

Median Bus Lane Design in Vancouver, BC: The #98 B-Line

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ABSTRACT

The #98 B-Line rapid bus service was planned to provide fast, reliable, and frequent bus service to connect Downtown Vancouver and Richmond City Center – a fast growing suburban business corridor. The #98 B-Line service covers a total distance of 16 km (10 mile) with 37 stations round trip spaced on average at approximately 1.0 km (0.6 mile) apart. Peak travel times were projected 39 to 42 minutes from previously 45 to 48 minutes travel times. The bus fleet consisted of 23 articulated buses operated at 6-minute headway during the peak periods.

In order to provide the #98 B-Line with more competitive travel speeds, transit priority measures were provided along the appropriate sections of the route. As a key transit priority measure, 2.0 km (1.2 mile) two directional median bus lanes were implemented on No.3 Road between Westminster Highway and Sea Island Way in Richmond. The median bus lanes encompass 11 signalized intersections, 4 median bus stops in each direction, and many abutting businesses.

This paper will discuss the considerations of median bus lanes, the access management schemes along the corridor, traffic operations at signalized intersections to accommodate U-turn provisions, the intersection design with offset opposing left-turn bays, the treatments at the transition area to the median bus lanes, and the median bus stop design parameters.

INTRODUCTION

The #98 B-Line is a key component of the Greater Vancouver Region's transit system. It is designed to provide a bus based rapid transit system using advanced bus technology and portions of dedicated right-of-way. The 16 km (10 mile) route connects Richmond City Center, the Vancouver International Airport, and downtown Vancouver, supporting the region's growth management goal of linking major city centers with high quality transit service. (1)

Richmond Center has experienced rapid growth in the past decade. The City Center has a population of 27,000 and an employment base of 32,000. There is 4.5 million square feet of commercial floor space, the second highest among the region's suburban centers. It also has the second highest concentration of hotel rooms in the region.

The Vancouver International Airport is Canada's second largest Airport with over 15 million passengers per year and with 20,000 employees; it is one of the region's largest employment centers. Much of the growth in Richmond is attributed to the Airport. Richmond is also a center for much of the region's high technology industry.

The emergence of Richmond City Center and the Airport as key regional destinations has resulted in significant changes to the travel patterns. In contrast to the traditional suburb to CBD travel demand, the travel demand is balanced in both directions throughout the day.

TransLink undertook a major investment in a bus-based rapid transit for the corridor. The cost of the project is \$50 million with contributions from Government of Canada through the federal infrastructure program, the Vancouver International Airport Authority, and the City of Richmond.

The #98 B-Line commenced service in August 2001. Within Richmond City Center, the #98 B-Line is operated in the new 2.0 km (1.2 mile) median bus lanes from Westminster Highway to Sea Island Way. There are 4 stations in each direction along the median bus lanes.

This paper discusses the topics related to the #98 B-Line service planning and the median bus lane design considerations. Following the introduction, the paper focuses on deliberation of the following key issues:

- considerations of implementing median bus lanes;
- access management along the median bus lanes;
- traffic operational issues at intersections with median bus lanes;
- transition to the median bus lanes; and
- median bus stop design parameters.



Figure 1. The #98 B-Line Route Concept.

CONSIDERATIONS OF MEDIAN BUS LANE IMPLEMENTATION

Route Selection

Route alternatives were generated during the planning phase of the project. Route alternatives were evaluated based on their suitability for the #98 B-Line service objectives, operational issues, and the potential community impact. The service objective comprised of the access to the major activity centers along the route. It considered the proximity to the major activity centers, rider origins and destinations, and the potential to attract more riders (2).

Bus operational issues mainly consisted of bus travel times, ease of operation, and schedule reliability. It analyzed to what extent the #98 B-Line service will be affected by the general-purpose and the pedestrian traffic and what mitigation measures would be required to mitigate the effects. Community impact assessments included impact on existing traffic, pedestrian, local businesses, and residential activities within the urban community.

The analyses resulted in the selection of No.3 Road among the alternatives in the City of Richmond based on a number of key factors including land use, potential ridership increase, and the future plan for rapid transit service in the middle of No.3 Road.

Existing No. 3 Road

No. 3 Road was first developed as a suburban arterial servicing both regional and local commercial activities. In the regional context, No. 3 Road is a key corridor connecting the City of Richmond, the Vancouver International Airport, and the City of Vancouver. It also represents one of the busiest City center commercial corridors in the region. It hosts a number of big box shopping malls as well as stripe malls in various sizes. Prior to the introduction of the median bus lanes, different design cross section standards were used on the section of No. 3 Road between Westminster Highway and Sea Island Way. For example, on the 0.8 km (0.5 mile) section from Ackroyd Road to Alderbridge Way, there was sidewalk on the east side of the road. Along the west side, there was a frontage road providing direct access to the abutting businesses.

On the 1.2 km (0.75 mile) section between Alderbridge Way and Sea Island Way, sidewalk was provided on one side only. Access to abutting businesses was provided by a two-way-left-turn lane, which had been an on going safety concern as the driveways were spaced densely at 20 to 30 m (60 to 100 ft) with a relatively high posted speed of 50 km/h (30 mile/hr).

The implementation of median bus lanes provided the opportunity to upgrade No. 3 Road to an urban design standard with sidewalk on both sides, to eliminate the two-way-left-turn lane, and to beautify the streetscape with banner poles and elimination of overhead power wires. Figure 2 illustrates the before and after effects of the median bus lanes.



a) No. 3 Road prior to median bus lanes



b) No. 3 Road after median bus lanes

Figure 2. No. 3 Road Before and After the Median Bus Lanes.

Issues of Median Bus Lanes

There are a number of pros and cons of the median bus lane arrangement versus curb bus lane arrangement. One issue of the median bus lanes is that it would complicate the intersection signal operations as the left-turn movements parallel to the bus lanes would have to turn from the right-hand side of a bus lane; this has in fact resulted in some incidents between the left-turn vehicles and the through buses during the first few months after the #98 B-Line commenced service. The introduction of the median bus lanes also resulted in wider intersections requiring more walk time and vehicle clearance times for signal operations. The side street left-turn motorists also tend to turn into the median bus lanes resulting in risk of head on collisions with an oncoming bus; this was mitigated with continuity lines to guide the side street left-turn motorists into the correct lanes.

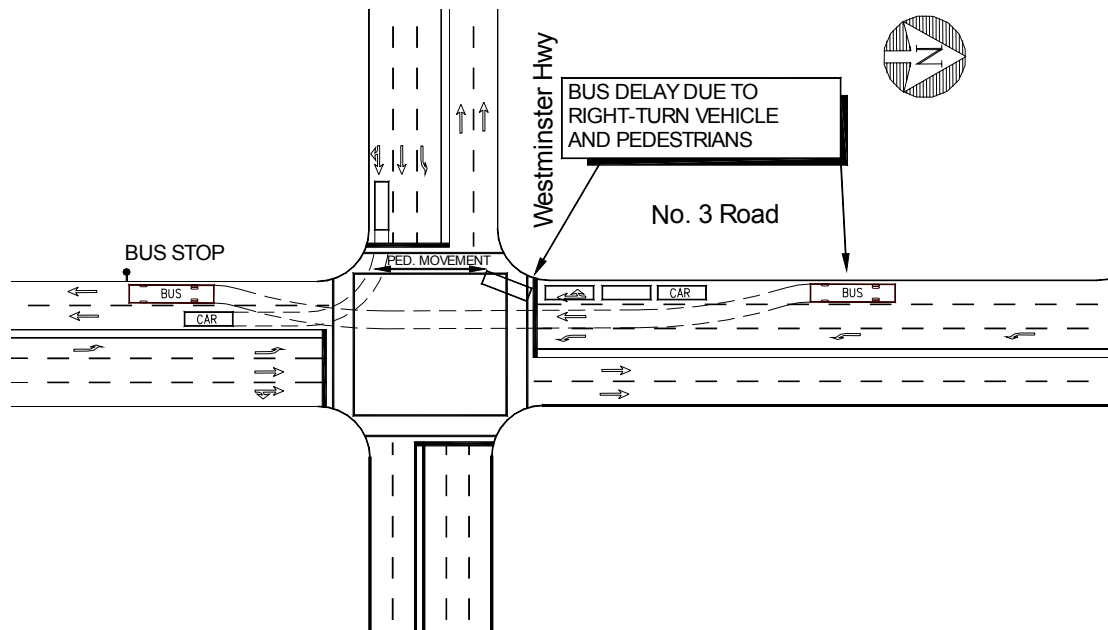
The median bus lane arrangement would also require passengers to cross the general-purpose lanes to access the median bus stops; this would in turn require the median bus stops be located at signalized intersections to facilitate passenger accessing the bus stops. The median bus stops would be used almost exclusively by the #98 B-Line service; other local bus services on No.3 Road would have to be operated in the general-purpose curb lane due to difficulties to get into / out of the median bus lane at intermediate intersections; this would preclude the possibility of shared bus stop arrangement with the local bus services. Finally, the construction cost of the median bus lanes would be higher than the curb bus lanes largely due to the additional property requirements to separate the bus lanes with the general-purpose lanes especially at the intersections with left-turn bays and the median bus stop platforms.

Benefit of Median Bus Lanes

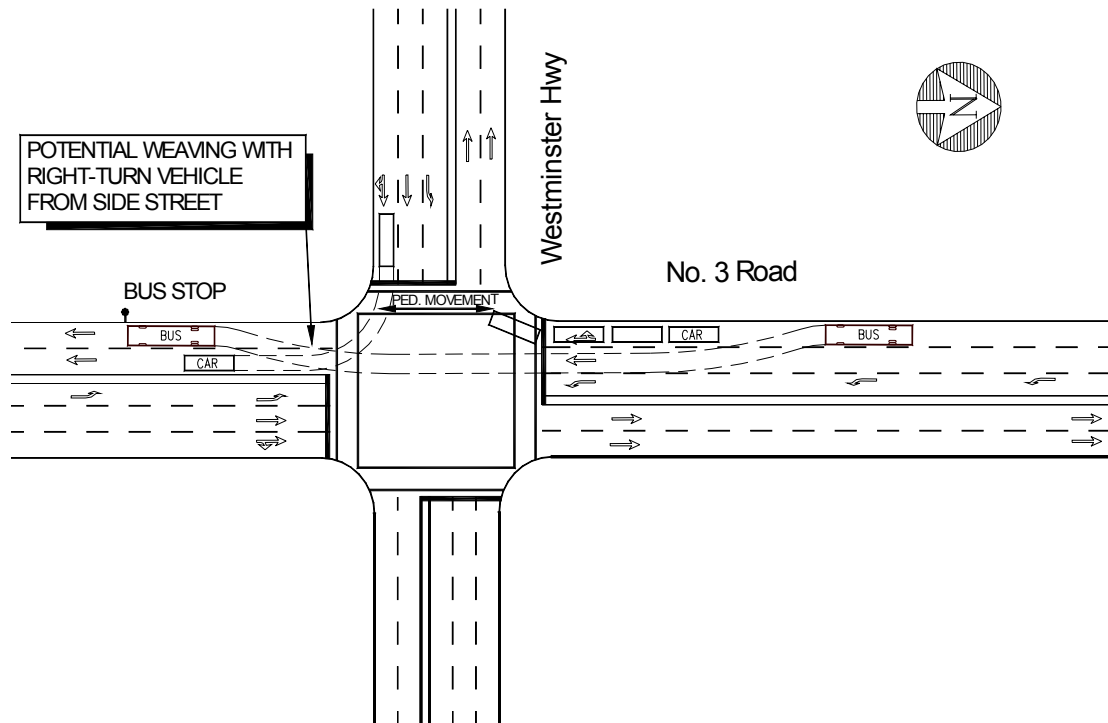
The major benefit of the median bus lanes is that the travel time delays at intersections can be significantly reduced; this in turn provides greater reliability for the service. Transit operators have reported that buses in the curb lane (the right-hand lane) are often delayed due to the right-turn vehicles having to yield to the pedestrians crossing the side street. Figure 3a) demonstrates this effect. Despite the delay, transit operators often choose to stay in the curb lane rather than to bypass the traffic queue of the right-turn traffic. This is because the bus is to make a stop at the far-side bus stop; many transit operators try to avoid the potential weaving with the side street right-turn movement as illustrated in Figure 3b) by staying in the curb lane.

In order to promote future rapid transit initiative and to avoid the friction and delay to the #98 B-Line service generated by the high number of right-turn into/out of commercial driveway and other side streets, the median bus lane concept was preferred to the traditional curb side operation. In addition, the exclusive operation of the #98 B-Line in the dedicated median bus lanes would further enhance the reliability of travel times without undue congestion caused by other traffic along the corridor.

The selection of the median bus lane concept required a number of issues to be resolved during the detailed design stage to mitigate impacts on the community adjacent to the corridor including access to abutting businesses, traffic operations at the signalized intersections, the transitions to the median bus lanes, and bus stop design issues.



a) Bus delay due to right-turn traffic and pedestrian crossing side street



b) Potential weaving with right-turn traffic from side street

Figure 3. Bus Delay and Operational Concerns at an Intersection.

ACCESS MANAGEMENT

A major design issue was to minimize impact on business access along the median bus lanes on No.3 Road between Westminster Highway and Sea Island Way. This section of No. 3 Road represents the busiest commercial corridor hosting a number of businesses. For example, there were more than 80 driveways directly off No.3 Road - approximately 30 driveways are on the east side of No.3 Road, and 50 driveways on the west side. This represents on average 60 to 100 m per driveway (200 to 330 feet per driveway).

Existing Accesses Prior to Median Bus Lanes

Prior to the median bus lanes, the businesses on No. 3 Road enjoyed good access to No.3 Road in both the northbound and the southbound directions. For example, on the 0.8 km (0.5 mile) section between Ackroyd Road and Alderbridge Way, there were 20 driveways that were serviced in both the northbound and the southbound directions by the Frontage Road immediately west of No.3 Road. With the introduction of the median bus lanes, the Frontage Road would be converted to two southbound lanes resulting in loss of access to the northbound direction.

On the 1.2 km (0.75 mile) section between Alderbridge Way and Sea Island Way, the existing road had a two-way-left-turn lane providing direct access to No.3 Road in both directions. The introduction of the median bus lanes would eliminate the two-way-left-turn lane resulting in restricted access to one direction only. This had generated a significant concern to the abutting business owners.

U-turn Provisions with Median Bus Lanes

A consultation process was initiated involving the adjacent business/property owners as well as general public to develop measures in maintaining convenient access to the businesses. As a result, provisions for U-turns were identified to allow U-turns under signal control at six intersections. To ensure traffic operation safety and efficiency, other access management measures such as driveway consolidation, right in / right out restrictions were also implemented at selected locations. Special signage was developed to permit U-turns at the pre-determined locations. Figure 4 denotes the locations where U-turns are permitted and the U-turn permission signage.

TRAFFIC OPERATIONS

The traffic operational impact of the median bus lanes is primarily associated with the elimination of the two-way-left-turn lane that existed in the center of the road and the required changes to the traffic signal operations along the corridor. The elimination of the two-way-left-turn lane and the provision of the U-turns at signalized intersection would introduce additional left-turn traffic volume at the intersections. To reduce the need for longer left-turn bays and the need for longer signal cycle time, the U-turn provisions were selected at intersections with relatively less side street traffic.

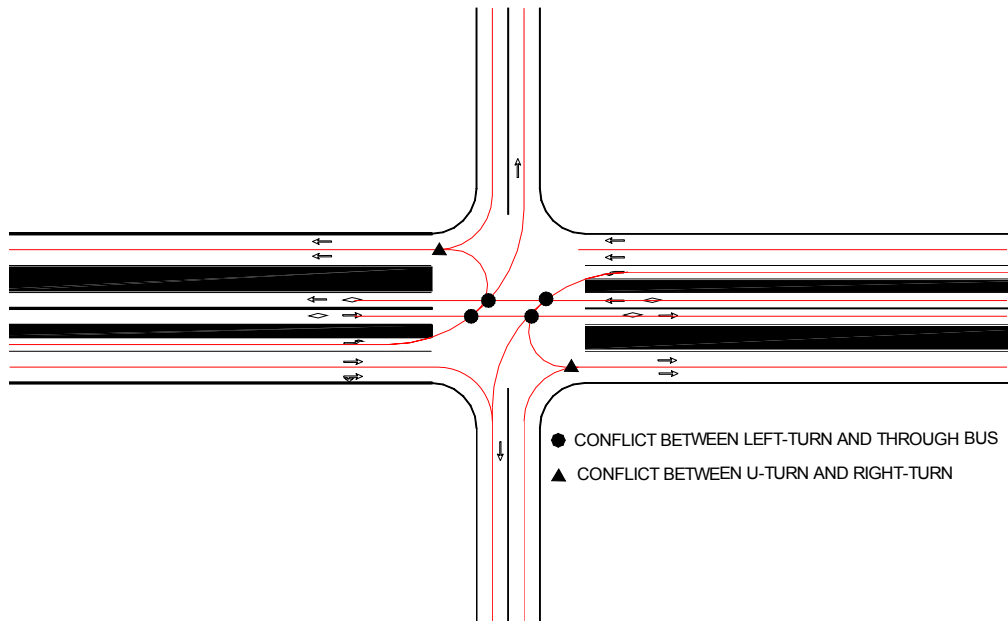
Accommodating U-turns at Signalized Intersections

The introduction of the median bus lanes and the U-turn provisions also generated additional potential conflict points at the intersections as indicated in Figure 5a). To eliminate these potential conflicts, left-turn and U-turn movements are permitted only under the protected left-turn signal phase.

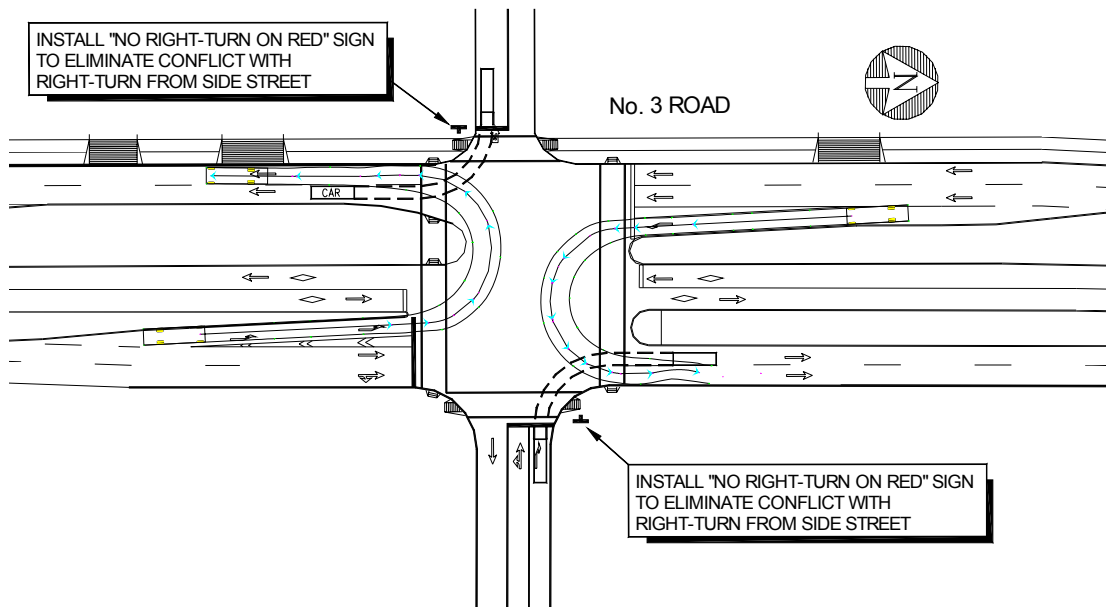
As many abutting businesses required delivery by large trucks, the intersection design accommodated SU-9 type vehicle. In addition to the U-turn signage, continuity lines indicating U-turn vehicle path is also used to emphasize positive direction for the U-turn motorists. As most vehicles would require the two opposite lanes to complete a U-turn, a “no right turn on red” sign is installed at the side street to ensure clear right-of-way for the U-turn motorists. Figure 5b) illustrates the U-turn vehicle tracking and the signage consideration.

Simultaneous Left-turns

As illustrated Figure 6, in the north-south direction, the median bus lanes and the station platforms created a 7.0 to 13.0 m (22 to 42 ft) offset between the northbound and the southbound left-turn lanes. The natural paths of the left-turn maneuvers would face a risk of conflict with the opposing left turn vehicles. To ensure efficient signal operations, the intersection is designed to accommodate simultaneous left-turn phase. Special vehicle turning templates were used to determine the setback of the median nose and to locate the continuity lines providing positive guidance for the left-turn traffic. Ensuring simultaneous left-turn phase was an important design feature in avoiding split phase signal operations therefore resulted in significant travel time savings for all traffic on the corridor.

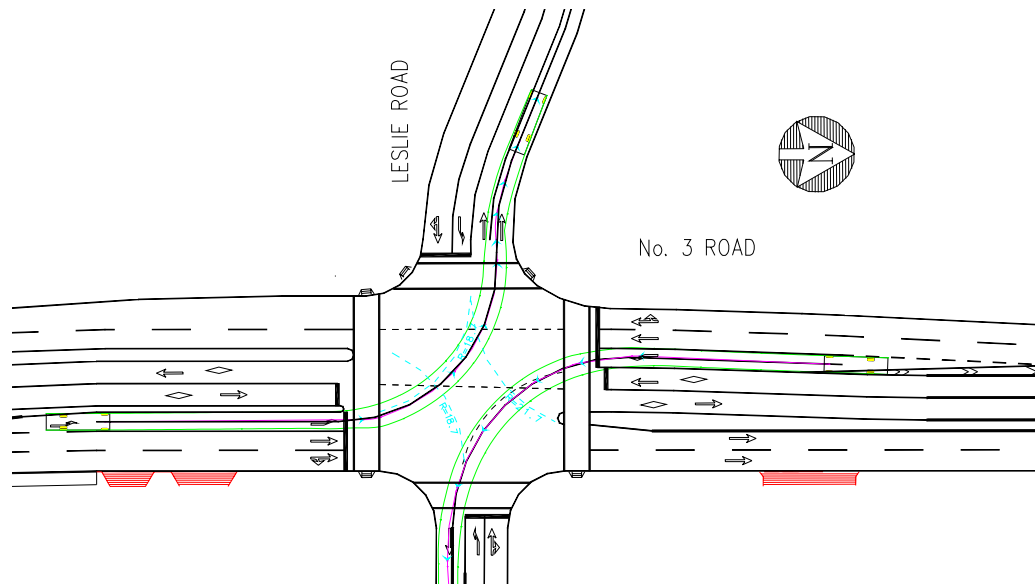


a) Major potential conflict points introduced by median bus and U-turn movements

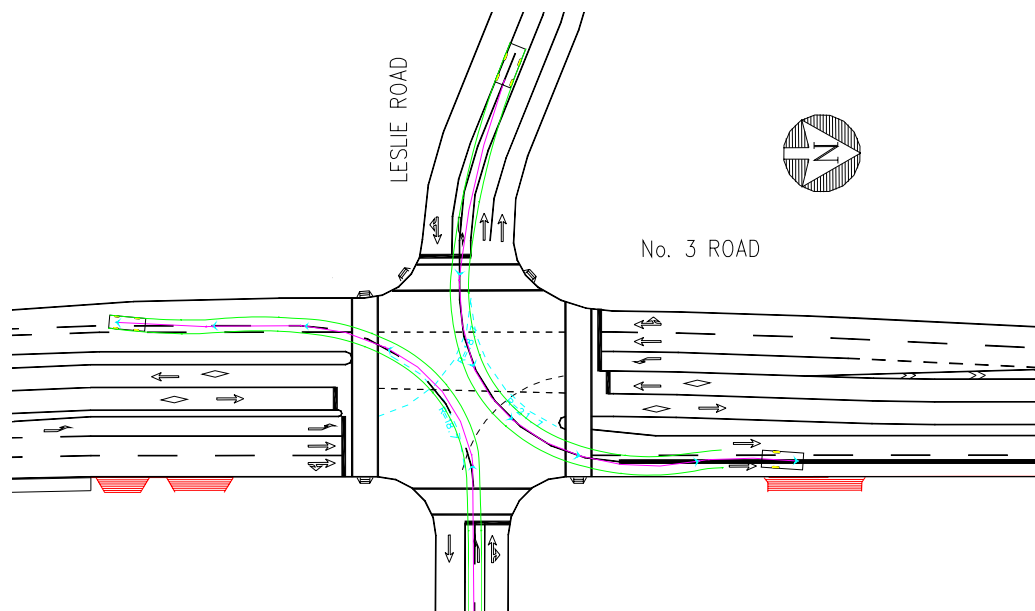


b) U-turn tracking with “no right-turn on red” sign at east-west side street

Figure 5. Potential Conflicts due to Median Bus and U-Turn Movements.



a) Simultaneous left-turn in the north-south directions (across median lanes)



b) Simultaneous left-turn in the east-west directions (cross street)

Figure 6. Accommodating Simultaneous Left-Turns.

TRANSITIONS TO THE MEDIAN BUS LANES

To enter the median bus lane, the #98 B-Line buses would potentially weave across the general-purpose traffic to get from the curb lane to the median lane. Likewise, to exit the median bus lane, the #98 B-Line buses would potentially weave with traffic to get from the median lane to the curb lane. Bus operational considerations such as operator decision distance, and weaving/lane change distance were addressed in the transition areas.

The South End Transitions

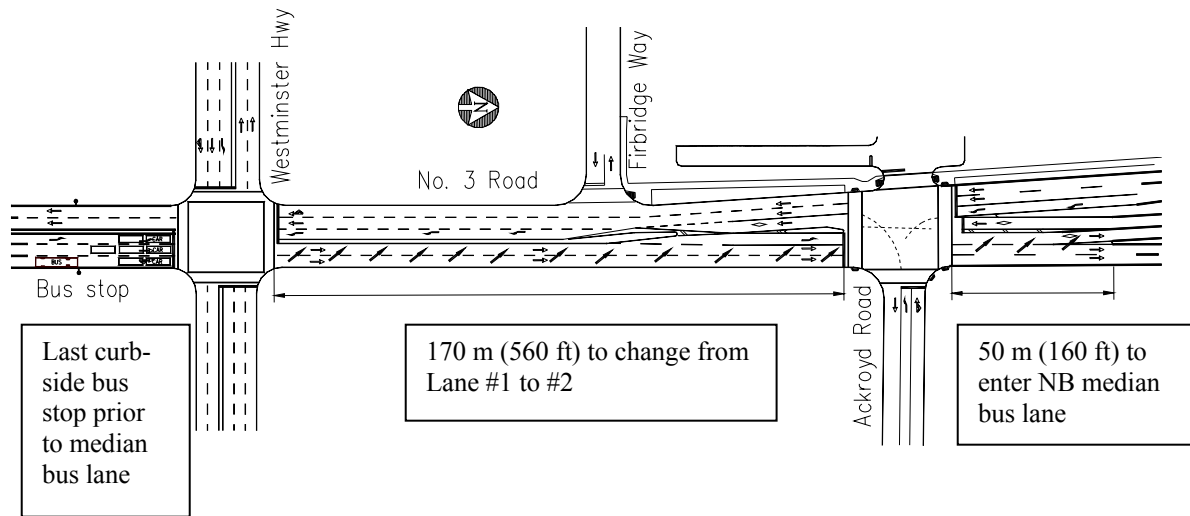
The northbound entrance to the median bus lane is immediately far side of Ackroyd Road. Buses are required to enter the median bus lane under the northbound through signal phase. The distance from the upstream curb side bus stop to the bus lane is approximately 200m (650 ft) providing sufficient distance for the bus to leave the curb-side bus stop and to make necessary lane changes to enter the median bus lane. Figure 7a) illustrates the transition to the northbound entrance.

At the southbound exit of the median bus lane, transit operators have expressed concerns over the potential right-hand side merge/weave with general-purpose traffic due to the sight line limitations to the right-hand side of the bus. To facilitate the #98 B-Line bus to reach the curb lane as soon as it leaves the median bus lane, the southbound bus lane is provided with a dedicated phase that stops the traffic in the southbound general-purpose lanes; this resulted in elimination of the right-hand merge/weave with the general-purpose traffic. Figure 7b) illustrates the southbound bus lane exit at Ackroyd Road.

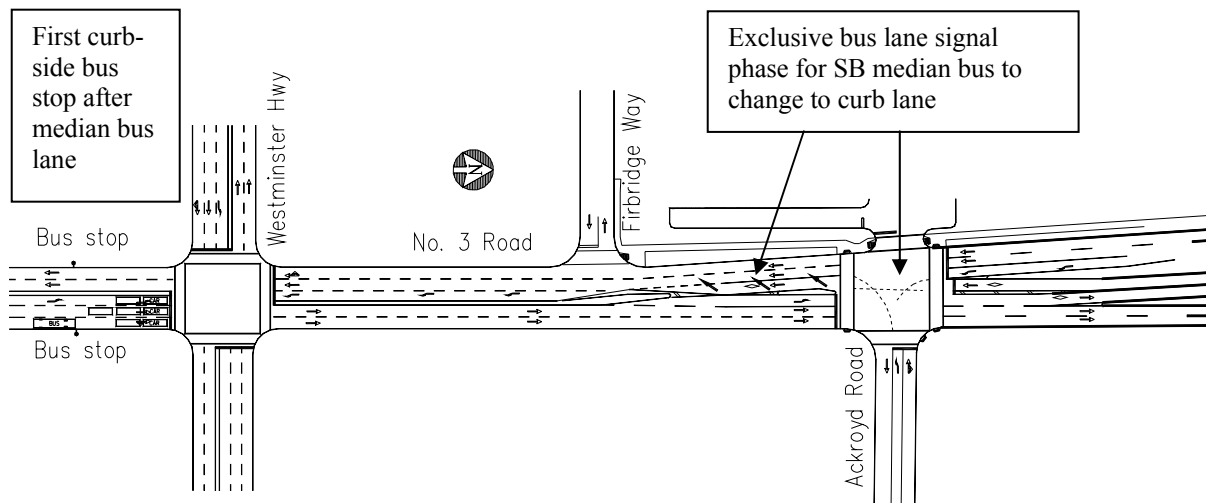
The North End Transitions

The southbound entrance to the median bus lane is located at the mid-block point approximately 80 m (260 ft) south of Sea Island Way. This allowed sufficient distance for the bus to change to the second lane and enter the median bus lane after completing the right-turn from eastbound Sea Island Way to southbound No.3 Road. A transit signal priority measure was also deployed to extend the eastbound green phase when the #98 B-Line bus is making the right-turn therefore reducing the possibility of weaving with the southbound general-purpose traffic. Figure 8a) provides detailed lane arrangement for the southbound entrance.

To exit the northbound bus lane, the #98 B-Line bus must make a left-turn from the northbound median lane to the westbound curb lane on Sea Island Way. A protected bus-only phase is provided for this median bus movement. To reduce the potential conflicts with the right-turning traffic from the southbound to the westbound, a yield sign is installed to clarify the right-of-way for the northbound median bus movement. Figure 8b) shows the arrangement at the northbound bus lane exit.

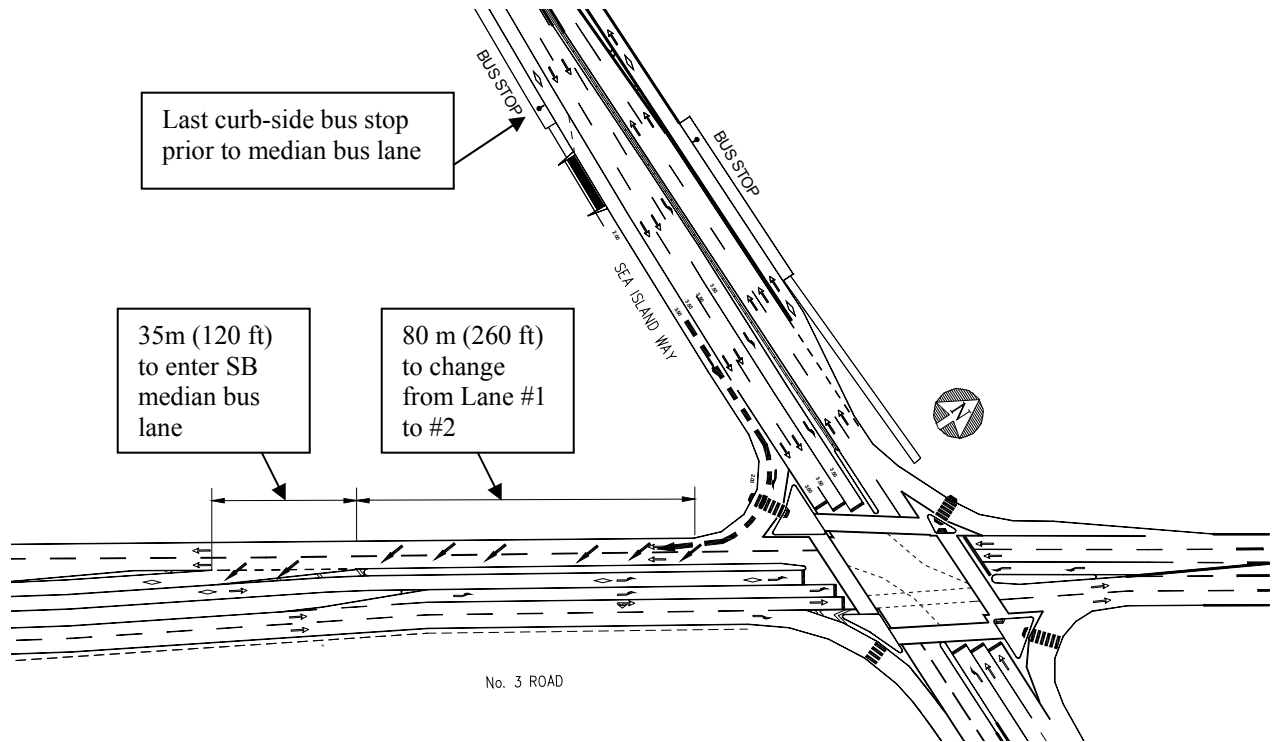


a) Northbound entrance to median bus lane

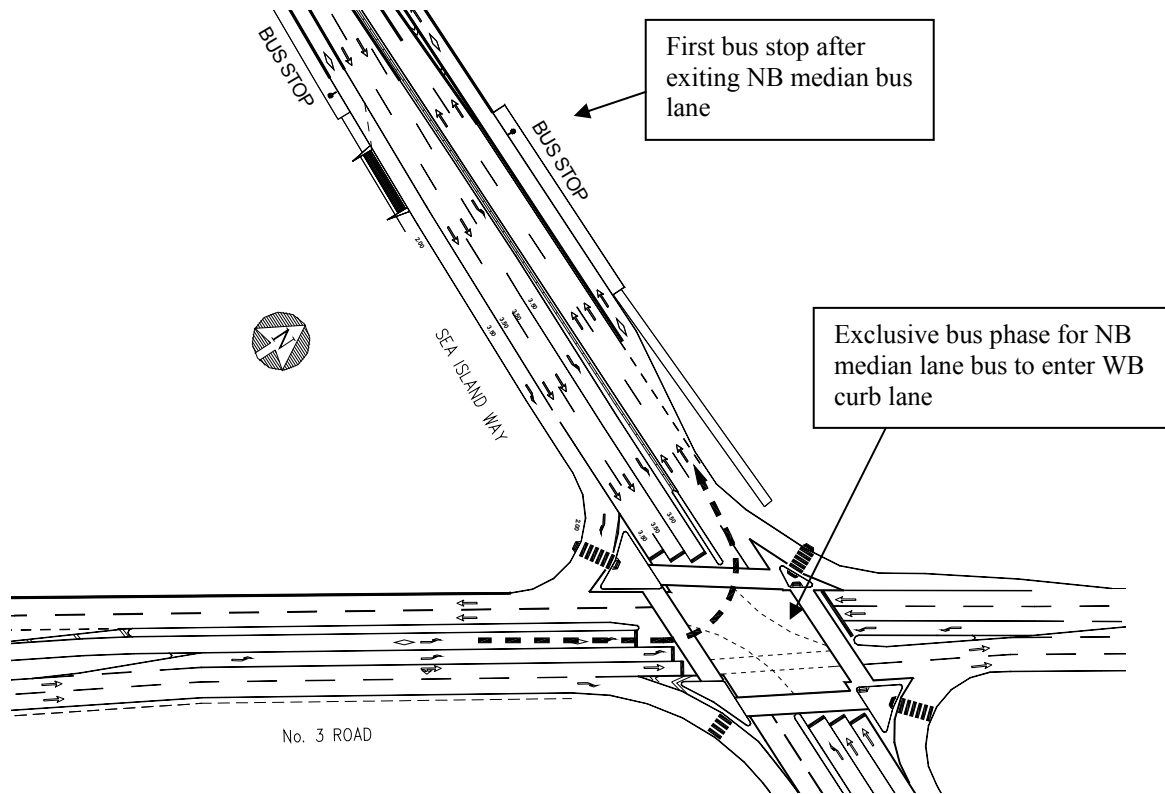


b) Southbound exit from median bus lane

Figure 7. Median Bus Lane Transitions at the South End.



a) The southbound entrance to median bus lane



b) The northbound exit from median bus lane

Figure 8. Median Bus Lane Transitions at the North End.

MEDIAN BUS STOP DESIGN PARAMETERS

Bus Stop Spacing

The spacing of bus stops affects the bus travel time, which in turn affects the attractiveness of the service. The number of the bus stops is one of the most significant factors affecting bus travel time. Based on market research conducted for the Greater Vancouver region, passengers are willing to walk further to higher quality services such as rapid transit. For the overall #98 B-Line corridor, the bus stops are spaced at 1.0 to 1.5 km (0.6 to 1.0 mile). In the Richmond City Center, the bus stops are spaced at 0.5 to 1.0 km (0.3 to 0.6 mile) to ensure a high level of accessibility in the higher density area while maintaining attractive travel speeds for passengers.

Wheelchair Accessibility

Based on field test data collected in the Greater Vancouver region, a minimum of 2.7 m (9 ft) clearance from face of curb to an obstruction such as fence is required to accommodate wheelchairs for low floor buses equipped with a wheelchair ramp. A 3.0 m (10 ft) clearance would be required to accommodate wheelchairs for buses with a lift mechanism (3). To ensure wheelchair accessibility at all median bus stops, a 3.0 m by 18.0 m (10 ft by 59 ft) platform is typically used. The effective waiting area of each bus stop is approximately 50 m² (530 ft²) which would be able to accommodate 40 waiting passengers at level of service A (1.2 m²/person or 13 ft²/person) based on the Transit Capacity and Quality of Service Manual by Transportation Research Board (4).

Considerations for Visually Impaired

In addition to wheelchair accessibility, the bus stop design also incorporated features to provide improved service to those with visual impairment. At all median stops, highly visible yellow tactile stripes were installed to clearly identify the curb on the bus lane side. The tactile stripes also have a raised surface that can be detected by visually impaired passengers. These tactile stripes are selected in consultation with the visually impaired community.

Bus Stop Locations

The general preference regarding the bus stop location in Greater Vancouver region is to locate stops at the far side of the intersection. Detailed bus stop location for the median stops was determined based on the right-of-way availability and impact on adjacent property. Figure 9 demonstrates different scenarios of the median bus stop arrangements. Figure 9a) shows a pair of standard far side bus stops at Capstan Way Station. This arrangement was selected to balance the right-of-way requirement at each side of the street.

Figure 9b) illustrates a pair of bus stops at Alderbridge Way Station with a southbound far side stop and a northbound near side stop. This is to take advantage of the available right-of-way south of Alderbridge Way. Similar bus stop arrangement was used at the Lansdowne Station, where a northbound far side bus stop is paired with a southbound near side bus stop.

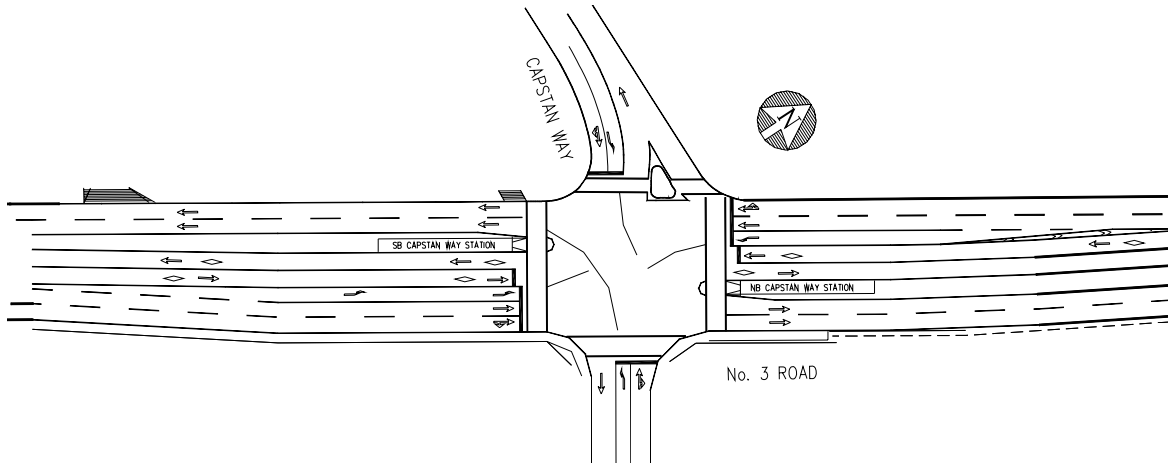
Figure 9c) demonstrates a pair of staggered far side bus stops at Aberdeen Station. This arrangement minimized the right-of-way requirements and maintains a smooth transition to the left-turn bays at the intersections.

CONCLUSIONS

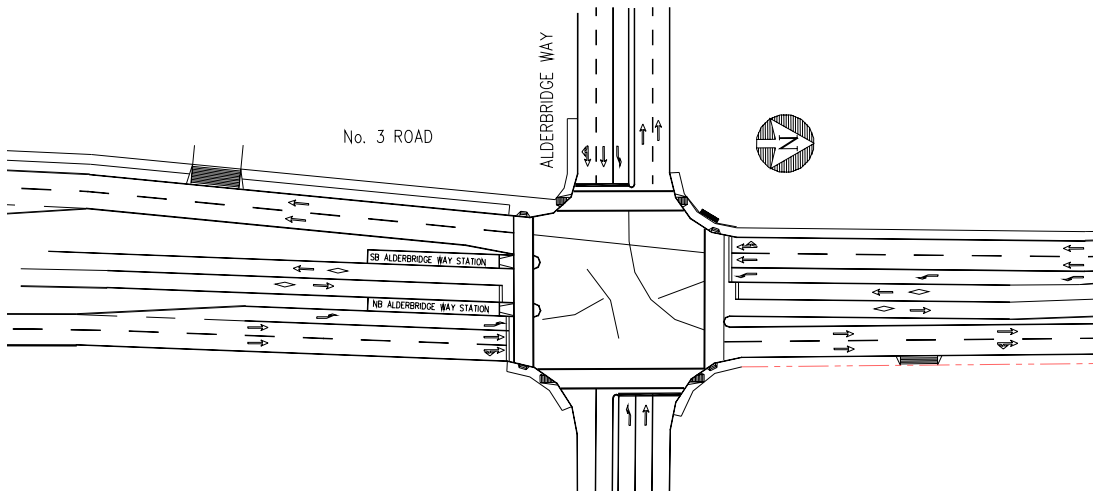
The median bus lane implementation for the #98 B-Line demonstrated that sensitive community concerns, traffic operational issues, transit operational issues can be handled through public consultation involving municipal staff members, general public, affected business owners, and transit operators. Much experience has been gained in addressing key issues including:

- measures to mitigating impact on abutting businesses;
- provision of U-turns at signalized intersections;
- accommodating simultaneous opposing left-turn movements to ensure traffic signal operational efficiency;
- treatments at the transition areas to / from the median bus lanes;
- considerations for the disabled in the bus stop designs; and
- locating bus stops to minimize property impact to the adjacent business owners.

The success of the median bus lane implementation for the #98 B-Line also demonstrated that, through public awareness and education, the median bus lane concept could be applied in a busy suburban corridor as a key measure to maintain attractive bus travel speed and enhance schedule reliability.



a) Standard far side – Capstan Way Station



b) Combination of far side and near side – Alderbridge Way Station



c) Staggered Far Side Stops – Aberdeen Station

Figure 9. Bus Stop Locations.

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