



Evergreen Line Rapid Transit Project

Burnaby, Port Moody, and Coquitlam, BC

Completed in December 2016

Canadian Consulting Engineering Awards 2017

Project Category: B. Transportation

Canadian Consulting Engineer

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Project Summary

Building on Canada's 150 years of confederation, SNC-Lavalin has delivered another rail milestone for Canada by completing the 11 km Evergreen Line Rapid Transit Project in Metro Vancouver, making the SkyTrain system the longest driverless system in the world. We are proud to have worked in close collaboration with First Nations groups, and the project features their artwork throughout the six new stations.

SNC-Lavalin was responsible for the design, build, and partial financing of the project and used a variety of innovative techniques to build 5 km of elevated guideway, 4 km of at-grade guideway, and a 2 km bored tunnel to deliver a complex transit infrastructure project in an urban area.

1. Innovation

Project Innovation

The Evergreen Line Rapid Transit (ELRT) Project consists of 11 km of advanced light rail transit that connects with and extends Vancouver's existing SkyTrain system from Burnaby through Port Moody to Coquitlam. The new line integrates rail, bus routes, and other existing transit facilities to improve mobility for the second fastest growing communities in Metro Vancouver.

The project included some challenging design and construction issues, including accommodating higher seismic requirements in areas of poor soil conditions, difficult tunnel boring conditions, 4 km of construction immediately adjacent to CP Rail's mainline, integrating new train control systems into the existing operation, and significant traffic management issues.

Key innovations utilized on the project include:

- > Hydraulic jacking of a massive completed station box under a local highway: traffic disruption was minimized and engineering prevailed by constructing a massive station box beside a major roadway, then jacking it under the road over a single long weekend.
- > Tight radius steel structures in combination with pre-cast segmental: special connection details and cross-sections were utilized to design and install tight radius curves on the new elevated guideway before transitioning to concrete segmental guideway.

- > Timber piles for ground improvement and seismic stability: SNC-Lavalin, in partnership with Tetra Tech EBA, utilized driven timber piles to provide resistance against seismic induced liquefaction and provide resistance for slope stability along the CPR cut for static load conditions and to address liquefiable soils, prevent settlement of MSE embankment and track slab, very wet groundwater conditions, obstructions, impact to adjacent CPR tracks, and an extremely limited right of way for construction activities.
- > Cement Deep Soil Mixing (CDSM) for ground improvement: in other areas, CDSM was used as an alternative approach for reducing the seismic lateral spreading displacements. Advanced dynamic analyses (using FLAC) were the basis of demonstrating that both seismic and non-seismic performance of CDSM would be equal to or exceed that of driven piles.
- > Large diameter tunnel bore, unique invert fill and centre wall: a single large diameter tunnel eliminated risk associated with cross-passages excavation, a unique granular fill option for the invert provided a softer interface with the tunnel lining when subjected to seismic racking loads, and a trowelled shotcrete centre fire wall provided schedule gains nearing completion.
- > The use of steel fibres in single pass concrete segmental liner: this was the first time steel fibres have been used on a one-pass, segmentally-lined tunnel in an area of moderate to high seismicity.

2. Complexity

The Evergreen Line Rapid Transit Project represents a large-scale complex Design-Build transportation infrastructure project delivered in an urban environment. Requirements included the design and construction of precast segmental elevated guideway, bored tunnel, at-grade construction, direct fixation trackwork, passenger stations, five traction power substations, and a maintenance and storage facility. It was constructed in the three Metro Vancouver cities (Burnaby, Coquitlam, and Port Moody), with complex traffic management, seismic, and soft soil considerations.

The work was incredibly complex, involving over a thousand workers, on up to 15 active work fronts, achieving \$1 million worth of construction every working day for four years in all types of weather and engineering disciplines. Complex controls and precision trackwork followed heavy civil, structural, and architectural teams.

Throughout tunnel construction, the team encountered challenging ground conditions. It was difficult to prevent water and sandy soils from entering the TBM cutter head during planned maintenance stops. To deal with these issues, the team implemented a ground improvement program, which involved dewatering and jet-grouting to strengthen the soil in front of the TBM to stabilize the ground and allow the team to safely change the cutterhead tools.

The tunnel boring program took almost 12 months longer to complete than planned, however with re-sequencing and acceleration of the follow-on works, the total delay to the project was mitigated to only three months. This was possible through innovation, close coordination of the various design and construction teams, as well as a very good working relationship with the Owner and Operator.

3. Social and/or Economic Benefits

Since opening in December 2016, the Evergreen extension has influenced the travel patterns of existing transit users while attracting new riders to the transit system. The Evergreen Line Project has met its primary goal of providing fast, frequent, and convenient SkyTrain service, connecting Coquitlam City Centre through Port Moody to Burnaby in approximately 15 minutes. It has already met its initial ridership projections and ridership is increasing steadily with 30,000 trips taken on an average weekday in January 2017.

The Project provided an estimated 8,000 direct and indirect jobs during construction. The Evergreen extension employed local people who did world class work.

The SNC-Lavalin consortium provided hands-on employment to local First Nations, achieving approximately 165,000 person-hours of direct employment to First Nations (82 person-years). This was 50% more than the target set by the Province of BC and exceeded First Nation expectations. Additionally, the SNC-Lavalin consortium provided \$55 million of economic opportunities to the First Nations through subcontracts with local/FN joint ventures (seven times the target).

The SNC-Lavalin led project team is proud that the vast majority of the design, fabrication, construction, and management work was performed by local Vancouver and BC residents. While some consultants with international experience were brought in to assist with tunnelling and elevated guideway construction, the Evergreen Line Project mainly made use of the local labour force by employing many qualified local subcontractors, including First Nations firms. Overall, This project team represents local people doing world class work!

4. Environmental Benefits

The Evergreen extension is expected to see 50,000 riders daily in its first year of operation and 70,000 daily riders by 2021, resulting in an estimated 40,000 reduction in car trips by 2021.

In addition to the transportation benefits, the Evergreen Line Project constructed over 13,000 m²(a) of more productive riparian and aquatic habitat, a 40% increase over the less productive habitat that was impacted by the project, resulting in an increase of more productive fisheries habitat within the project corridor, and offering more valuable rearing and refuge fish habitats than existed prior to the start of construction.

Habitat Compensation Works

Fisheries and Oceans Canada Authorization was contingent upon compensation measures to be implemented to offset inevitable temporary and permanent project impacts to the various creeks adjacent and within the project alignment.

Compensation measures included the rehabilitation, restoration, and enhancement of fish habitats within Schoolhouse, Slaughterhouse, Hoy, Pigeon, Scott, and Suterbrook Creeks in Port Moody and Coquitlam. The objective of these measures was to increase the functional capacity of habitats, within the Project corridor, to sustain spawning and rearing by salmon.

The compensation concepts and design were developed in consultation with the project identified First Nations, stream keepers, municipalities, regulators, and the Province. The design processes were directed by biologists, with comprehensive support by engineers from a variety of disciplines.

5. Meeting Client's Needs

The Evergreen Line is an integral part of the Provincial Transit Plan and the broader regional planning objectives of Metro Vancouver, connecting regional centres with rapid transit to achieve sustainable growth.

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The Owner chose a fixed price Design-Build-Finance contract model to achieve the following:

- > Better risk transfer to the Design-Build Contractor related to scope and schedule, in particular, SNC-Lavalin retained the risk of geotechnical conditions in the tunnel.
- > Better opportunities for innovation in the design and construction, which allowed SNC-Lavalin to solve challenging design conditions and to mitigate schedule delays. SNC-Lavalin's efficient private financing resulted in significant savings in interest during construction.

The overall project structure, with one Design-Build Contractor responsible for coordinating the sub-contractors, partners and multiple external stakeholders, led to the overall success in completing the Project. The close working relationship between the design-build entities, the Province (Owner), and the ultimate LRT Operator was fostered by the design-build approach, which allowed innovation and flexibility to balance the desired outcomes for all stakeholders.

The Province received cost certainty right from the initial financial submission, and the small amount of changes during the project allowed the Province to complete well under its budget. The contract structure motivated and allowed the Design-Builder to mitigate schedule impacts and achieve a successful opening despite significant impacts to the construction schedule.



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To build the tunnel, a tunnel boring machine (TBM) was assembled and launched in Port Moody in March 2014. The TBM made one pass, creating a large tunnel that was then divided into inbound and outbound tunnels. The depth of the tunnel is approximately 50 m at the deepest point, with depths ranging between 17 and 50 m.

The TBM was 10 m in diameter and 11 m long. It extended to 85 m when attached to trailing gear that used a conveyor belt system to remove tunnel spoils and assist in the installation of concrete tunnel liner rings. The TBM cutterhead alone weighed 130 t and had replaceable cutting teeth.



Compensation measures for the Evergreen Line included the rehabilitation, restoration, and enhancement of fish habitats within six creeks in Port Moody and Coquitlam, BC. As a result there has been an increase in more productive fisheries habitat within the project corridor and approximately 13,000 m²(a) of more productive riparian and aquatic habitat, a 40% increase.





