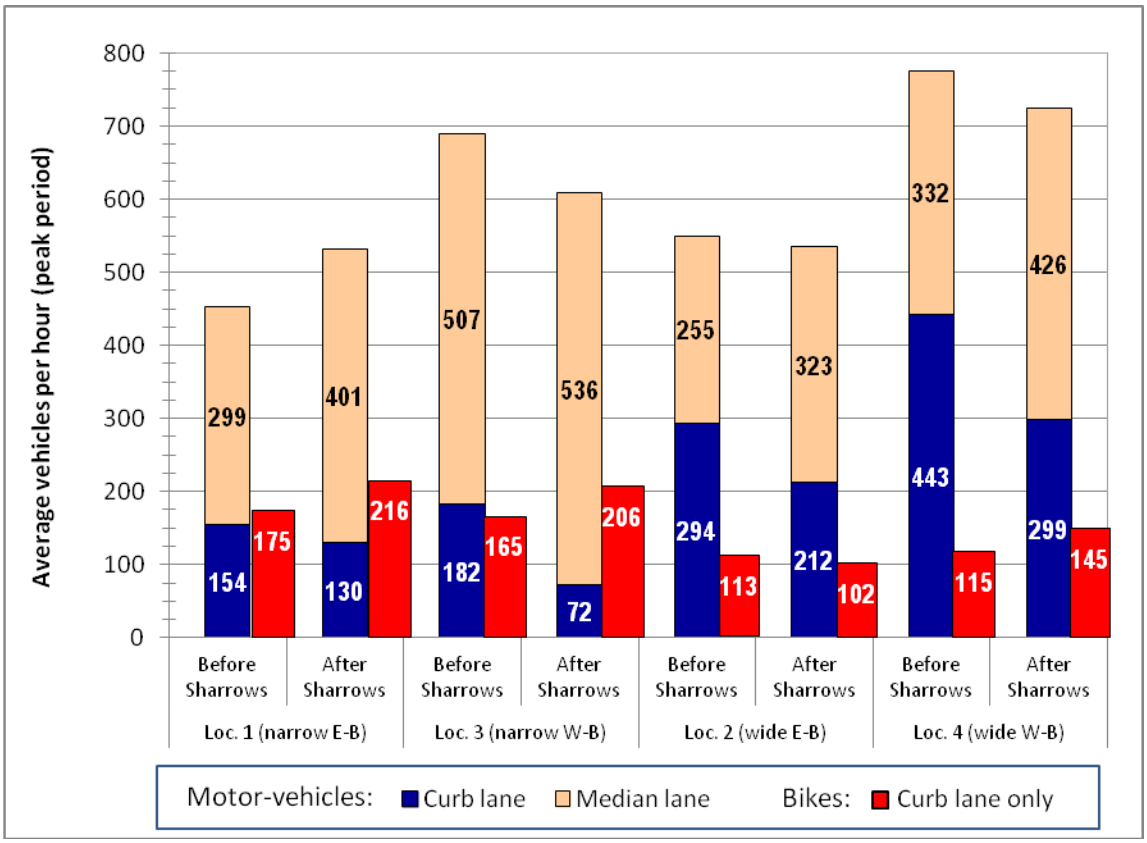


Figure 17. Average 1-hour vehicle counts by lane

Towards the end of the video review process, the analysts noticed that motorists in the wide curb lanes generally seemed to be avoiding driving on the sharrow markings. In the lanes that were treated with side-by-side sharrows, most motorists seemed to be driving to the left of the centre of the lane, even when there were no cyclists in their immediate vicinity. A brief review of portions of the "before" video seemed to support the assumption that most motorists in lanes without sharrow markings tend to drive near the centre of the lane, except when overtaking cyclists. In the portions of video that were reviewed, the shift in motorists' lane positioning change was widespread enough to suggest that this probably represents a statistically robust finding, although a more comprehensive analysis would be required to confirm this.

[6] The decrease in the number of bicycles observed at location 2 might be explained by the fact that the "after" video-taping for this location took place during preparations for the G-20 summit, when some roads and businesses in the downtown core were closed. The "after" video-taping for the other locations took place a few days earlier.

4.2.Survey

4.1.4. Sample Group Overview

A large majority (85%, n=47) of the cyclists who completed the survey are frequent cyclists who ride their bicycle five to seven times per week during good weather. Participants who identified themselves as female outnumbered males 32 to 22. The group has a fairly normal age distribution for commuter cyclists, based on Census Journey to Work data (Figure 18). In the general population, cyclists tend to be slightly younger than those who participated in the survey, and cycle less frequently. The over-representation of females is notable, even for "downtown" cyclists,[7] and may reflect a more receptive attitude among females towards participating in this type of study.

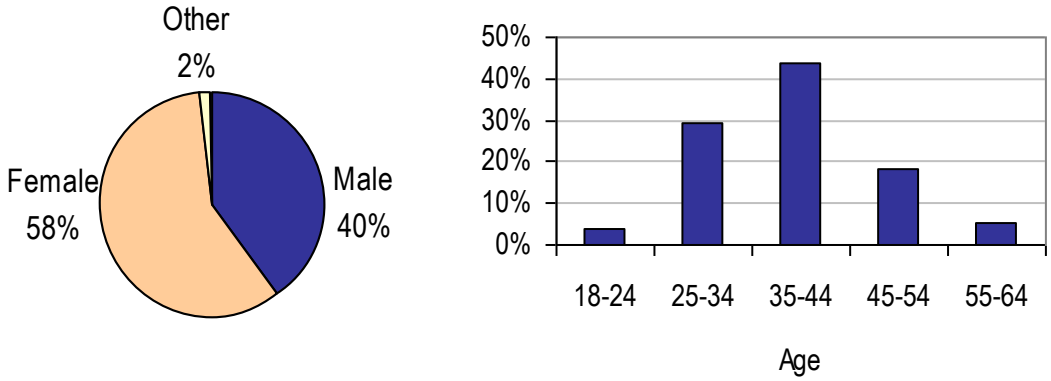


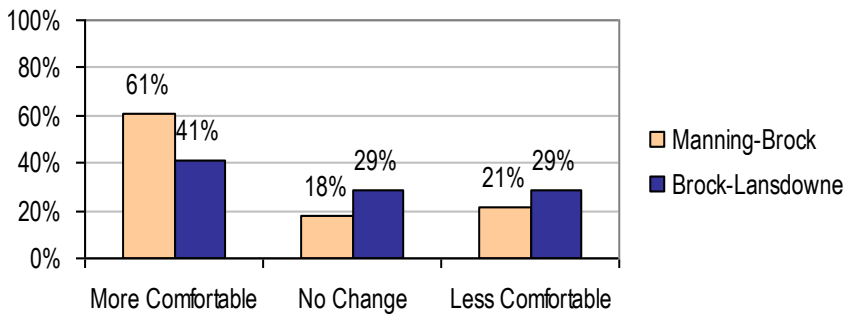
Figure 18. Age and gender profile of survey participants

Cyclists travelling eastbound in the morning rush hour made up 60% (n=33) of the survey sample, with the remaining 40% (n=22) riding westbound in the afternoon rush hour. The majority (+80%) of cyclists reported sunny weather for the last time they rode on College Street during rush hour before and after the installation of sharrows, and 95% (n=53) of cyclists noticed the sharrows while riding on College Street during rush hour.

4.1.5. Level of Comfort

The majority of cyclists (61%) travelling in the single-file (Manning-Brock) section reported feeling more comfortable after the sharrows were installed. Cyclists riding in the side-by-side (Brock-Landsdowne) section were more divided in their assessment. While 41% reported feeling more comfortable after the sharrows were installed, 29% reported "no change" and 29% said they felt less comfortable (Figure 19). The lane striping installed between Brock and Lansdowne at the same time the sharrows were installed may have influenced the survey results, since the striping effectively narrowed the curb lane.

[7] The "2009 City of Toronto Cycling Study" found that 43% of the city's "utilitarian cyclists" were female. A cordon count conducted in 2010 found that 38% of the cyclists entering or leaving the downtown core were female, and 40% of those crossing the screen-line at College Street were female.

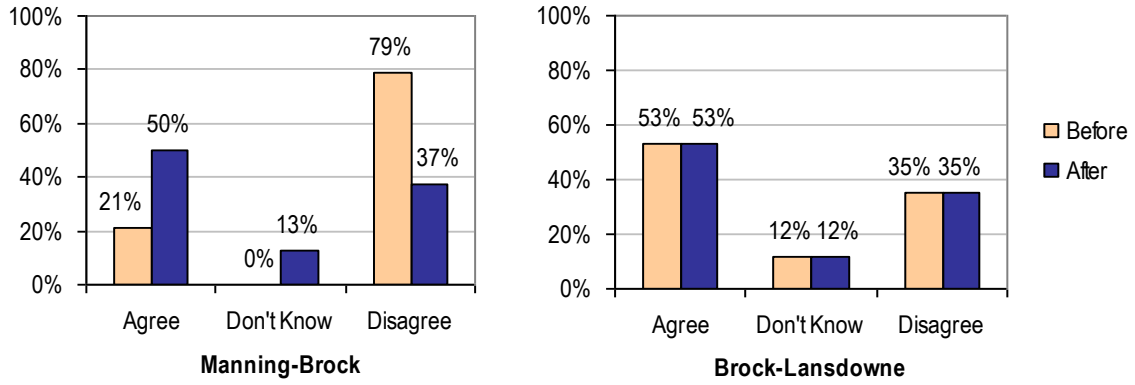


	More Comfortable		No Change		Less Comfortable		Total
	n	%	n	%	n	%	n
Single File (Manning-Brock)	23	61%	7	18%	8	21%	38
Side-by-Side (Brock-Lansdowne)	7	41%	5	29%	5	29%	17

Figure 19. Change in cyclists stated level of comfort after sharrows installed

4.1.6. Road Sharing

Cyclists were asked how strongly they agreed with the statement "Motorists give me enough space on the road when passing or driving behind me." After the sharrows were installed the percentage of cyclists who agreed with this statement increased from 21% to 50% among cyclists riding in the single file section (Manning-Brock), but stayed the same, at 53%, for cyclists riding from in the side-by-side section (Brock-Lansdowne) (Figure 20).



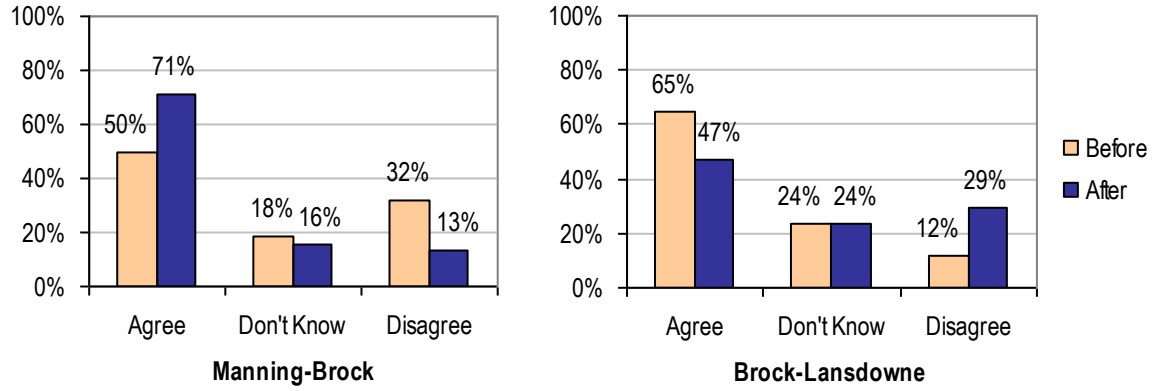
	Single File (Manning-Brock)				Side-by-Side (Brock-Lansdowne)			
	Before		After		Before		After	
	%	n	%	n	%	n	%	n
Agree	21%	8	50%	19	53%	9	53%	9
Don't Know	0%	0	13%	5	12%	2	12%	2
Disagree	79%	30	37%	14	35%	6	35%	6
Total	100%	38	100%	38	100%	17	100%	17

Figure 20. Cyclists' response to the statement, "Motorists give me enough space on the road when passing or driving behind me"

As with "level of comfort," cyclists riding in the narrow curb lanes between Manning and Brock reported a greater improvement in "road sharing" after the single file sharrows were installed than did cyclists in the section that received side-by-side sharrows. However, cyclists were more likely to report feeling that motorists gave them enough space in the wide curb lanes between Brock and Lansdowne than in the narrow curb lanes between Manning and Brock, both before and after the installation of sharrows.

4.1.7. Motorists Awareness of Cyclists

After single file sharrows were installed, 21% more cyclists riding between Manning and Brock agreed that motorists were aware of their presence. Cyclists riding between Brock and Lansdowne reported the opposite, with 20% *fewer* cyclists agreeing with the statement after the side-by-side sharrows were installed (Figure 21). Again, it is possible that the new lane striping negatively affected the experiences of some cyclists riding during rush hour in this section.



	Single File (Manning-Brock)				Side-by-Side (Brock-Lansdowne)			
	Before		After		Before		After	
	%	n	%	n	%	n	%	n
Agree	50%	19	71%	27	65%	11	47%	8
Don't Know	18%	7	16%	6	24%	4	24%	4
Disagree	32%	12	13%	5	12%	2	29%	5
Total	100%	38	100%	38	100%	17	100%	17

Figure 21. Change in cyclists' agreement with the statement "Motorists were aware of my presence"

4.1.8. Parking Compliance

Although sharrows are not intended to convey any message related to parking prohibitions, a question was included in the survey for cyclists to report seeing illegally parked or stopped vehicles in the curb lane. According to survey respondents, parking compliance improved in the narrow curb lanes between Manning and Brock, but worsened in the wide curb lanes between Brock and Lansdowne. Both before and after sharrows were installed, the vast majority of cyclists reported seeing illegally parked or stopped vehicles (Figure 22). Better enforcement of the City's parking prohibitions has the potential to improve cycling conditions along sharrow routes – and bike lanes.

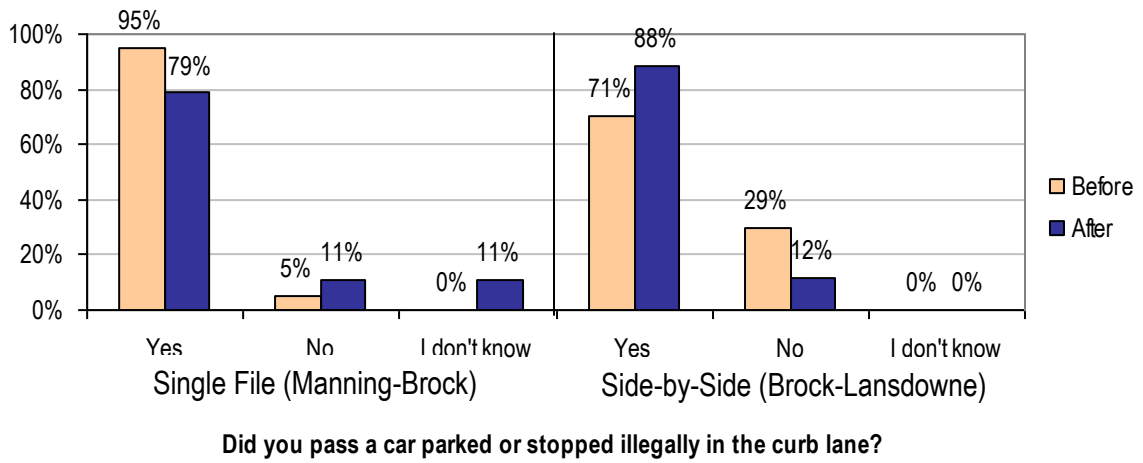
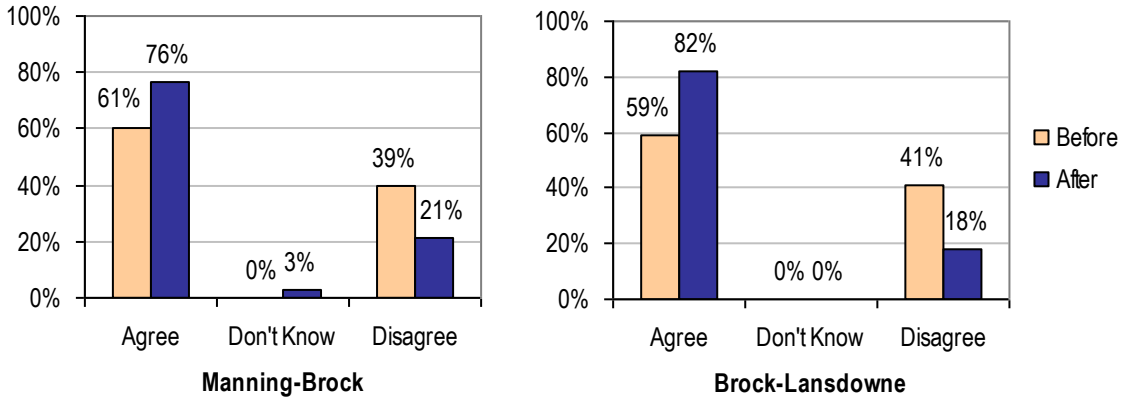


Figure 22. Parking compliance as reported by cyclists

4.1.9. Cyclist Positioning

Cyclists were asked if they agreed with the statement "In general, I rode my bicycle far enough from the curb to avoid sewer grates and curb-side debris". Before the sharrows were installed, cyclists in both sections of College Street responded similarly, about 60% agreeing (Figure 23). After the sharrows were installed, cyclists reported an improvement in their lane positioning, with 76% in the single file section (Manning-Brock) and 82% in the side-by-side section (Brock-Lansdowne) agreeing with the statement



	Single File (Manning-Brock)				Side-by-Side (Brock-Lansdowne)			
	Before		After		Before		After	
	%	n	%	n	%	n	%	n
Agree	61%	23	76%	29	59%	10	82%	14
Don't Know	0%	0	3%	1	0%	0	0%	0
Disagree	39%	15	21%	8	41%	7	18%	3
Total	100%	38	100%	38	100%	17	100%	17

Figure 23. Cyclists response to the statement "In general, I rode my bicycle far enough from the curb to avoid sewer grates and curb-side debris"

The improvement in lane positioning reported by cyclists is supported by the video data, which shows that the percentage of cyclists riding less than 75 cm from the curb decreased, and the percentage of cyclists riding at least 100 cm from the curb increased (Table 1, above).

4.1.10. Media Exposure & Interpretation

Prior to participating in the survey, 45% of participants had heard or read information about what sharrows are in the media (including television, radio, newspapers, e-newsletters and blogs) (Figure 24). The most common interpretation of sharrows was that motorists should share the road (Figure 25). A slightly greater percentage of cyclists interpreted the sharrow markings in this way at the Brock-Lansdowne location (39%) than the Manning-Brock location (31%). The second most common interpretation was that "cyclists are allowed to use the full traffic lane," and the third was that sharrows indicate "the correct position for cyclists to ride in."

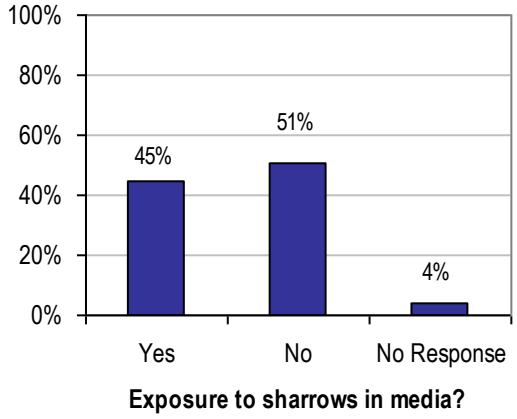


Figure 24. Cyclists exposure to information about sharrows in the media and online

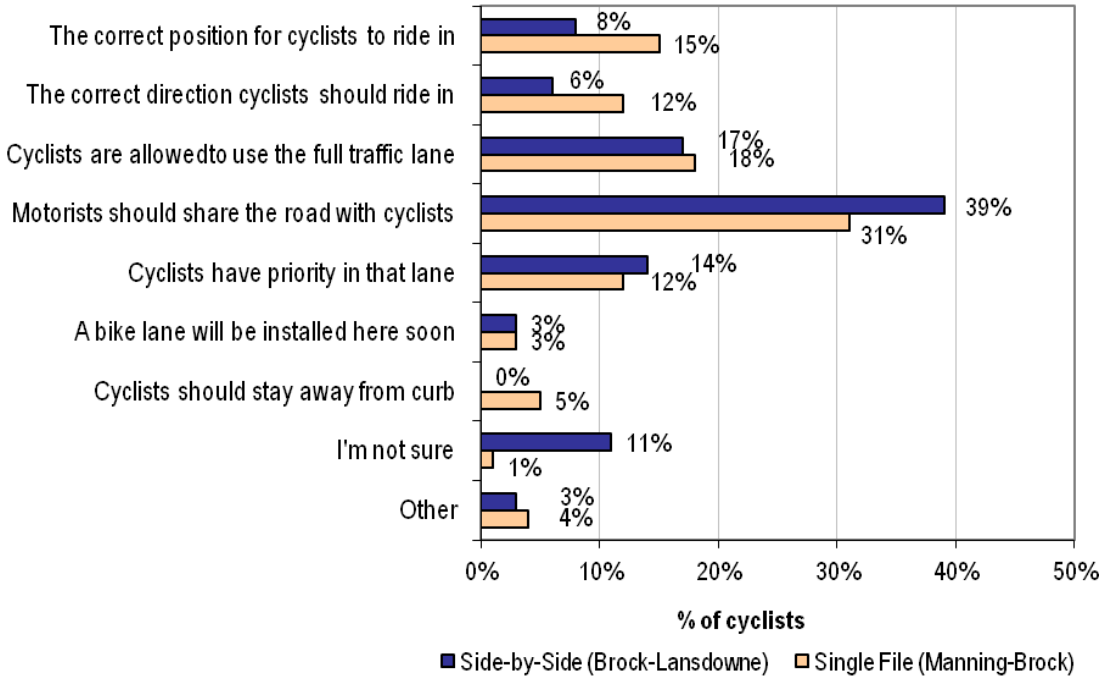


Figure 25. Cyclists response to the question, "What message do you think the sharrow pavement markings are supposed to convey?"

4.1.11. Design

Cyclists were asked to provide feedback on the placement of the sharrow markings, in terms of their distance from the curb and their longitudinal spacing. On both accounts, the majority of cyclists in both sections of College Street felt that the sharrow marking placement was "about right" (Figures 26 and 27). The greatest difference in cyclists feedback was that 26% of those riding the single-file sharrows in the Manning-Brock section felt the sharrows were too far apart (Figure 27). This suggests that where sharrows are used to encourage cyclists to "take the lane," a tighter longitudinal spacing would provide extra comfort for cyclists.

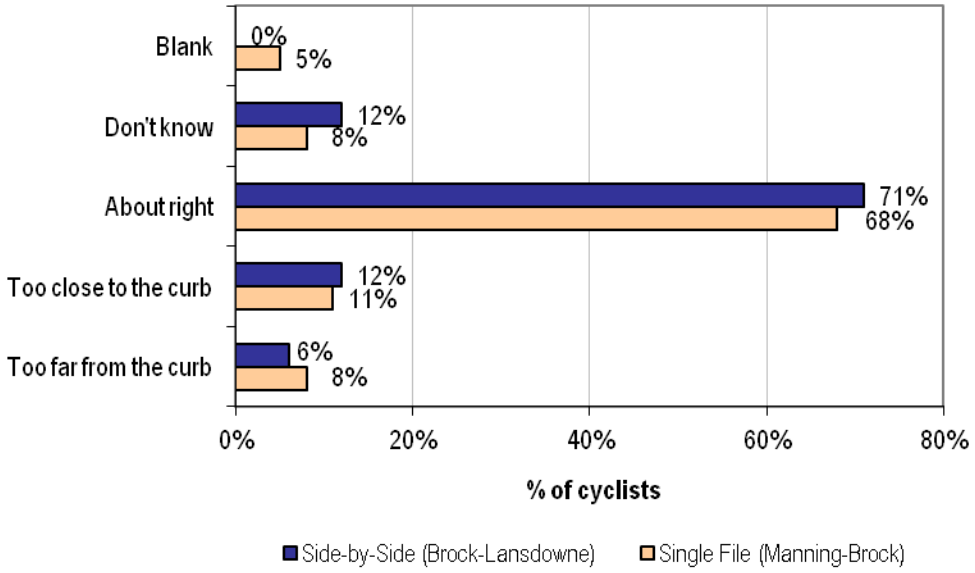


Figure 26. Cyclists response to the question "Did you feel the placement of the sharrow markings on the road was…"

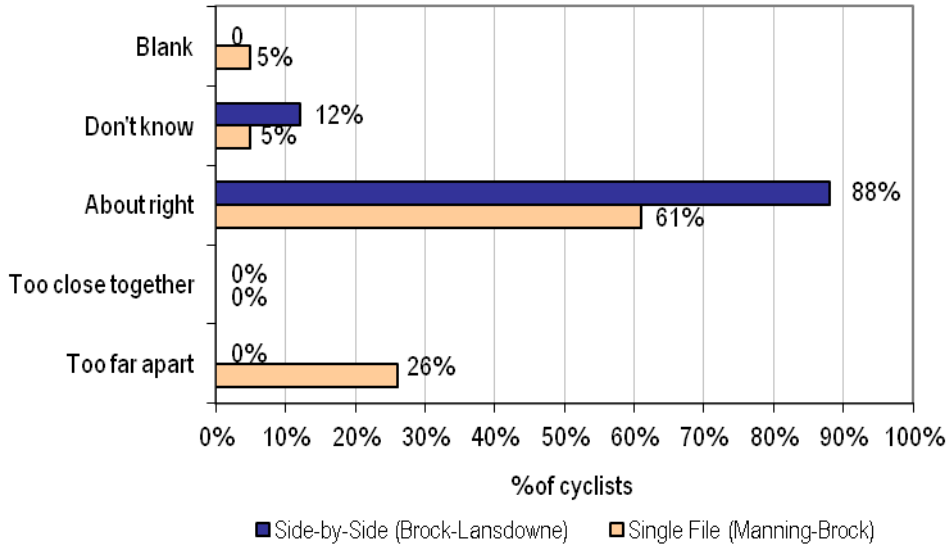


Figure 27. Cyclists response to the question "Did you feel the spacing between the sharrow markings was..."

5. Discussion

The findings of this evaluation indicate that sharrows can improve cycling conditions in several respects. Most significantly, the video results suggest that sharrows can help discourage motorists from passing cyclists within the curb lane. The rush-hour sharrows on College Street encouraged motorists to use the median lane instead of the curb lane, especially in sections with the single file treatment, where sharrows were applied near the centre of the lane. In the wide curb lanes, the side-by-side sharrow treatment seemed to encourage motorists to give cyclists more space within the lane. These effects were apparent even when there were no cyclists in the drivers' immediate vicinity, suggesting that they can be attributed directly to the pavement markings. The message that "drivers should share the road with cyclists," which was the most frequent interpretation offered by surveyed cyclists, seems to be effectively communicated to drivers by sharrow markings.

The sharrows' effects on driver behaviour can be expected to provide real improvements in safety for cyclists, by reducing the risk of conflicts with motorists and by increasing the amount of space available for cyclists to manoeuvre around obstacles in the roadway. It should also lead to a perception of increased safety and comfort for cyclists. The survey results confirm this, particularly in the single file sections, where most cyclists reported that their comfort level increased after the sharrows were installed. Cyclists also noticed an increase in the amount of lane space motorists gave them, and an improvement in motorists' awareness of their presence.

As for sharrows' direct effect on cyclists' behaviour, the understanding that sharrows are meant to indicate the "proper" cycling position was much less frequently reported by the cyclists surveyed. However, if motorists respond to sharrows by leaving more lane space to cyclists, cyclists ought to find it easier to ride a safe distance from the curb. At most locations there was a decrease in the number of cyclists riding "too close to the curb." In particular, cyclists travelling "alone" in the lane rode significantly farther from the curb, although this effect was consistent mainly among west-bound cyclists.

Indeed, the video results yielded inconsistent findings for most measures of the sharrows effectiveness at influencing cyclists' lane positioning. At one location (eastbound in the Manning-Brock section), where the results were particularly inconsistent, many cyclists were observed riding very close to the curb as they passed a queue of vehicles behind a streetcar or at a red light. Because this affected their choice of lane position, the data from this location was treated as invalid in terms of its contribution to understanding the effect of sharrows on cyclists' lane positioning behaviour.

Future studies of this nature should separate out cases where cyclists are observed overtaking stopped vehicles, and observation sites should be carefully selected to avoid locations where motor vehicle queuing is likely to occur. Other potential confounding factors, such as the simultaneous alteration of other elements of the infrastructure (in this case, the addition of new lane striping) should be avoided wherever as possible. Surveys aimed at evaluating public opinion of new cycling infrastructure should be based on larger sample sizes.
Along with the methodological lessons learned in this, Toronto's first "before-and-after" sharrow evaluation, several new questions were raised. Future studies might investigate whether the

sharrows' effect on motorists' behaviour diminishes with increasing traffic volume; whether decreasing the spacing between sharrows improves their effectiveness; and whether or not side-by-side sharrows have any impact on motor vehicle speeds. Follow-up studies could be done, after a significant period of time, to determine whether the effects of sharrows can be attributed to the "novelty effect" of new infrastructure, or if they represent lasting impacts.

6. Recommendations

Based on the findings of this evaluation and other feedback received from the public, the City of Toronto should:

1. Consider use of rush hour sharrows on other downtown streetcar routes in Toronto.

2. As new routes are installed, collect more "before and after" data, to study the impact of single-file and side-by-side operation sharrows on cyclists' and motorists' behaviour. Future studies should incorporate improvements in methodology mentioned in Section 5.

3. Work with the Toronto Police Parking Enforcement Unit on future enforcement campaigns for the rush hour no-stopping prohibitions on downtown arterials that are popular with cyclists, focusing on streets with sharrows and bike lanes.

4. Continue to develop new, and expand existing sharrow education campaigns.

5. Develop specifications for single-file and side-by-side operation sharrows, to be included in a new bikeway design guide for Toronto.