IMPLEMENTATION OF BICYCLE SIGNALS FOR A TWO WAY CYCLE TRACK ON A ONE WAY STREET WITHIN A FIXED TIME COORDINATED NETWORK

The implementation of a two way cycle track on a one way street creates a contraflow bicycle facility along the corridor. This type of facility does not meet drivers expectations and creates complex manoeuvers at the signalized intersections along the corridor. In order to provide for safe, protected bicycle movements through a signalized intersection bicycle signals with separate signal heads can be provided for each direction of the bicycle track. This paper outlines the development of a two way cycle track along a one-way road with multiple signalized intersection.

Pandora Avenue is a multi-lane one way westbound street in Downtown Victoria. A two way cycle track is being constructed on the north of the road in the summer of 2016. Two of the cross streets connect to highways heading north out of the city (Highway 1 and Highway 17) which creates heavy right turn volumes throughout the day. The corridor includes seven signalized intersections which are part of the City's downtown fixed time coordinated network. Two phasing sequences were reviewed to provide for the vehicles, bicycles and pedestrians at each intersection. This paper will provide an overview of the two phasing sequence options, the evaluation of the options (including modeling results, safety impacts, and user expectations), and the selected option. Protected bicycle corners were explored at the start and ends of the cycle track and at a key intersection where a future priority corridor is planned.

A summary of key considerations on the implementation requirements for bicycle signals for two way cycle tracks will be provided including, controller/cabinet requirements, signal heads, and signage will be provided. Other elements explored in this paper include cycle protection and crossings at the intersections.

Background

Separated cycling facilities within the roadway are gaining popularity as they provide separate facilities for cyclists from moving vehicles. These types of facilities promote the concept of providing for all ages and abilities or for age 8 to 80. These separated facilities can be unidirectional or bidirectional. Bidirectional cycle tracks require less width within the roadway (compared to providing protected facilities on both side of the road). By providing a two way cycle track on one side of the road the other side of the roadway can remain unchanged, which can be a benefit if there is significant parking on one side of the road, a high number of driveways, and/or need to directly access the sidewalk. Based on NACTO[1] the additional benefits of two way cycle tracks are as follows:

- Dedicated and protected space for cyclists by improving perceived comfort and safety
- Eliminates risk and fear of collisions with over-taking vehicles
- Reduces risk of 'dooring' compared to a bike lane, and risk of a doored cyclists being run over by a motor vehicle
- On one way streets provides for contra-flow movement for cyclists

However, two way cycle tracks can create confusing starting and endpoints, provide less connectivity to the opposite side of the roadway, and does not meet drivers' expectations of vehicles (including bicycles) traveling in the same direction. The contraflow nature of two way cycle tracks; especially on one way streets can be stressful for users. Two way cycle tracks also create more complex and more dangerous intersections (based on Dutch and European research). When riding on a two way cycle track the chances of a collision are almost twice as high as on a unidirectional cycle track[2]. This is based on the fact that for motorists, bicycles appear from an unexpected direction as well as from the expected direction.

The focus of this paper will be bidirectional or two way cycle tracks on a one way street.

Options for Cycle Track Intersections

In order to provide for safe, protected bicycle movements through a signalized intersection with a two way cycle track on a one way street bicycle signals with separate signal heads can be provided for each direction of the bicycle track. Two types of intersections for the cycle track can be provided: a standard intersection or Dutch Junctions.

The standard intersection for cyclists maintains the cycle track adjacent to the road and cyclists are provided a stop bar in a similar alignment to the vehicle stop bar, behind the crosswalk. See Figure 1.

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1 http://nacto.org/publication/urban-bikeway-design-guide/cycle-tracks/two-way-cycle-tracks/

2 Traffic safety figures from the City of Antwerp, Belgium.

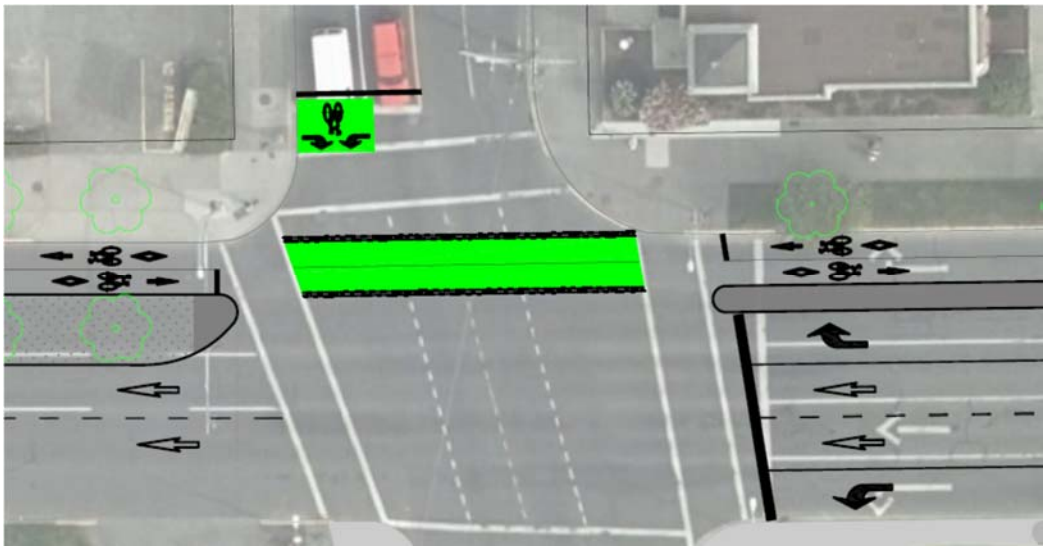


Figure 1: Example of a Standard Two Way Cycle Track Intersection

A Dutch Junction or Protected Intersection allows the cyclists to move ahead of the vehicle traffic and makes them more visible. This type of junction also allows cyclists to make a protected right turn without having to wait for the signal; only for one set of pedestrians. Other benefits of this type of junction are it provides extra time for all users to perceive a conflict, creates an increased protected waiting area, creates shorter crossing distances for pedestrians and cyclists and easier for left turning vehicles to align for a two stage left turn. Dutch Intersections require side street connectivity and depending on the intersection additional space. See Figure 2.

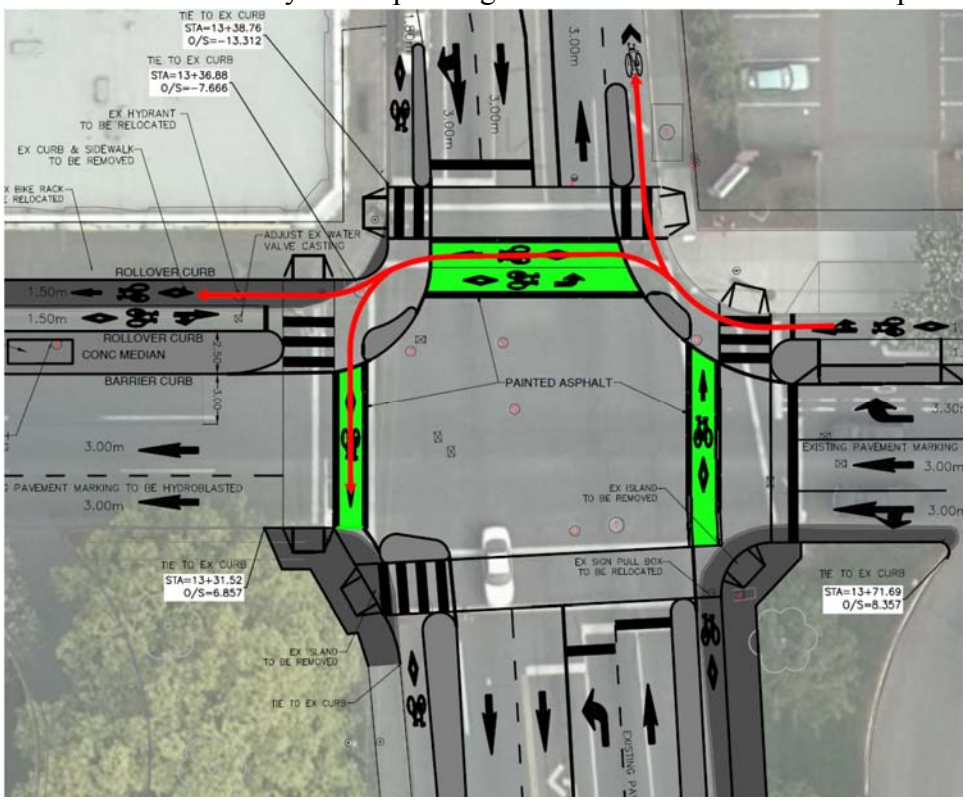


Figure 2: Example of a Dutch Junction at the Termination of a Two Way Cycle Track

Options for Vehicle (Traffic) Signals

When a two way cycle track in on the right side of vehicle traffic on a one way street, a conflict is created between the one way right turning vehicle traffic and the two way cycle track traffic. Two potential options to mitigate the conflict between these two streams of traffic are creating a protected right turn vehicle phase or a cycle track phase. Both of these options require one additional phase to be added to the existing traffic signal cycle. Both options also require that right turns on red for the one way street vehicle movement be banned.

A protected right turn phase option allows the cycle track (bicycle signal) to operate at the same time as the one way vehicle traffic phase followed by the protected right turn phase. See Figure 3. This option requires a separate right turn lane on the one way street and no right turn on red signage. There is the potential for significant noncompliance with the right turn signal; especially for high volume right turns in a fixed timing situation. The length of the right turn signal phase may add significant time to the cycle depending on the volume and may require a long storage lane which may impact on-street parking and/or physical median separation between the roadway and cycle track.

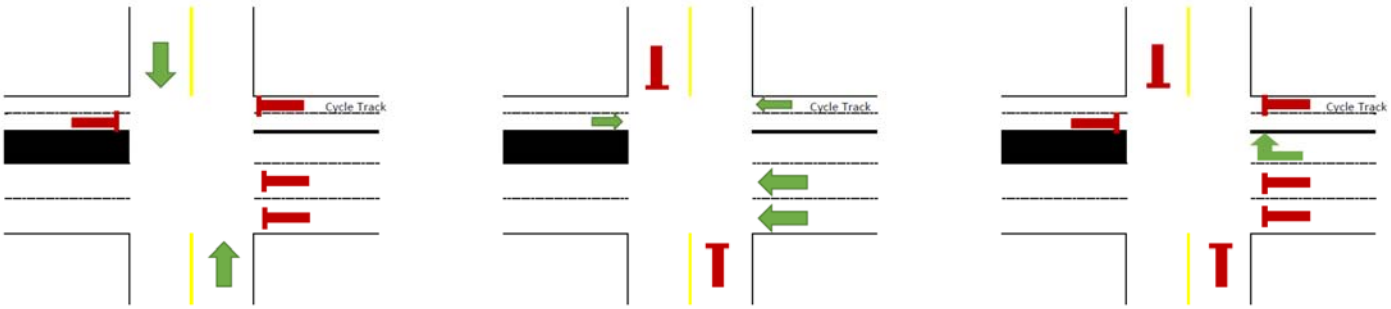


Figure 3: Protected Right Turn Phasing Sequence

The use of a bicycle signal phase is required to be used if there is no separate right turn lane; however, it may also be utilized if there is a separate right turn lane, but no desire to add a separate protected right turn phase. This option will require that right turns on red be restricted. Technically the right turns only need to be restricted during the bicycle phase; however, conveying the message to motorists that right turns are allowed during the opposing vehicle phases, but not the bicycle phase adds too much complexity. Figure 4 illustrates the phasing sequence for the cycle track phase.

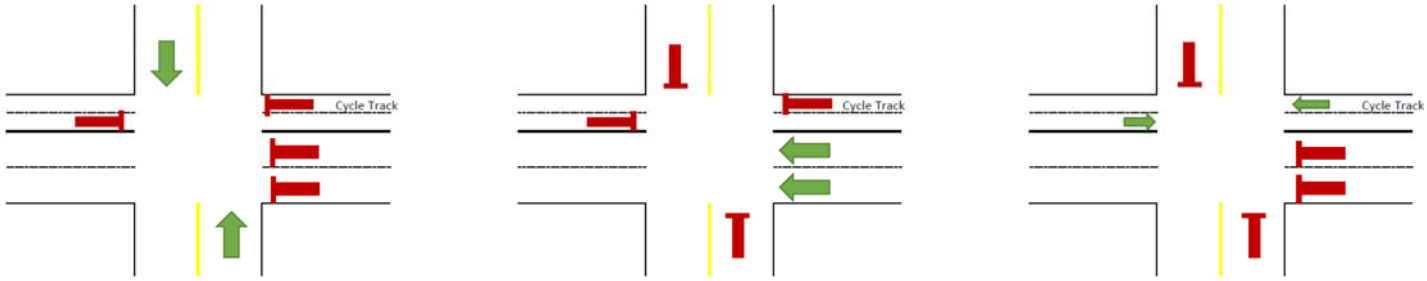


Figure 4: Separate Cycle Track Phasing Sequence

The maximum green time for the bicycle phase may be lower than require to accommodate the right turning vehicle depending on right turn volumes. However, one advantage of the bicycle phase it that the pedestrian phases (on the one way street) can be recalled / extended, which will extend the bicycle length phase, but provide increased crossing time for both pedestrians and bicycles.

Case Study – Pandora Avenue, Victoria, BC

Pandora Avenue is a multi-lane (two to three lane) one way westbound street in Downtown Victoria that carries approximately 10,000 vpd. There is currently on-street parking along both sides of the roadway. A two way cycle track is being constructed on the north side of the road between Cook Street and Wharf Street in the summer of 2016. Two of the cross streets connect to highways heading north out of the city (Highway 1 and Highway 17) which creates heavy right turn volumes throughout the day. The corridor includes seven signalized intersections, of which six are part of the City's downtown fixed time coordinated network and operates together with an adjacent intersection. The seventh signal is an actuate signal that is not part of the downtown coordinated Two phasing sequences were reviewed to provide for the vehicles, bicycles and pedestrians at each intersection. See Figures 5 and 6 for the location of the corridor.

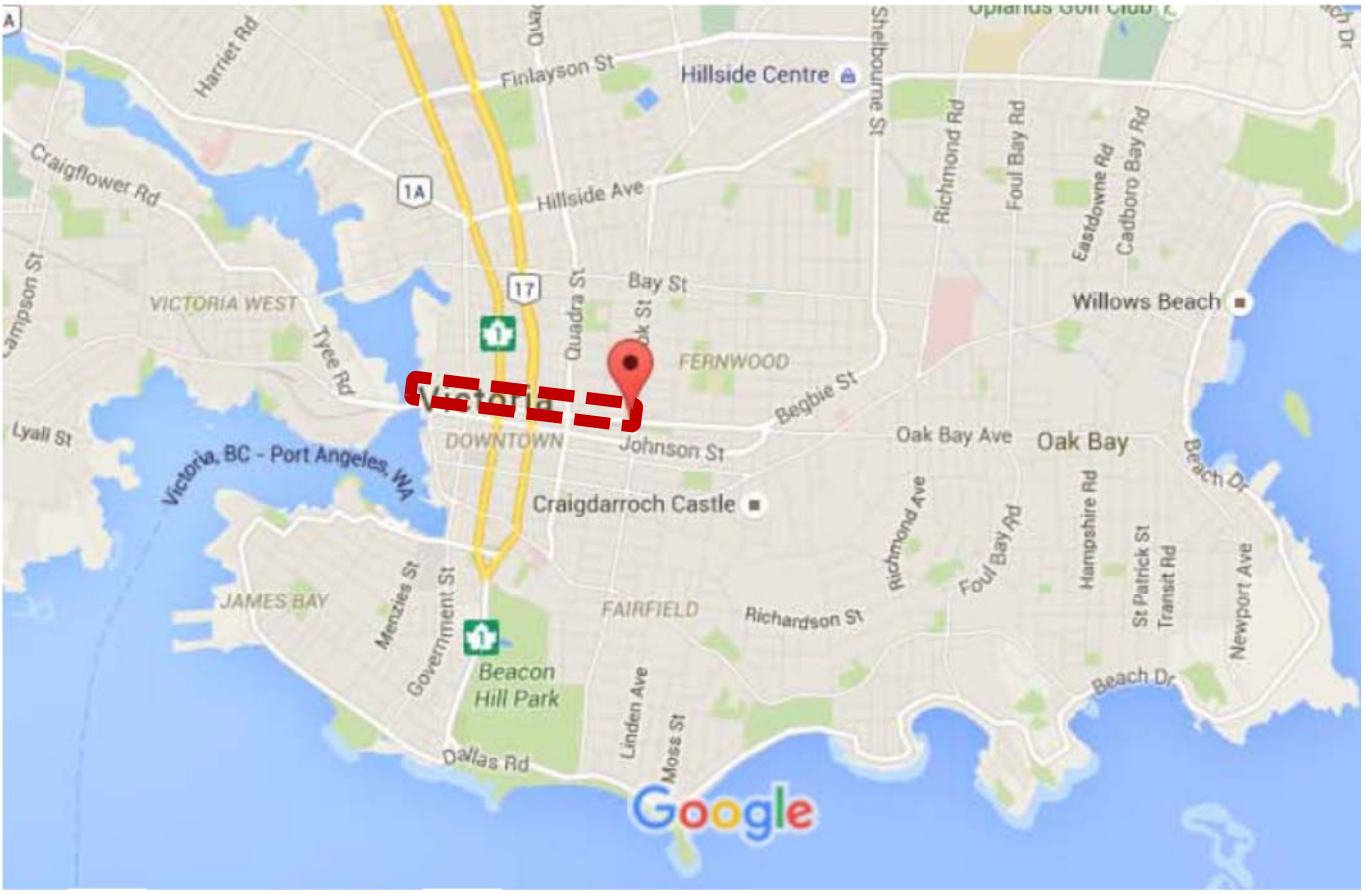


Figure 5: Overview Map of Pandora Avenue, Victoria, BC

Figure 6: Pandora Avenue Two Way Cycle Track Corridor

Fixed Coordination Network

The City's downtown signal network consists of over 30 traffic signals in a fixed time coordinated system. The system has a mixture of hardwired coordination and time based coordination and does not include any vehicle detection. The traffic controllers and cabinets are a mixture of types from pole mounted 2300F Cabinets/6905 Controllers to Econolite ASC/3. As part of the cycle track project all controllers are being upgraded to Econolite ASC/3. Pandora Avenue is not an emergency pre-emption corridor; however, there are emergency (fire, ambulance, police) and transit priority corridors within the network. The transit priority network crosses Pandora Avenue at Douglas Street.

Due to the lack of detection within the network the entire network (including the Pandora Avenue corridor) has four time of day plans with offsets which are as follows:

- AM Peak (0630-0900)
- Mid-Day Peak (1100-1500)
- PM Peak (1500-1800)
- Off Peak (all other times of day)

The time of day plans run Sunday to Saturday. Since this area is within the City's downtown core area pedestrian crossings are provided on all four legs and are called during every phase. The further west along the corridor the higher the pedestrian volumes are along Pandora.

Separate right turn lanes from Cook Street to Government Street were able to be accommodated in the two way cycle track design of the corridor. Separate right turn lanes were identified as required based on the high volumes of right turners at the majority of the intersections. Right turn volumes, typically ranged from 100 to 250 vph throughout the weekday at each of the intersections. With the provision of the separate right turn lane the use of the protected right turn signal was selected as the signal phasing for the six signals within the fixed network as the best option to protect cyclists from right turning vehicles. One of the goals for the fixed network was to maintain the current cycle lengths (60 to 80 seconds) and minimize impacts to the overall vehicle operations. Providing for the bicycles during the westbound vehicle phase provides cyclists will the same maximum green time as the vehicles. The maximum green times ranged between 22 seconds (night time) and 34 seconds (PM peak) and depended on the time of day and intersection. The majority of the intersections received 26 to 27 seconds of green time for the westbound vehicle and two way cycle track phase. Table 1 outlines the level of service at the intersections by time of day.

Table 1: LOS, by Time of Day, with Protected Right Turn Phasing

	NB	SB	WB (Veh+Bike)	WBR (Prot)
Cook St AM	C	C	C	D
Cook St Mid-Day	B	B	C	D
Cook St PM	B	B	D	D
Cook St Night Time	B	B	C	D
Vancouver St AM	C	C	B	C
Vancouver St Mid-Day	C	C	A	C
Vancouver St PM	C	B	D	C

Vancouver St Night Time	C	B	A	C
Quadra St AM	B	B	C	D
Quadra St Mid-Day	B	B	B	C
Quadra St PM	C	C	B	C
Quadra St Night Time	B	B	B	C
Blanshard St AM	B	B	B	F
Blanshard St Mid-Day	C	D	A	D
Blanshard St PM	A	C	B	F
Blanshard St Night Time	C	C	A	F
Douglas St AM	B	B	C	D
Douglas St Mid-Day	C	C	B	D
Douglas St PM	C	C	D	E
Douglas St Night Time	C	C	B	F
Government St AM	B	B	B	B
Government St Mid-Day	B	B	A	C
Government St PM	B	B	A	C
Government St Night Time	B	A	A	D

As the above table illustrates the addition of the protected westbound right turn does not significantly impact traffic operations for the majority of intersections; however, at the two busiest right turns (Douglas Street and Blanshard Street) poor traffic operations will be experienced throughout the day for the right turn movement. Other movements at those two intersection continue to operate at reasonable LOS. It is expected that westbound right turners will shift along Pandora Avenue to alternate right turns and/or utilize parallel roads within the downtown including Yates Street (also one way westbound).

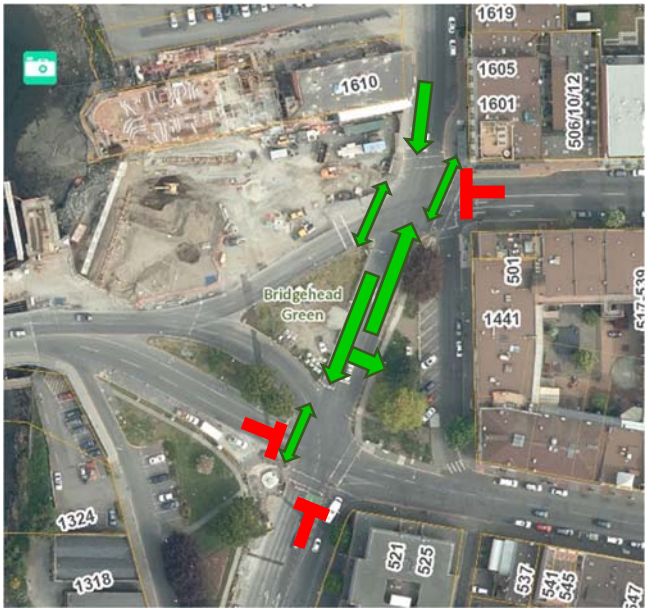
Wharf Street / Pandora Avenue

The intersection of Wharf Street/Pandora Avenue is actually the convergence of two one-way streets to two way operations. This is further complicated by the merging occurring immediately east of the Johnson Street Bridge (currently under construction). Locally the intersections of Wharf/Pandora and Wharf/Johnson are referred to as the bridgehead. Pandora Avenue is the one way street westbound and Johnson Street is the one way street eastbound. Wharf Street is the last north-south roadway on the east side of the Johnson Street Bridge (blue bridge). While the scope of the Pandora two way cycle track project excludes Johnson Street and the west side of Wharf Street they were required to be included in the signal analysis since one traffic controller operates the two intersections together. Also since these two intersections operate as one this intersection operates independent of the downtown fixed time network and both intersections have loop detection for actuation. See Figure 7 for the two intersections.

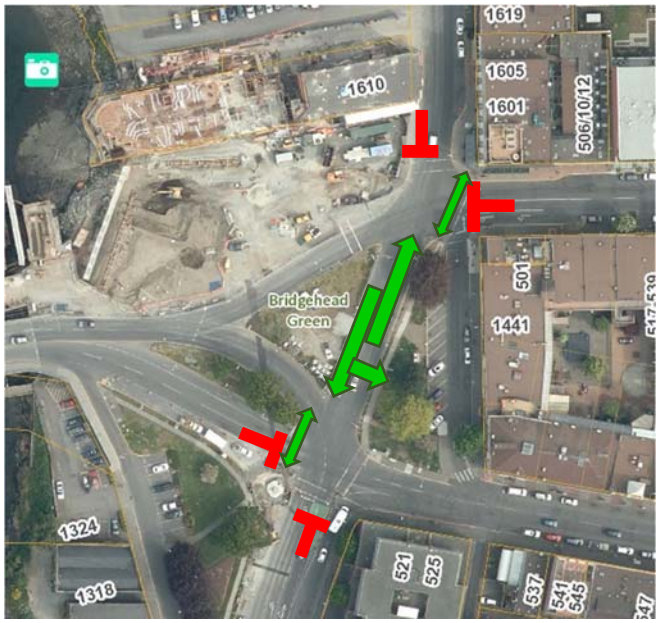
Figure 7: Wharf Street/Pandora Avenue and Wharf Street/Johnson Street

The existing signal phasing for these two intersections is as follows:

Phase 1: East- West



Phase 2: NB-SB at Pandora; SB at Johnson



Phase 3: NB Pandora; SB Johnson to Clear

Phase 4: NB Pandora and Johnson

Based on the existing right-of-way, existing constraints within the pedestrian realm, fixed curb alignments completed by the Johnson Street Bridge construction project on the west side of Wharf Street, and capacity requirements a separate right turn lane on Pandora Avenue was not able to be accommodated at Wharf Street. Therefore a separate bicycle phase was required to be implemented. Along the corridor this intersection has one of the lower westbound right turn movements with 30 to 80 vph throughout the day. Wharf Street has a significant volume of

pedestrians (over 200 per hour) crossing through the intersection as it connects Chinatown, downtown retail and restaurants, and the City's Inner Harbour. Since the bicycle phase was selected, there is a high pedestrian volume, and the cycle length was not required to be a set time it was determined that there would be significant benefit to providing a bicycle phase that also allowed for the pedestrian phases to be recalled / extended. This required ensuring that the maximum green time for the bicycle phase was equal to or exceeded the walk plus pedestrian clearance time (24 seconds). The bicycle phase can occur before the east-west vehicle phase or after the east-west vehicle phase. However, since the east-west phases will add vehicles to the short section between Johnson and Pandora Avenue it was selected to have the bicycle phase occur before the east-west phases. Therefore this phase will be added to the existing phasing between Phase 4 and Phase 1. See Figure 8 for the bicycle phase to be added to the existing phasing.

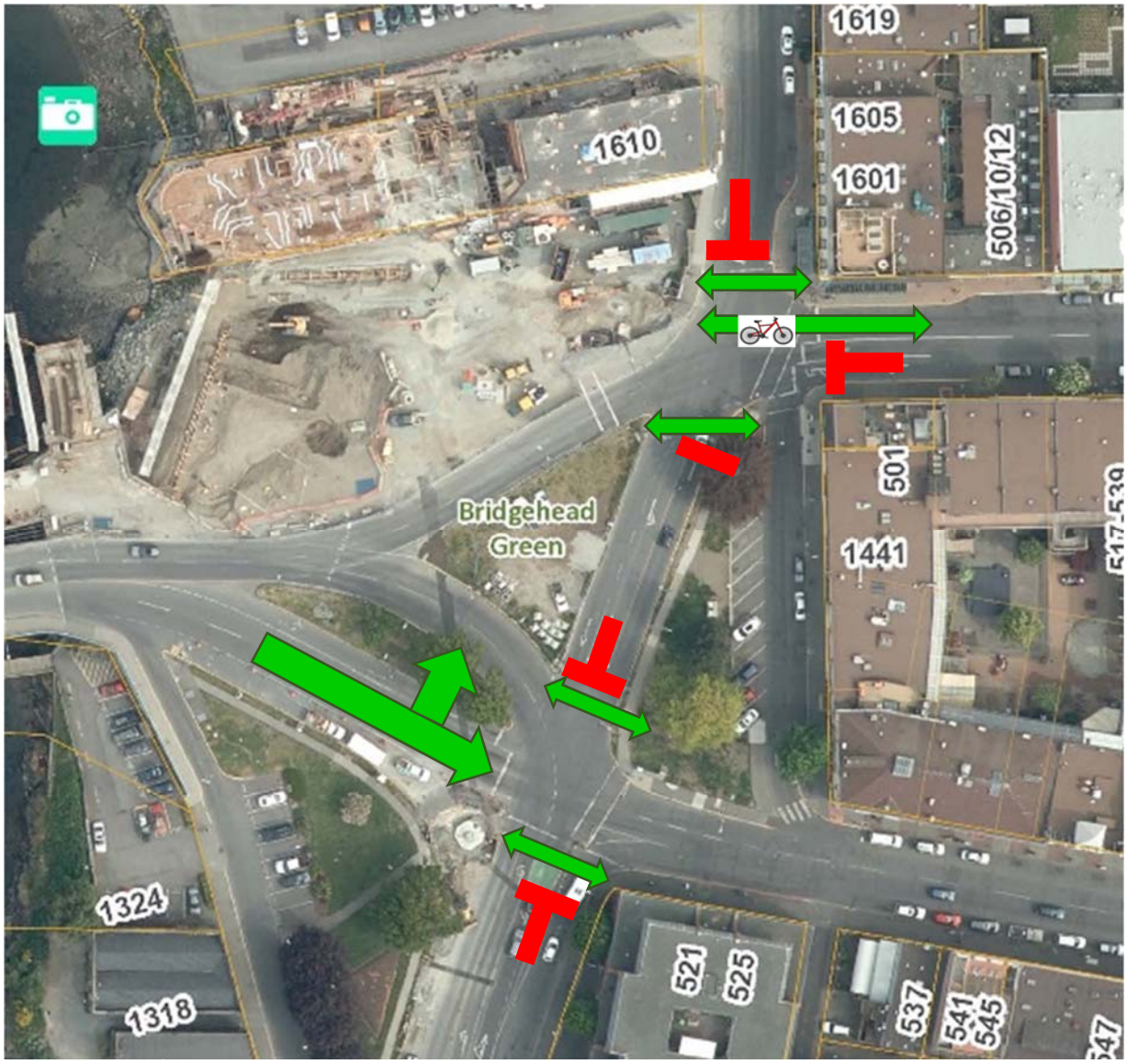


Figure 8: Bicycle Phasing at Pandora/Wharf and Johnson/Wharf

Signal Heads and Signage

For the separate right turn phase option an additional vehicle signal head is required to be added to the vehicle traffic signals. This signal head is a three piece signal head with a red, yellow (amber), and green right turn arrow. A Right Turn Signal Sign (RB-17R) is to be added adjacent to the signal head on the overhead pole. No Right Turn on Red (RB-17R) signage should be added to re-enforce the right turn on red restriction. This signage should be on the far side overhead pole and on the near side in the median. A modified RB-18 (Right Turn Signal) sign will also be required to be mounted adjacent to the right turn signal head. See Figure 9 for details.

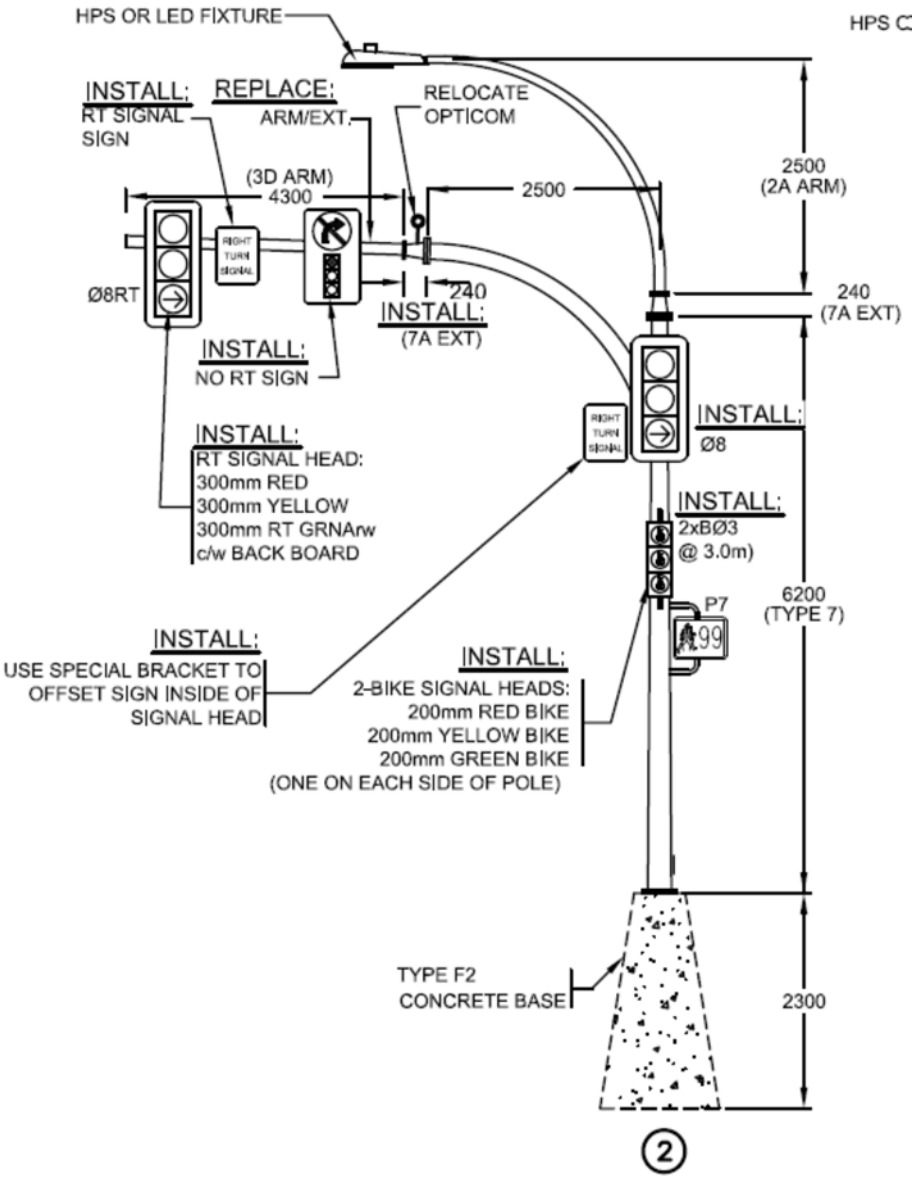


Figure 9: Example of a Protected Right Turn Signal Pole (courtesy GNEC 90% Pandora Coordination Design Drawings)

For the bicycle signal phase option separate bicycle signals are provided along the entire corridor for the bicycles and there is no change at an intersection with a bicycle only phase. For the vehicle traffic the No Right Turn on Red (RB-17R) signage is critical to inform right turning vehicles of the right turn on red restriction. This signage should be on the far side overhead pole and on the near side in the median. Enforcement may be required during the initial implementation of this restriction.

For the bicycle signal the three head display of a red bicycle, yellow (amber) bicycle, and green bicycle are provided in each direction on the far side of the intersection from the bicycle stop bar, similar to how a vehicle traffic signal is place. The bicycle signal heads are placed above the pedestrian signal, but below the secondary signal heads. See Figure 9 for an example.

Summary

Once a two way cycle track on a one way street has been selected as the design for the cycling facility along a corridor the consideration of vehicle / bicycle conflicts are required to be assessed and the type of intersection control for bicycles selected. In the case of a two way cycle track on the right side of a one way street there is a conflict between right turning vehicles and contraflow cyclists that is unexpected and requires protection. The implementation of a bicycle signal will provide this protection; however consideration for the vehicle/bicycle phasing and the type of bicycle intersection is needed.

This paper outlines of two intersection types for bicycles: standard intersections and Dutch Intersections. While Dutch Intersections provide significant benefits including protected areas for cyclists to wait, they require side street connectivity and an increased footprint. Standard bicycle intersections can safely accommodate two way bicycle movements through an intersection; however vehicle phasing needs to be considered to increase protection for the cyclists. The type of phasing and its impact on the intersection's operation is required to be assessed. Two options for phasing include a protected right turn vehicle phase (with bicycles operating with the one way street's through movement) and a separate bicycle phase. The designer needs to consider traffic volumes, especially right turning volumes, pedestrian and bicycle volumes, type of signal control (actuated, fixed time), and available laning in determine the appropriate phasing. In all cases right turns on red are required to be banned through signage and an education program with the community.

Author Information
Nadine King, P.Eng., PTOE
Senior Transportation Engineer
Boulevard Transportation, a division of Watt Consulting Group
#201-791 Goldstream Avenue
Victoria, BC V9B 2X5
Ph. 250-388-9877
Fax. 250-388-9879
Email. nking@blvdgroup.ca / nking@wattconsultinggroup.com