Feature

Vancouver *SkyTrain*—A Proven Success Story

Greater Vancouver is the third largest metropolitan community in Canada; 1.8 million people live in an area spread across the Fraser River delta between the Pacific coast and the US border.

The area has developed a unique land-sea-rail network known as the Vancouver Regional Transit System, covering 1800 km^2. The backbone of this system is the 29-km *SkyTrain* Line, Vancouver's Advanced Rapid Transit (ART) system linking downtown Vancouver, East Vancouver, Burnaby, New Westminster and Surrey (Fig. 1), operated by the British Columbia Rapid Transit Company Ltd. (BCRT) for BC Transit.

The line, which blends the design principles of Light Rail Transit (LRT) systems and so-called 'automated people movers', was developed by the Urban Transportation Development Corporation (UTDC) of Ontario, now the Transportation Systems Division of Bombardier Inc.

SkyTrain standing at platform *(BCRT)*

Staged Opening

Phase 1 of the *SkyTrain* project was inaugurated into revenue service on 3 January 1986 with a later extension opening in March 1990 across the Fraser River via a 616-m cable-stayed bridge dedicated to rapid transit, the only example of its type in the world. The final extension of 4.3 km into Surrey was opened in March 1994, and *SkyTrain* now carries about 40 million boarding passengers a year.

Fraser River 616-m cable-stayed bridge for SkyTrain *(BCRT)*

Segregated Elevated Guideway

A feature of the *SkyTrain* service is that it runs entirely on segregated right-of-way with no road vehicle or pedestrian crossings. The elevated guideway section carries one track for each direction and is constructed of pre-stressed concrete trapezoidal box beams supported on poured-in-place columns. Phase 1 utilized over 1000 of these beams, each weighing an average of 100 tonnes. The beams were fabricated in Richmond, British Columbia and carried in—six each night—to the construction site.

Standard track (45 kg/m) is fixed directly to the beams using resilient mounts. The guideway also carries the two power rails at 650 V dc and the Linear Induction Motor (LIM) rail. Two power rails (positive and negative) were chosen instead of the conventional single third rail system with return via the track, to eliminate electrolytic corrosion in underground structures and in the guideway itself. This dual power rail system also provides significant protection against ground faults.

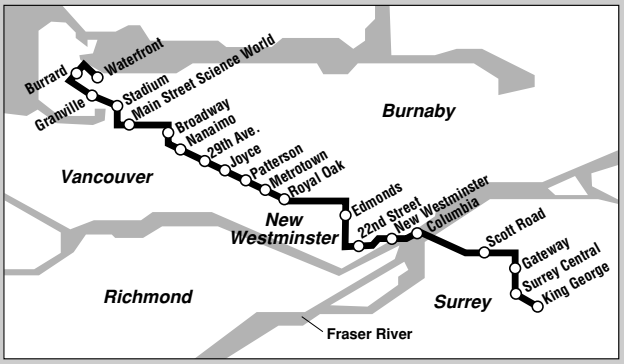
In addition to the elevated section, the guideway runs through two tunnels: a 1.3-km tunnel in the downtown Vancouver section, and a 300-m tunnel in New Westminster. A further 3.5 km is in-cut (below grade) or at grade.

ART Vehicles

A fleet of 150 cars serve the 20 stations on the 29 km of guideway. They are configured as four- or six-car trains running at maximum speeds up to 90 km/h with an average service speed of 43.5 km/h between the Waterfront and King George termini. During peak hours, the service headway averages 150 seconds, and is 5 minutes or better at other times.

Each car is designed to accommodate 36 seated and 45 standing passengers, although they often carry in excess of 100 passengers. The body is constructed of lightweight welded aluminium with a low fire load and weighs about 15 tonnes. This relatively light weight reduces wear on the

Figure 1 The Vancouver *SkyTrain* Route



(BCRT)

Table 1 *SkyTrain* System Performance Record

	1987/88	1995/96	Change
Guideway (Kilometers)	21.4	28.9	+35%
Stations	15	20	+33%
Total vehicles	114	150	+32%
Peak vehicles	88	136	+55%
In-service car-hours	308,500	581,238	+88%
In-service car-kilometers	12,884,900	23,412,318	+82%
Boarding passengers	21,375,000	39,158,332	+83%
Operating cost	$26,168,000	$35,830,501	+37%
Employees (Full-time equivalents)	307	325	+6%
Passengers/Car-hour	69.3	67.0	-3%
Average operating cost/Passenger	$1.22	$0.92	-25%
Average operating cost/Hour	$84.82	$61.65	-27%
Car-hours/Employee	1,005	1,788	+78%

(BCRT)

track and guideway and enables higher performance with lower installed motive and braking power. In the first 10 years of operations, each car has logged more than 1.5 million km.

Propulsion uses two Linear Induction Motors—straight line versions of the conventional AC rotary electric motor. The motors react with an aluminium-capped steel rail on the guideway to provide motive power. *SkyTrain* was the first major application of LIM technology to mass transit systems. There are no moving parts, substantially reducing maintenance and risk of mechanical failure.

Service braking is provided by using the LIMs to perform regenerative braking. As part of the final braking at low speeds, the LIMs are powered to provide reverse thrust. This electrical braking mode is supplemented by spring-applied hydraulically-released disc brakes for final stopping and parking. Four electro-magnetic track brakes that slide along the running rails assure a rapid stop in an emergency.

A unique feature of the car trucks is the adoption of steerable axles. The axles of each truck steer independently with the track curvature almost eliminating flange contact with the rail, substantially reducing rail noise and truck maintenance, and extending wheel life to almost 1 million km.

ATC & Moving Block System

All train movements are controlled from the Operations and Maintenance Centre at Burnaby.

The unmanned trains operate under an automatic, computerized train-control SELTRAC system supplied by SEL. This system was originally developed in Germany for both rapid-transit and trunk railway systems. SELTRAC is software based, relying on continual communication between all trains and trackside computers rather than the conventional track-circuit method in which trains are detected by their wheels shorting out track circuits.

The on-board train equipment detects the crossovers in a trackside inductive loop cable using the phase shift, counts them, and combines the count data with output from axle-mounted tachogenerators to provide reliable train position and speed measurements.

The moving block principle is used to keep trains a safe distance apart. In this system, the portion of track reserved for a train is adjusted in very small units of about 6 meters and is updated as frequently as every second. Unlike the conventional fixed-block system using track circuits, the minimum spacing between trains is speed dependent, with fast-moving trains given more stopping room than slow trains, allowing maximum capacity and safety throughout the system.

The ATC hardware is divided into two parts: the Vehicle On-Board Control (VOBC) located on the vehicle and composed a dual-processor computer that continually monitors the position, speed and general status of the train, and the Vehicle Control Centre (VCC) located in the Operations and Maintenance Centre that directs the train movement via the VOBCs. The VCC normally communicates with trains at least once every second and is capable of controlling up to 125 trains. If communications between a VOBC and the VCC is lost or garbled for more than 3 seconds, the VOBC fail-safe mechanism halts the train by applying the emergency brakes.

Established Performance Record

In the 10 years since Vancouver Expo 86, *SkyTrain* has made substantial gains in productivity and delivery of service to the Vancouver public (Table 1), proving that ART systems have a guaranteed future in integrated urban mass-transit systems.

The experience gained from the Vancouver *SkyTrain* is already bearing fruit in the form of new ART projects in Ankara, Turkey, and Kuala Lumpur, Malaysia. ■

Acknowledgement

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