Vancouver's Bicycle Lanes:
Retrofitting Arterial Streets to Accommodate Cyclists

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ABSTRACT

The City of Vancouver has been developing facilities for cyclists since the mid 1980s. However, the development of a more comprehensive bicycle network began in earnest in the mid 1990s when cycling was reaffirmed as one of the City's priority transportation modes. Since that time, the network has grown to incorporate almost 400 lane-kilometres of designated bicycle facilities of varying types, including off-street pathways, local street bikeways and arterial bike lanes. Although the majority of the City's facilities are "local street bikeways" on minor streets, a network of bicycle lanes on arterial streets has also emerged over the past decade.

As with most transportation challenges, the provision of bicycle lanes in a highly developed urban environment cannot be achieved with a "one-size-fits-all" solution. The constraints posed by Vancouver's relatively narrow street rights-of-way has required creativity to retrofit bicycle lanes where road capacity, parking demands and pedestrian space are often at a premium. Transit operations and goods movement are also important design considerations that are potentially affected by the implementation of bicycle lanes.

A range of options needs to be considered that recognizes physical and operational constraints, and potential impacts on other modes. Design options that have been used in Vancouver to incorporate bike lanes on arterial streets include:

- reconfiguration/adjustment of motor vehicle travel lanes
- addition or removal of on-street parking
- installation of bike lanes within unused or excess road space
- installation of bike lanes as part of street reconstruction/widening
- usage of shared-lane markings (sharrows)
- combination of bike lanes and shared-lane markings
- separated bike lanes/cycle tracks

The implementation of bike lanes within the constrained street environment of Vancouver has required design and operational tradeoffs and new approaches often unique to each facility. These tradeoffs must be considered and evaluated through the design and consultation process. More work can be done to develop additional bike lanes throughout Vancouver and other design options may emerge, but to date the City has been successful in retrofitting a well-established arterial street system with bike lanes while increasing the number of cyclists using the network. This paper will explore the various design approaches that have been used to implement bike lanes in Vancouver, and will provide general commentary on the City's experiences with bike lane design to date.

Vancouver's Bicycle Lanes:
Retrofitting Arterial Streets to Accommodate Cyclists

The City of Vancouver has been developing facilities for cyclists since the mid 1980s through the development of the off-street Seawall and the BC Parkway, parallel to the Expo SkyTrain line, which was completed in 1986.

However, the development of a more comprehensive bicycle network began in earnest in the mid 1990s when cycling was reaffirmed as one of the City's priority transportation modes. Since that time, the network has grown to incorporate almost 400 lane-kilometres of designated bicycle facilities of varying types, including off-street pathways, local street bikeways and arterial bike lanes. Although the majority of the City's facilities are "local street bikeways" on minor streets, a network of bicycle lanes and shared-use facilities on arterial streets has also emerged over the past decade.

Context

The City of Vancouver is the most populous of 21 municipalities in the Lower Mainland of British Columbia. The Metro Vancouver region currently has a population of approximately 2.1 million and is constrained on three sides by mountains, water and the US border.

The City of Vancouver has a population of approximately 578,000 and occupies an area of 115 km^2. The City was settled in the late 1800s and developed primarily through the 1900s on a typical grid network of streets, with major roads spaced approximately 800 m or ½ mile apart. The City is bordered on two sides by water: Burrard Inlet on the north and the Fraser River on the south. West of the City are the University Endowment Lands, the University of British Columbia and Pacific Spirit Park. East of Vancouver lies the City of Burnaby.

The City of Vancouver is fully developed, although some former industrial lands are now undergoing residential and commercial redevelopment. Further population growth will be accommodated through densification. For example, the City's Downtown peninsula has undergone significant redevelopment over the past decade and the population in this small area of the City has grown by over 50% since 1996.

The 1997 Transportation Plan reaffirms the City's commitment to non-automobile modes of transport, with the planning priorities being walking, cycling and transit. The Transportation Plan commits to maintaining City-wide road capacity at 1997 levels, thereby requiring further growth in travel demands to be accommodated primarily by non-automobile modes.

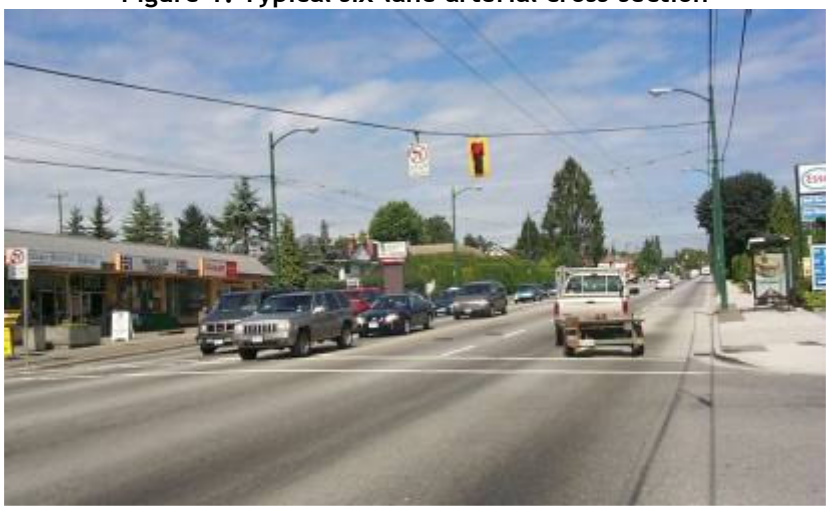
The 1999 Bicycle Plan recommends the continued development of a grid network of bikeways, primarily on local streets. However, it also recommends that bicycles be accommodated on arterial streets wherever possible, including a network of bicycle lanes on Downtown streets. The Bicycle Plan also emphasizes the importance of parking facilities for bicycles, as well as monitoring bike and motor vehicle traffic on bikeways.

Bicycle Network Development

The major streets in Vancouver are generally located within a 24-m right-of-way and are developed to a six-lane cross-section. Pavement width is typically 18-20 m. This leaves a small amount of space for sidewalks on both sides. A typical example is illustrated in Figure 1.

In many cases, parking is permitted on Vancouver's major streets, at least during off-peak periods. As well, most of the City's major streets accommodate frequent transit services, with some corridors carrying over 100 buses per hour during the peak. There is a desire to preserve the existing roadway capacity on the City's major streets for moving motor vehicles, including trucks and transit. This is partly in an attempt to mitigate congestion and minimize motorist short-cutting through residential neighbourhoods.

Figure 1: Typical six-lane arterial cross-section



With the constraints posed by the City's relatively narrow street rights-of-way, a conscious decision was made around 1990 to pursue a network of bikeways on local residential streets, parallel to the major streets. Consistent with this decision, the development of the City's bicycle network began in earnest in the early 1990s with early focus on the establishment of bicycle routes on local residential streets.

Around 2003, however, the City began to develop bicycle lanes on some streets, primarily in the Downtown. This was in response to the Downtown Transportation Plan adopted in 2002.

Since that time, bicycle lanes have been established on streets across the City. As well, the City recently undertook construction of its first separated bicycle lane (commonly known as a cycle track) on Carrall Street. Finally, the City has adopted the new shared-use lane marking recently approved by TAC and has deployed it in several locations under various circumstances, but particularly where bike lanes cannot be developed within the existing street cross-section.

Bicycle Lane Design Approach

The City of Vancouver strives to follow existing TAC guidelines in the design of bicycle lanes and shared-use facilities. However, each design scenario presents unique physical characteristics, operational issues and other factors that require case-by-case assessment and consideration.

Consistent with the TAC guidelines, the City requires a minimum width of 1.5 m for bicycle lanes but strives for wider facilities. In some instances where space has permitted, the City has developed 1.8-m and 2.0-m bike lanes.

For on-street parking adjacent to a bike lane, the City generally uses a standard width of 2.5 m.

Lastly, motor vehicle travel lanes within the City of Vancouver may be as narrow as 3.0 m, although the City strives to provide a minimum of 3.2-m travel lanes wherever possible, particularly on transit and truck routes. In fact, some arterial streets with no bike facilities have travel lanes narrower than 3.0 m.

Bicycle Lane Development

This section describes several approaches to the development of bicycle lanes that have been used in the City of Vancouver. Each approach has its own advantages and challenges, some of which are outlined below.

As with most transportation challenges, the provision of bicycle lanes in a highly developed urban environment cannot be achieved with a "one-size-fits-all" solution. The constraints posed by Vancouver's relatively narrow street rights-of-way has required creativity to retrofit bicycle lanes where road capacity, parking demands and pedestrian space are often at a premium. Transit operations and goods movement are also important design considerations that are potentially affected by the implementation of bicycle lanes.

A range of options needs to be considered that recognizes physical and operational constraints, and potential impacts on other modes. Design options that have been used in Vancouver to incorporate bike lanes on arterial streets include:

- reconfiguration/adjustment of motor vehicle travel lanes
- addition or removal of on-street parking
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The following subsections outline each of these approaches and present case studies of specific locations where each has been implemented.

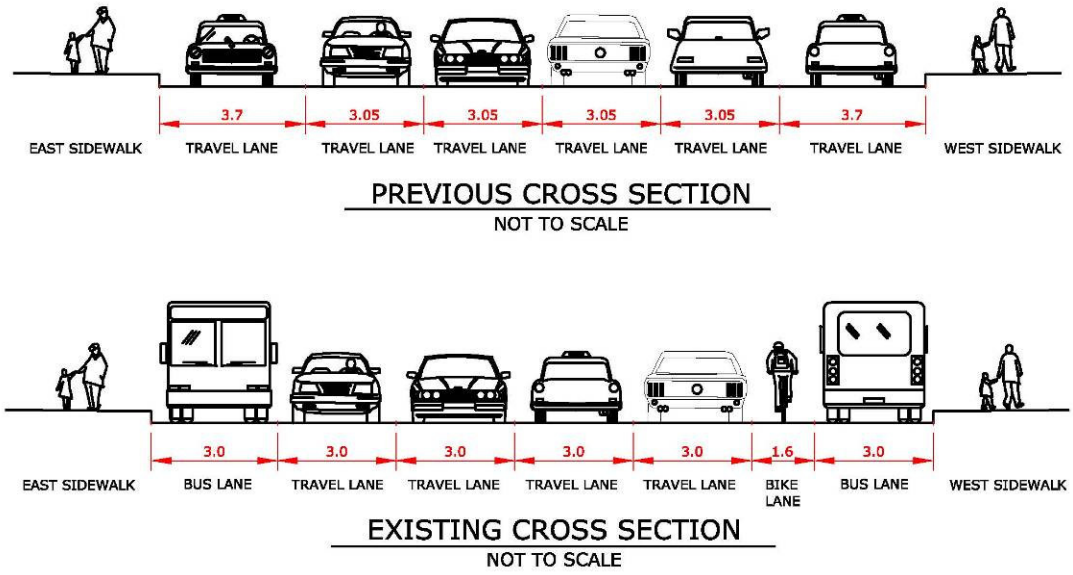
Street Reconfiguration

Some of the Downtown bicycle routes developed in the mid 2000s involved the reconfiguration of the existing street layout by adjusting lane widths. In most cases, motor vehicle travel lanes were narrowed slightly to provide sufficient space at the right side to accommodate a 1.5-m bicycle lane either adjacent to the curb or adjacent to the curbside parking lane. Most Vancouver bike lanes are located adjacent to curbside parking.

Case Study: Burrard Street

Burrard Street is a major arterial street running north-south in the Downtown core. Prior to the bike lane being installed, the road had a six-lane cross-section with parking permitted during off-peak periods at curbside in both directions. Lane widths were as illustrated in the following diagram.

Figure 2: Burrard Street cross-section before and after bike lane implementation
(LOOKING SOUTH)



A single southbound bicycle lane was implemented by narrowing the two curbside lanes from approximately 3.7 m to 3.0 m (see Figure 2). The southbound curbside lane accommodates parking during off-peak periods and is a reserved bus lane during the afternoon rush period.

The bike lane is well used during peak periods, was relatively inexpensive and quick to implement, but the City has heard concerns about positioning cyclists to the left of the reserved bus lane (Figure 3). The bus lane is heavily used during peak periods and allows cyclists using the bike lane to easily pass buses stopped to pick up or drop off passengers, but violations of the reserved lane by private and commercial motor vehicles are relatively frequent. Some private vehicles use the lane as a queue jumper and speed past on the right side of cyclists using the bike lane, leading to a feeling of discomfort for cyclists.

Figure 3: Burrard Street southbound bike lane

Other Examples: Melville Street, Expo Boulevard, Pacific Boulevard

Addition/Removal of Parking

On many of the City's arterial streets, parking is permitted during off-peak periods. During peak conditions, parking is prohibited (at least in the peak direction of travel) to facilitate motor vehicle movement. Traffic volumes in the Downtown area have gradually declined over the past 15 years, despite an increase in total trips Downtown taken up by transit, cycling, and walking. Consequently, there has been reduced need for peak-period parking restrictions. Conversion of off-peak parking to full-time parking on some streets has allowed for the establishment of permanent bicycle lanes against curbside parking.

Case study: Richards Street

Richards Street is a one-way southbound arterial street on the eastern edge of the Downtown commercial district. At its southern extent, much of the adjacent land use is high-rise residential. Prior to bike lane implementation, Richards Street accommodated four southbound travel lanes during peak periods. Parking was permitted on both sides of the street during off-peak periods (see Figure 5).

A bike lane was introduced by converting the curbside lane on the right side to full-time parking and shifting the remaining travel lanes. North of Nelson Street, the left curb lane continues to allow off-peak parking with parking prohibited during the afternoon peak. This facilitates motor vehicle access to Nelson Street, which provides a connection to the Cambie Bridge out of the Downtown peninsula. South of Nelson Street, full-time parking is permitted on the left side.

Figure 4 and Figure 5 illustrate the configuration of Richards Street before and after bike lane implementation.

Figure 4: Richards Street cross-section before and after bike lane implementation

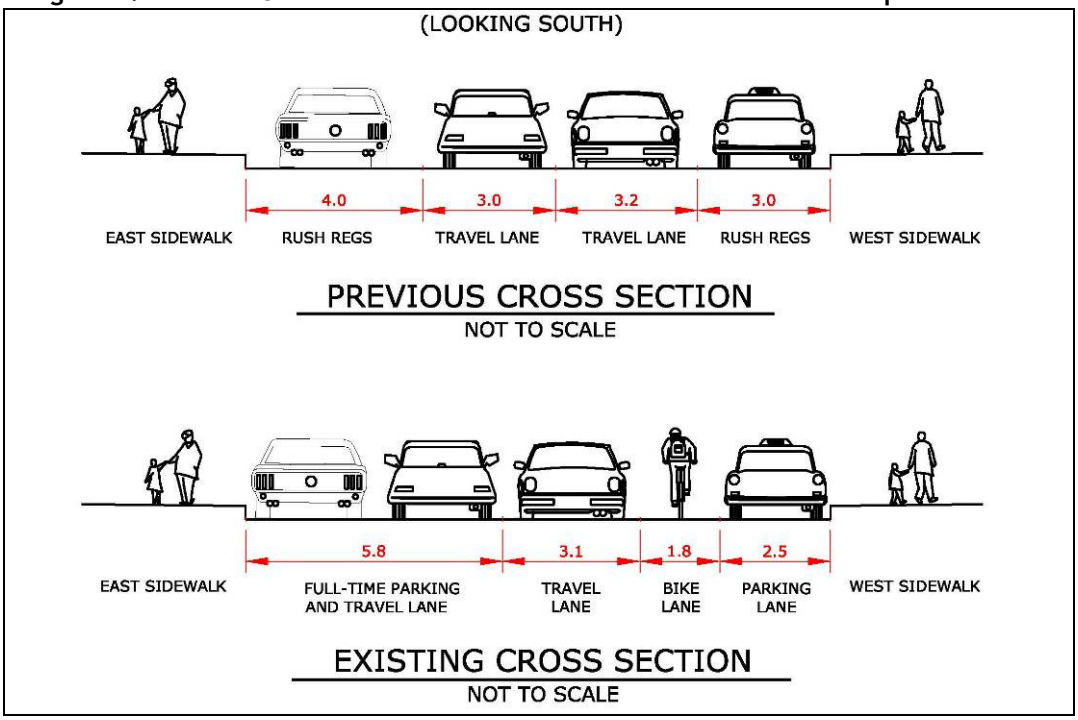


Figure 5: Richards Street before and after bike lane implementation

Before

After

This project was relatively quick and inexpensive to implement and benefited from the public support gained from the installation of full-time parking. The reduction in peak-period capacity has not had a significant impact on traffic operations in the Downtown. Several other streets Downtown have been similarly converted, providing a significant expansion in the bicycle network serving Downtown residents and workers.

Case Study: Midlothian Avenue

Midlothian Avenue is an east-west secondary arterial between Cambie Street and Ontario Street passing along the north edge of Queen Elizabeth Park, located in the centre of the City.

Prior to bike lane implementation, the street accommodated two moving lanes and allowed parking on both sides within a curb-to-curb width of approximately 12.8 m.

Bike lanes were installed by prohibiting parking along the south curb adjacent to the park. The width allowed for a 2.1-m bike lane eastbound against the south curb and a 1.8-m bike lane westbound adjacent to the 2.5-m parking lane. There remain two 3.2-m travel lanes. The configurations before and after bike lane implementation are illustrated in Figure 6 and Figure 7.

Figure 6: Midlothian Avenue cross-section before and after bike lane implementation

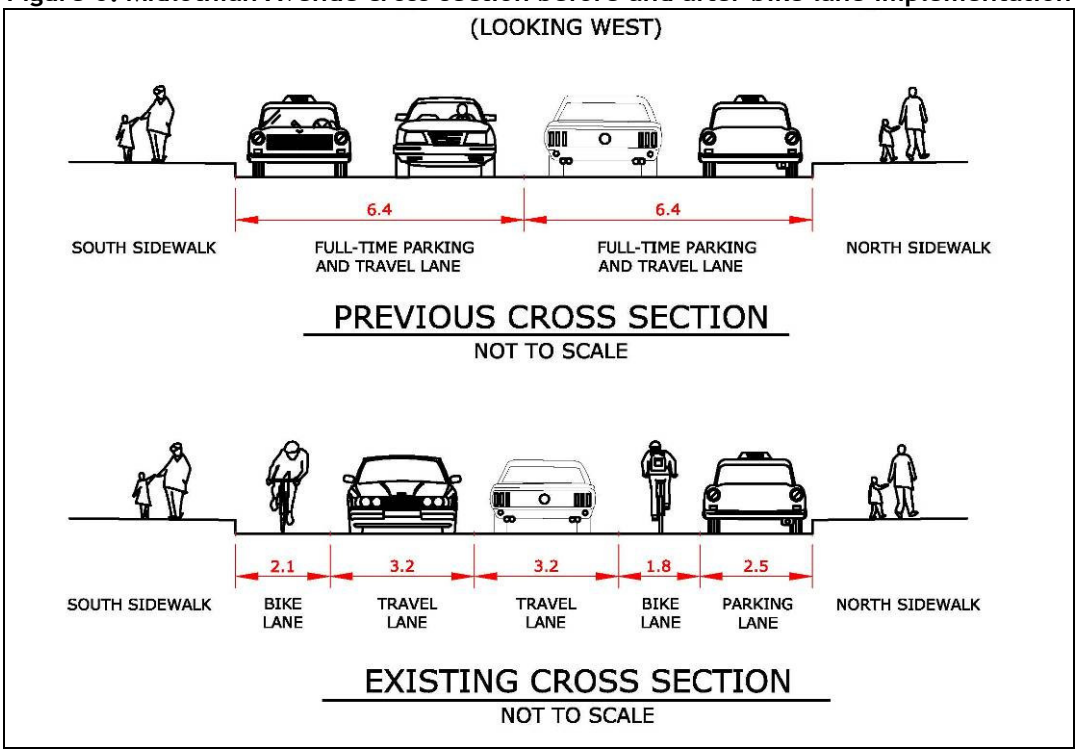


Figure 7: Midlothian Avenue before and after bike lane implementation

Before

After

The implementation of bike lanes on Midlothian Avenue was relatively straightforward and inexpensive. There was no opposition to the prohibition of parking on the south side of the street, as parking demand adjacent to Queen Elizabeth Park was very light. Although there

was no public opposition to the removal of parking on Midlothian Avenue, the City is about to implement bike lanes on two streets where parking will be removed adjacent to commercial uses. It is uncertain what the response will be to these proposals.

Other Examples: Homer Street (full-time parking added), Hornby Street (full-time parking added)

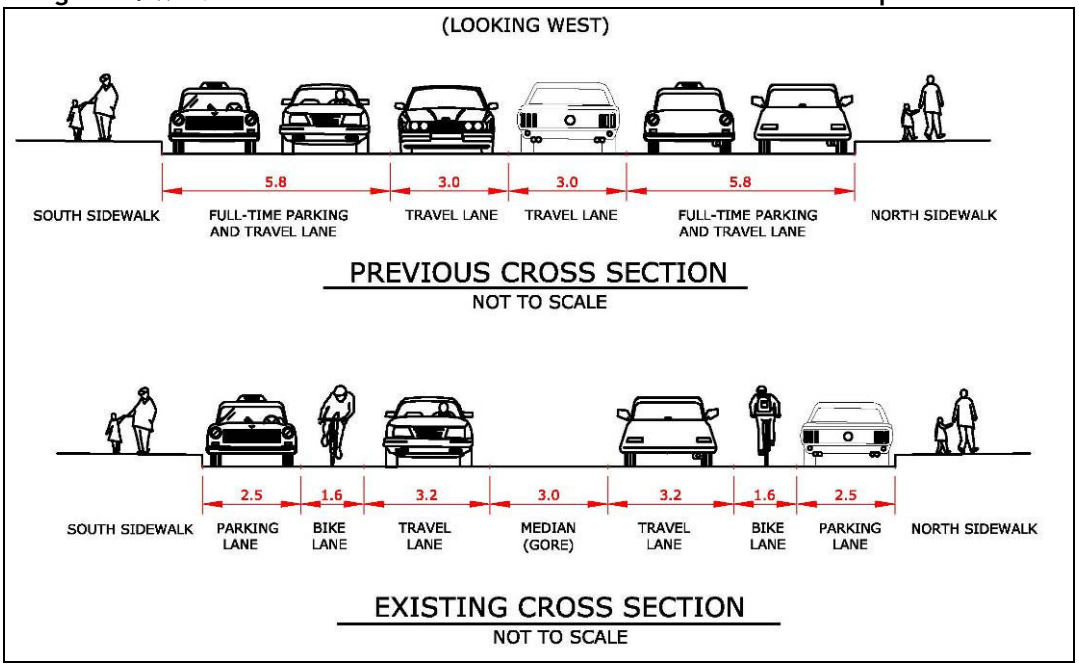
Road Diet

The City of Vancouver has undertaken one project that might be referred to as a 'road diet', whereby the number of travel lanes was reduced to accommodate bicycle lanes. A common approach to road dieting involves four-lane streets whereby one motor vehicle lane is converted to two bicycle lanes and a second lane is converted to a centre two-way left-turn lane. Vancouver's 'road diet' was somewhat different, as outlined below.

Case Study: W 49th Avenue

49th Avenue is an east-west secondary arterial in the southern portion of the City of Vancouver. Along most of its length, 49th Avenue is a two-lane roadway with full-time parking on both sides on a 12- to 14-m curb-to-curb cross-section. However, the segment of W 49th Avenue between Oak Street and Cambie Street has a 17-m cross-section. Prior to bike lane implementation, this short segment (850 m) accommodated four travel lanes and full-time parking on both sides, as illustrated in Figure 8.

Figure 8: W 49th Avenue cross-section before and after bike lane implementation



Bike lanes were implemented between Oak Street and Cambie Street by removing two motor vehicle travel lanes. This makes the cross-section consistent with the rest of the street across the City. The two bike lanes used up a single travel lane and the remaining width was painted as a gore/median. The gore and bike lanes can be seen below in Figure 9. Although most road diets involve conversion of one lane to a two-way left-turn lane, the configuration of W 49th Avenue is not conducive to this arrangement, and a gored median was implemented instead.

Figure 9: W 49th Avenue before and after bike lane implementation

Before

After

As with other bike lane projects, this facility was relatively inexpensive and quick to implement. There was some initial negative public response to the reduction in travel lanes, primarily related to ongoing rapid transit construction at one end of the corridor that was generating significant congestion along W 49th Avenue. It was perceived that the reduced capacity on W 49th Avenue was contributing to additional congestion in the area. However, east-west intersection capacity at Cambie Street – the primary capacity constraint in the corridor – was not changed as part of the bike lane project. (However, east-west intersection capacity was occasionally reduced for construction activities.)

Unused Road Space

In the summer of 2009, several new bicycle lanes will be implemented that simply use up available road space that is otherwise not required for moving motor vehicle traffic or for on-street parking. In most cases, these are being implemented on streets that have sufficient width to accommodate four moving lanes of traffic, but currently accommodate only two travel lanes with parking. As the City's policy is to preserve road capacity at 1997 levels, there are no plans to provide four travel lanes on any of the subject corridors.

In these cases, a bike lane is painted in each direction between moving traffic and parking. The width of the bike lanes depends on the available street width, but a minimum bike lane width of 1.5 m is required. The parking lane is maintained at 2.5 m and a travel lane width of at least 3.2 m is desired although not always available, as discussed in the case study below.

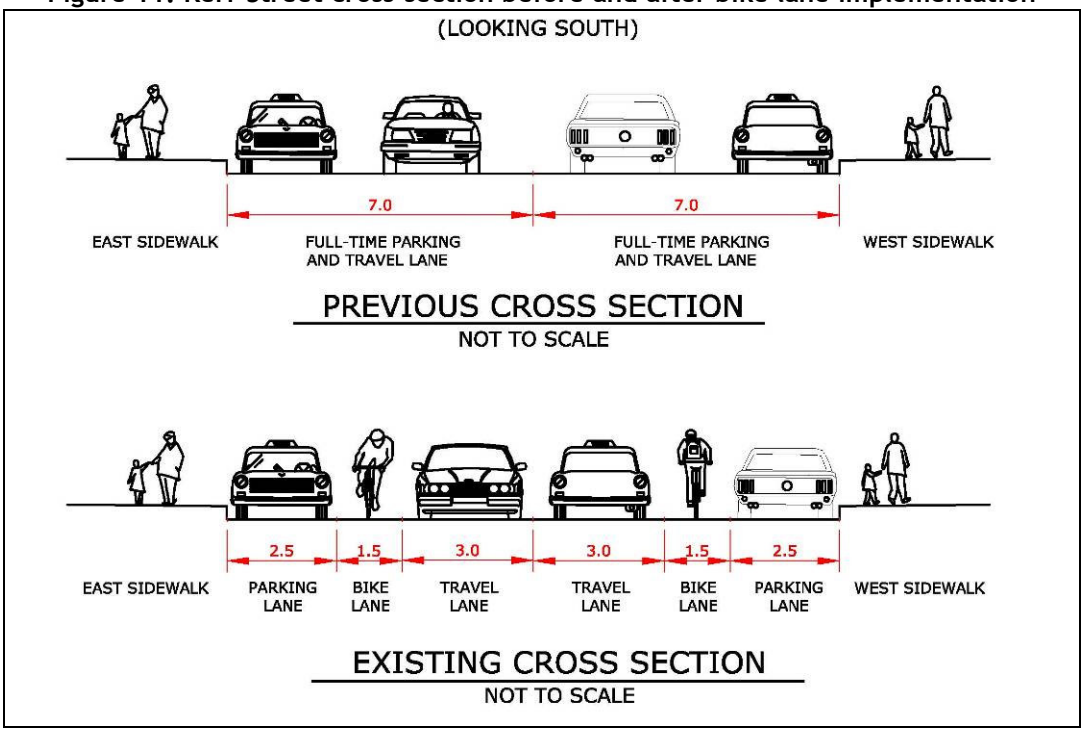
Case Study: Kerr Street

Kerr Street is a north-south secondary arterial in the southeast corner of the City. Along most of its length, Kerr Street provides two moving lanes and full-time parking on both sides within a 14-m curb-to-curb cross-section (Figure 10). At the extreme southern extent, the curb-to-curb width is less than 14 m.

Figure 10: Kerr Street prior to implementation of bike lanes

Bike lanes will be developed by painting reserved space between the moving and parking lanes. However, minimum lane widths are necessary to accommodate the bike lanes. Although the minimum desired width for the motor vehicle travel lane is 3.2 m on bus routes, the transit authority has accepted a trial usage of 3.0-m travel lanes in this corridor. The bike lanes will be 1.5 m wide and parking will be maintained at 2.5 m.

Figure 11: Kerr Street cross-section before and after bike lane implementation



Further south, where Kerr Street passes adjacent to a park and a municipal golf course and is on a steep grade (12%), parking demand is very light. Because the road is narrower in this segment, parking will be prohibited on one side of the street and wider (2.0-m) bike lanes will be provided. This will be particularly helpful to uphill cyclists, who typically use more road space when climbing in a standing position.

Other Examples: Rupert Street, 22nd Avenue, Dunbar Street

Street Reconstruction

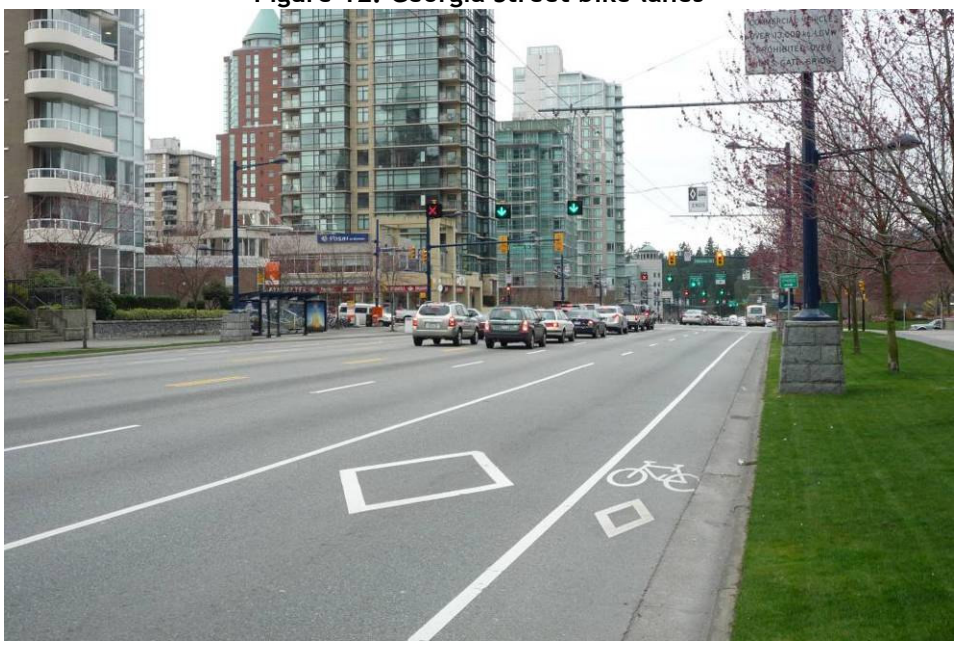
Opportunities for implementation of bike lanes occasionally arise through wholesale street reconstruction. This may be done as part of a capital program, a safety program, or through adjacent redevelopment. The implementation of bike lanes can be a relatively low incremental cost for the overall project, or may be funded through development.

Case Study: Georgia Street

W Georgia Street is a major east-west arterial street through the Downtown peninsula that connects to the Stanley Park Causeway and the Lions Gate Bridge. It is a primary access to and from the City and serves very heavy traffic demands of over 64,000 vehicles per day. Many cyclists also use the Lions Gate Bridge to access Vancouver from the North Shore communities, so there is also heavy cycling demand in the corridor. Prior to bike lane implementation, W Georgia Street had a seven-lane cross-section, including a westbound reserved bus lane and reversible centre lane, within a curb-to-curb width of approximately 23 m.

In 2002, the portion of W Georgia Street entering Stanley Park was realigned to address safety issues on a sharp S-curve, and to address transit operations and queue jumping. As part of the project, bike lanes were implemented from Nicola Street to the Stanley Park Causeway by widening the street to approximately 25 m and adjusting lane widths. The westbound bike lane is shown below in Figure 12.

Figure 12: Georgia Street bike lanes



Although the overall safety improvement project cost approximately $13 million, bike lanes were implemented at a relatively modest incremental cost.

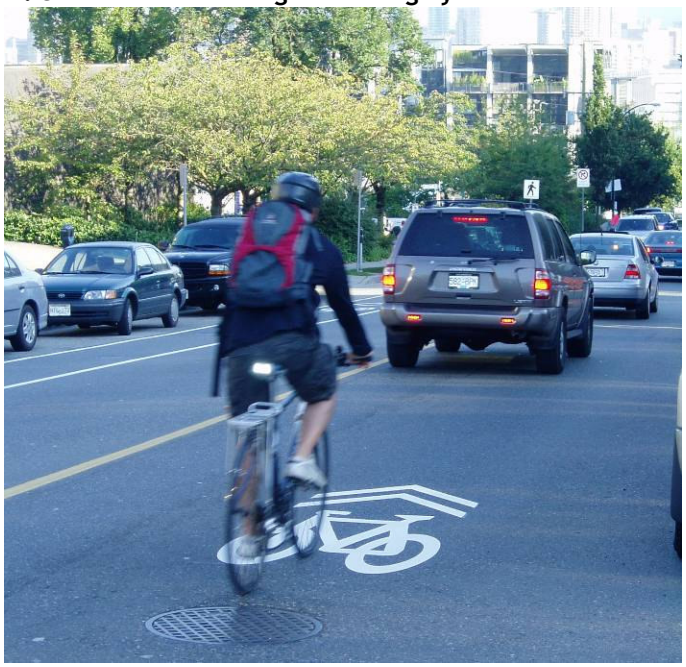
Other Examples: W 33rd Avenue, Cambie Street

Shared-Use Lanes

Shared-use lane markings, now colloquially referred to as 'sharrows', were recently adopted by TAC as an approved pavement marking. They are intended to guide cyclists where to position themselves laterally on the road and to advise motorists that cyclists should be expected on the road. Sharrows may be used in side-by-side operation, showing where cyclists should position themselves while preserving space for motorists to pass. In this case, the markings are generally positioned adjacent to curbside parking. TAC guidelines suggest that they be placed 3.4 m from the curb, which generally provides sufficient space for cyclists to stay clear of the 'door zone' of adjacent parked cars.

Sharrows may also be used to advise cyclists when to 'take the lane' where travel lanes are too narrow to allow side-by-side operation or where cyclists may be reasonably expected to integrate with motor vehicle traffic. A common usage of this approach is on downhill segments where cyclists are able to ride at the speed of other traffic. Figure 13 shows an example of a sharrow where cyclists are encouraged to take the lane on a downhill segment.

Figure 13: Shared-use marking indicating cyclists should take the lane



<u>Case Study: Earles Street</u>

Earles Street is a north-south secondary arterial on the east side of Vancouver that is also part of a broader north-south bicycle route implemented in 1998. The cross-section provides two travel lanes and full-time parking on both sides of the street. The curb-to-curb width is approximately 12.5 m, insufficient to accommodate the existing cross-section as well as bike lanes.

To more clearly indicate the presence and appropriate positioning of cyclists, the City recently implemented shared-use markings. These markings are generally spaced at a frequency of 50-60 m and are located 3.3 m from the curb (measured to centreline of marking). This lateral distance was selected to keep cyclists clear of the door zone, while recognizing the relatively low turnover of parked cars in the residential area.

Approaching the Kingsway intersection, southbound Earles Street provides an additional lane for intersection capacity. The shared-use markings on the approach to this intersection are located in the centre of the travel lane, indicating that cyclists should take the lane. The shared-use markings are illustrated in Figure 14.

Figure 14: Earles Street shared-use lane markings

Typical midblock configuration

Approaching major intersection

Research from San Francisco indicates that, on streets with shared-use markings, motorists tend to provide more space to cyclists and that cyclists ride further from parked cars. The results also indicate that fewer cyclists ride on sidewalks or the wrong way on shared-use streets. Anecdotal feedback from Vancouver cyclists support these findings.

Other Example: W 49th Avenue

Different Treatments in Each Direction

On two streets in Vancouver, the City has employed a bike lane in one direction and shared-use markings in the opposite direction. This approach may be considered where street width does not allow for bike lanes in both directions but where there may be rationale for providing a bike lane in one direction. For example, on relatively steep hills, it may be desirable to provide a bike lane in the uphill direction to provide reserved space for cyclists who will be riding more slowly than motor vehicle traffic. In the downhill direction, sharrows may be appropriate because cyclists can ride at the same speed as motor vehicle traffic.

<u>Case Study: W 4th Avenue</u>

W 4th Avenue is a major east-west arterial serving the west side of Vancouver and providing a connection to the University of British Columbia. A portion of W 4th Avenue west of Highbury Street was recently modified to better accommodate cyclists.

The segment in question is a median-divided roadway that accommodates four motor vehicle travel lanes and, prior to implementation of bike facilities, provided full-time parking on both sides.

The north side of the street (westbound carriageway) runs past a major park that hosts community events and generates relatively high parking demand, but is not wide enough to accommodate the addition of a bike lane. The parking demand and adjacent use on the north side led to the selection of shared-use markings for the westbound direction. These were accommodated with a modest narrowing of the median lane from 3.3 m to 3.0 m and corresponding widening of the second travel lane adjacent to parking. The configurations of westbound W 4th Avenue before and after sharrow implementation are shown below in Figure 15. The previous lane markings, which were ground off and moved slightly to the south, can be seen in the photo on the right.

Figure 15: Westbound W 4th Avenue before and after implementation of sharrows

Before

After

The south side (eastbound carriageway) runs past a Department of National Defence garrison with substantial off-street parking capacity. There was very little parking demand prior to bike lane implementation. For this direction, it was decided to prohibit stopping and convert the former parking lane to a dedicated bicycle lane, as illustrated in Figure 16.

Figure 16: Eastbound W 4th Avenue before and after implementation of bike lane

Before

After

Other Example: Yukon Street

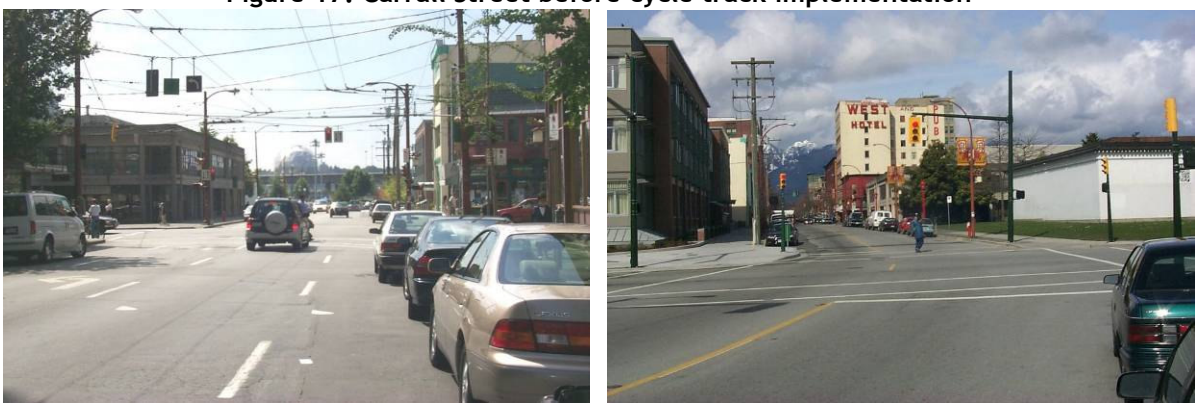
Separated Bike Lanes/Cycle Tracks

Separated bike lanes generally incorporate some form of physical separation from motor vehicle traffic. This is commonly achieved by installing a barrier or rollover curb between the motor vehicle traffic or parking lane and the adjacent bicycle lane. Bollards or barriers may also be used for separation. This approach is commonly used in Europe, particularly in Denmark, where they are known as 'cycle tracks'. Recognizing the high cycle mode shares in northern Europe, the local cycling community strongly supports separated bike lanes, considering them one of the most appropriate and appealing approaches for attracting more people to cycle for transportation.

<u>Case Study: Carrall Street</u>

Vancouver's first separated bicycle lanes are currently under construction on Carrall Street. Carrall Street is a north-south arterial on the eastern edge of the Downtown peninsula connecting Gastown with Chinatown through the Downtown East Side. Prior to reconstruction, Carrall Street was a four-lane street approximately 13 m wide (Figure 17). The northern portion of the street is one-way southbound and had rush-hour parking restrictions to facilitate traffic flow, whereas the southern portion is two-way and permitted full-time parking on both sides.

Figure 17: Carrall Street before cycle track implementation



Carrall Street is designated as a City Greenway and is currently being entirely reconstructed from property line to property line to provide wider sidewalks, pedestrian amenities and separated bicycle lanes. To facilitate this modification, the street has been narrowed to two 3.2-m travel lanes, with limited parking on one side of the street (Figure 18). The cycle tracks are generally 2.0 m wide and are separated from the motor vehicle lanes by a rollover curb (Figure 18, right). In locations where parking is permitted, the cycle track is located between the parking area and the sidewalk and is separated from parked vehicles with bollards (Figure 18, left).

Figure 18: Carrall Street cycle track

Completed section

Section nearing completion

As this is a complete street reconstruction and beautification, the cost has been significant. The removal of much of the on-street parking along Carrall Street generated some public opposition, but this project included a significant outreach effort to address these concerns. There have been some early issues to date with vehicles stopping or parking on the bicycle lanes, and with pedestrians walking on the cycle tracks. However, this is a new treatment for the City of Vancouver and time will be required for education of motorists, pedestrians and cyclists, and enforcement of violations. As the project is still under construction, there are as yet no data available to provide information on bicycle volumes or overall safety. Anecdotal feedback from early users (particularly cyclists) has been very positive.

Conclusion

The implementation of bike lanes within the constrained street environment of Vancouver has required design and operational tradeoffs and new approaches often unique to each facility. These tradeoffs must be considered and evaluated through the design and consultation process. More work can be done to develop additional bike lanes throughout Vancouver and other design options may emerge, but to date the City has been successful in retrofitting a well-established arterial street system with bike facilities while increasing the number of cyclists using the network.