# CHAPTER EIGHT

# THE CANADA LINE RAPID TRANSIT PROJECT

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## Abstract

The Canada Line Rapid Transit Project being a Public Private Partnership largely under the control of one company, SNC Lavalin Inc., has provided an ideal environment for fostering innovation. This paper describes the project, discusses the organization and presents many examples of innovation.

## 1 Introduction

Construction on Canada Line, a new 18.5 km rapid transit system that connects Downtown Vancouver with Vancouver International Airport (YVR) and Richmond City Centre, started in late 2005. Full transit service will commence on or before November 2009, in time for the 2010 Winter Olympics.

The $2 billion project is a public-private partnership between various levels of government and InTransitBC, the private sector concessionaire. SNC Lavalin Inc. (SLI) under an EPC Contract with the Concessionaire is responsible for all design, procurement and construction.

The alignment which is shown in Figure 1 travels from south to north from near Richmond Centre (Brighouse), along Number 3 Road to Bridgeport Station. From here the alignment splits in two. One segment travels westbound over the Middle Arm of the Fraser River and parallels Grant McConachie Way to a terminus at YVR

Airport Station. The second segment crosses over the North Arm of the Fraser River to the City of Vancouver. The alignment is elevated over Marine Drive and enters a tunnel portal at 63rd Avenue. The alignment then continues in a tunnel under the northbound lanes of Cambie Street until it reaches Olympic Village Station. The alignment downtown travels in twin tunnels under False Creek, Davie and Granville Streets to a terminus at Waterfront Station.


**Figure 1. Canada Line alignment**

There are four types of guideway structure:

- A 2.5 km long bored tunnel,
- A 6.5 km cut and cover tunnel,
- A 7.5 km elevated guideway which includes two bridges (over the North Arm and Middle Arm of the Fraser River), and
- A 2 km at-grade section near the airport.

There are 16 stations on the line, eight underground, six elevated and two at-grade.


**Figure 2. Segment erection truss**

The elevated guideway was constructed using the precast segmental methodology. The 3 m long precast segments were lifted into place using a special truss (Figure 2) and post tensioned together into a beam. The majority of the elevated alignment is dual guideway with track for both directions of travel. Single guideway sections are located near the termini and at the junction between the Airport and Richmond lines. The bridge over the North Arm of the Fraser River has a 180 m navigational span and is the first Extradosed Cable Stayed Bridge built in North America (Figure 3). Since it is located beneath the flight path to the Airport, the towers had to be shorter than normal which lead to a relatively flat cable angle. The structure was built using the balanced cantilever method as was the Middle Arm Bridge (Figure 4).

Between 63rd Avenue and 2nd Avenue in Vancouver the cut and cover technique was employed to build the tunnel. In this method, a trench was excavated from the surface using backhoes. The sides of the excavation were supported using soil anchors and shotcrete. The cast in place concrete tunnels were then constructed, backfill was placed over the top and the road surface reinstated. The tunnels were of both side-by-side and stacked configurations (Figure 5) depending on the space available for construction.

**Figure 3. North Arm Bridge**

**Figure 4. Middle Arm Bridge**

A Tunnel Boring Machine (TBM) was used to tunnel under False Creek in Vancouver. Twin bored tunnels were constructed between 2nd Avenue in the south and Granville/Pender in the north. The tunnels are lined with pre-cast concrete segments (Figure 6).

The Canada Line is a traditional metro transit system with a fully segregated alignment. The vehicles are powered via pick up shoes from a power rail alongside the running rails (Figure 7).

**Figure 5. Stacked cut and cover tunnel**

**Figure 6. Bored tunnel**

**Figure 7. Canada Line vehicle**

The system will operate with fully automated trains on 3 minute headways to provide frequent service and meet capacity requirements.

Construction started in late 2005, and revenue service will commence on or before November 30, 2009 in time for the 2010 Winter Olympics.

## 2 Project Organization

There are four public funding partners, the Federal Government, Provincial Government, Greater Vancouver Transportation Agency (GVTA) and the Vancouver Airport Authority (YVRAA). The public partner is Canada Line Rapid Transit Inc. (CLCO) a subsidiary of GVTA (Figure 8). The private partner called InTransitBC, LLP (ITBC) entered into a Concession Agreement with CLCO and GVTA in July 2005 after a competitive tendering process. ITBC is comprised of SNC-Lavalin Inc. (SLI) and two pension funds. The Concession Agreement allows ITBC to design, build, operate and maintain the Canada Line over a 35 year period and requires the Canada Line to be open for public revenue service by November 30, 2009.

ITBC awarded the following two sub-contracts:

- Engineering / Procurement / Construction (EPC): SLI
- Operations and Maintenance: ProTransBC Operations Ltd. a subsidiary of SLI

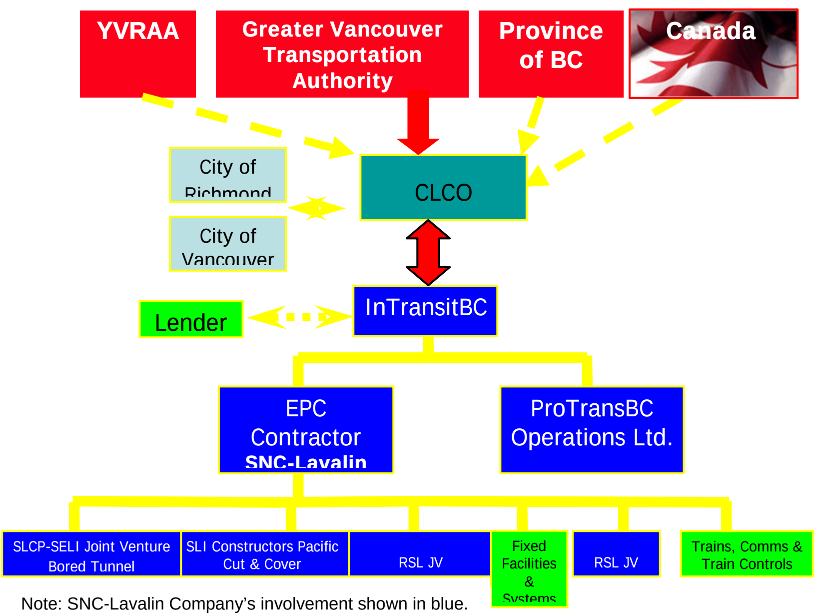


**Figure 8. Project organization**

SLI is delivering the EPC Contract through a series of design/build joint ventures formed by its affiliate SNC-Lavalin Constructors (Pacific) Inc. (SLCP), certain design and supply subcontracts and conventional design-bid-build subcontracts as follows (Figure 8).

- A Joint Venture (RSL JV) was formed by SLCP and Rizzani de Eccher of Italy to design/build the elevated guideway and two bridges over the Fraser River (Buckland and Taylor designed the North Arm Bridge).
- The twin Bored Tunnels underneath downtown Vancouver were designed and built by a Joint Venture (SSJV) formed by SLCP and SELI, an Italian Contractor.
- SLCP acted as Construction Managers for the cut and cover section; Cambie Street Constructors were the contractor. SLI provided the design.
- Trackwork and some of the E&M systems were installed by the RSL JV. SLI provided the design.
- E&M systems, stations and other fixed support facilities such as the Operations and Maintenance Centre (OMC) were generally delivered using design-bid-build subcontracts.
- The vehicles, automatic train control system and communications system were delivered through three design/supply subcontracts awarded to specialist suppliers. SLI is the systems integrator.

In most construction projects many small contacting parties are engaged in a large number of independent subcontracts providing little incentive for innovation and effective integration. However, the Canada Line has provided an ideal environment to foster innovation because of the dominant role of SNC-Lavalin companies at all levels of the project, as can be seen in Figure 8. Some of these innovations will be discussed in the next section.

## 3 Examples of Innovation

As noted above SNC-Lavalin has been involved at most levels of the project; Concessionaire, EPC Contractor, subcontractor and operator. The following examples of innovation include some at the time of bidding, some in the management structure and some in the detailed construction methods.

- The RFP for the project called for the alignment to be underground for approximately 6 km in Vancouver. SLI proposed a bored tunnel in downtown Vancouver and under False Creek. They proposed the more efficient cut and cover method for the remainder and extended it so that the total tunnel length was 9 km. The cut and cover alignment allowed the stations to be closer to the surface making them more user friendly and thus encouraging higher ridership since the travel time from surface to the platform would be reduced. It also meant shallower and faster station excavations. Since the cut and cover tunnel could be constructed in several locations simultaneously there were additional schedule advantages which were critical since the line had to open for the 2010 Winter Olympics.

- SLI worked with the local construction industry to develop an efficient cast in place concrete construction method using special tunnel forms (Figure 9). The ground support was the commonly used shotcrete and soil anchor system. This ensured that there was sufficient local capability to construct the tunnel in the time frame. In addition SLI hired a very experienced Construction Manager to help their subcontractor with project management and optimize their pour cycle and work methods.
- SLI elected to act as systems designer/integrator and not name a vehicle supplier in its proposal. It was therefore able to tender the vehicles to a broad range of suppliers and able to select the best value and ensure that the other systems were suitable for the selected vehicle.
- The size of the excavation pit required to launch and service the tunnel boring machine was modified so that one of the stations could be later constructed inside it. This led to a risk that if the tunnel was delayed, the station would also be delayed. In order to mitigate this risk the critical rooms required to install the systems equipment were relocated nearby between the cut and cover tunnels. This space would have to have been excavated in any case.

**Figure 9. Tunnel forms**

- Richmond is located at the mouth of the Fraser River so is founded on inter-bedded layers of silts and sands that are prone to liquefaction in an earthquake. SLI worked closely with a geotechnical consultant and a Professor from UBC to design an innovative piling system consisting of expanded base (Franki) piles with a steel casing (Azizian and Robinson, 2007). The piles were founded in a layer of dense sand approximately 13 m below grade. The expanded base compacted the ground at the tip so it was not susceptible to liquefaction. In addition the steel casing made the piles more flexible so that any liquefied soil above the base would "flow" around them. In this way the normal method of improving the ground by jetting in gravel columns was avoided. This reduced the affected area and averted moving several utilities.

- Also in Richmond a detailed study was performed to optimize the alignment so the piles would mostly avoid a large concrete storm sewer which ran parallel to the alignment. SLI also worked with the City to produce an almost straight alignment that also satisfied their "urban design" needs.
- The stations were constructed towards the end of construction. This could have led to a significant conflict between the formwork and shoring for the upper floors of the stations and the installation of the trackwork on the lower level. SLI worked with the structural engineers for the stations, the shoring designer, the contractor and the trackwork installer to minimize the conflict. This was achieved with the use of heavy shoring posts and steel beams (Figure 10) and/or redesigning the roof so it could be poured in two pours with a horizontal pour joint (Figure 11).

**Figure 10. Shoring above tracks**

**Figure 11. Horizontal joint pour in slab**

- The bored tunnel alignment had three low points each of which required a sump to collect water inflows. The sumps were to be built at the side of the tunnel which entailed removing part of the precast concrete tunnel lining, temporarily supporting the opening and then pouring the sump under and on the side of the tunnel. At one location the contractor drilled an exploratory hole in the liner that immediately flowed water and sand under artesian pressure which had not been foreseen from the geotechnical investigation. The hole was sealed without delay and it was quickly decided that it would be too dangerous to construct the sump. SLI immediately brought together their structural and mechanical designers and contractors to brainstorm alternate solutions. Without delay a decision was made to place a horizontal sump in the invert of the tunnel inside the lining (Figure 12). A pump was procured that was tubular in shape and could operate in a low head of water.

**Figure 12. Sump invert**

## 4 Conclusions

The above section has described a few of the examples of innovation that were employed on the Canada Line Project. Innovation was fostered throughout the project by SNC-Lavalin because of its dominant role in all aspects of the project.

The project is currently on budget and ahead of schedule largely because of the synergy within the project team and their innovative thinking.