Advanced light rapid transit (ALRT) system, Vancouver, BC

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Advanced Light Rapid Transit (ALRT) System, Vancouver, BC

Système de transport en commun en site propre, Vancouver, BC

Öffentliches Verkehrssystem auf Eigentrasse, Vancouver, BC

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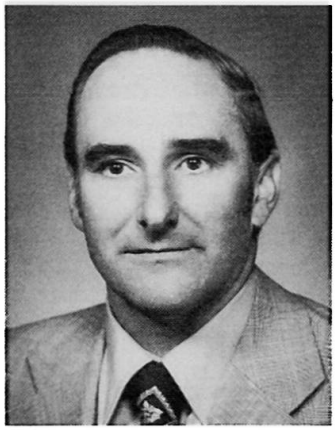


After qualifying as a structural engineer in the United Kingdom in 1952 Terence M. Wardle came to Canada and participated in bridge design with a major railroad, consultant and the BC Highways Ministry. In the sixties he spent six years on structural research in New Zealand and the U.K. Mr. Wardle joined Acres in 1969 and is now responsible for the direction of a broad range of transportation, energy and industrial sector prospects in the Pacific region.

RESUME
The paper describes the 21 km system and the project management approach to the project. The organization of the project group is discussed and the management strategies which are being utilized to meet the budget and schedule constraint. The project approval was given in mid '81 and completion was required by January 86 in time for the Expo 86 World Fair. A prebuild section was constructed to demonstrate the design and operation in 1983. The system utilizes linear motor, driverless trains and the cars have steerable trucks making the system unique.

RESUME
L'article décrit le système de transport en commun de 21 km de longueur et sa réalisation, à l'aide de la gestion de projet. L'organisation du groupe d'études est présentée ainsi que les techniques de gestion de projet appliquées pour respecter les délais et budgets. L'approbation du projet date du milieu de 1981 et sa réalisation doit être terminée en janvier 1986 pour l'ouverture d'Expo 86. Un tronçon d'essai a été construit en 1983, afin d'évaluer la structure et l'exploitation. Le système fait appel entre autres, au moteur linéaire et à la conduite automatique des trains.

ZUSAMMENFASSUNG
Der Artikel beschreibt das 21 km lange Verkehrssystem und dessen Ausführung durch die Projektleitung. Die Organisation der Projekt-Gruppe und die angewandte Strategie zur Erfüllung der Randbedingungen, gesetzt durch das Budget und den Zeitplan, werden erläutert. Die Genehmigung des Projekts wurde Mitte 1981 erteilt und die Vollendung auf Januar 1986 gefordert, rechtzeitig für die Weltausstellung Expo 86. Ein vorgefertigtes Segment wurde 1983 gebaut, um die Gestaltung und die Funktionsweise zu zeigen. Das System bedient sich eines Linearmotors, führerloser Züge, und die Wagen haben lenkbare Drehgestelle, welche das System einzigartig machen.

1. INTRODUCTION

In May of 1981 the Hon. W. Bennett Premier of British Columbia announced the commitment to a rail transit system in the Lower Mainland. The system chosen was to be high technology. The first 21.4 km leg of the system was to be in full operation prior to the opening of EXPO '86. A clear objective was established to create a highly cost effective system within the schedule required to meet the exhibition opening.

B.C. Transit (BCT) was given the responsibility of creating the system and bringing it to full operation. A system master contract was awarded by BCT to the Urban Transportation Development Corporation, an Ontario Crown Corporation, and it's subsidiary Metro Canada Ltd. (MCL) for the design, supply installation and commissioning of an advanced light rail system. At the time, BCT did not have a project team in place nor was there a previous project to serve as an example. The challenge was to create the management infrastructure with which to direct and control the project. This paper describes this challenge and how it has been met.

2. THE ALRT PROJECT

The ALRT line runs from the Burrard Inlet waterfront in downtown Vancouver to downtown New Westminister. The line is 21.4 km in length, of which 14 km are on elevated guideway structure 6 km at grade and 1.5 km in tunnel. There are fifteen stations, two underground, eight elevated and five at grade. The vehicle control centre and maintenance complex is 20 acres in extent. Plate I shows the route of the line.

The initial capacity of the system is 10,000 passengers/hour with a maximum future capacity of 30,000 passengers/hour. The total trip time is thirty minutes. The minimum headway between trains is 1 3/4 minutes. The cars have a seating capacity of 40 and total capacity of 75 people. Trains will consist of four cars in peak periods and two cars in the off peak late evenings. Each car is driven by two linear induction motors reacting with a continuous plate between the rails. Power is supplied at 600 volts DC from side rails and is converted on board to variable voltage and variable frequency three phase AC. A unique feature of the vehicle is the steerable axle truck which is designed to reduce noise and improve ride quality.

The system is driverless. The train control has three computer systems. The system management centre computer, which is under the direction of a control operator, carries out supervisory functions e.g. startup, scheduling, emergency operations and shutdown. The vehicle control centre consists of three linked computers for train movement monitoring and direction. The third system is the vehicle on board computer which activates propulsion, braking, door operation and monitors on board equipment.

The track is standard gauge continuous welded 112 lb. rail. The twin guide-ways are 28 cm concrete slab in the at-grade sections of the line. The elevated sections consist of precast prestressed box section girders spanning 30 metres. The girders are post tensioned for continuity at alternate piers. The cast in situ piers are tee shaped with post tensioned cross heads. Plate II shows a typical/guideway crossection. The underground section utilized an existing

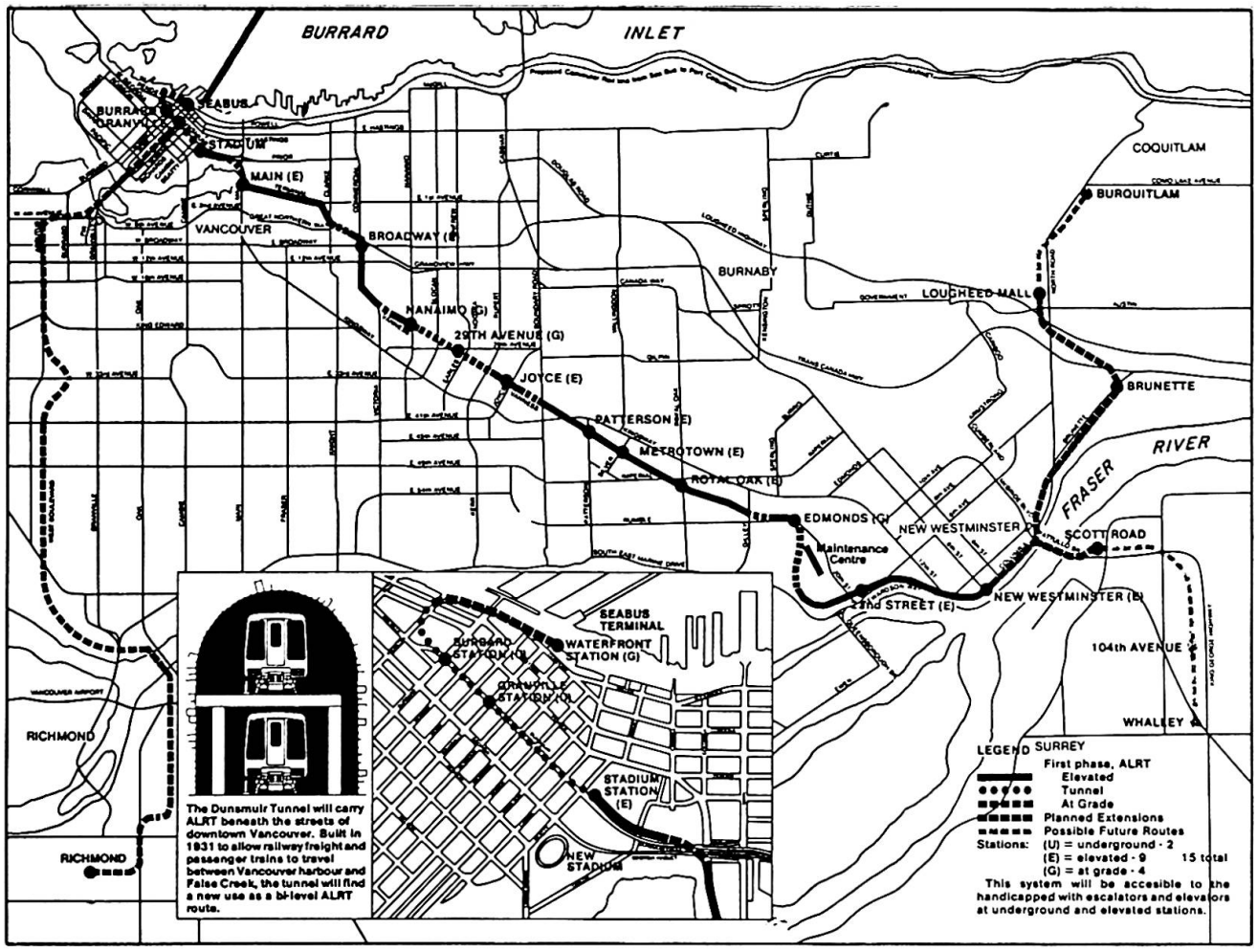
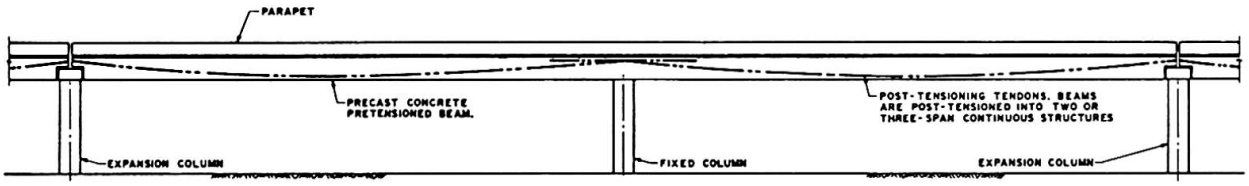
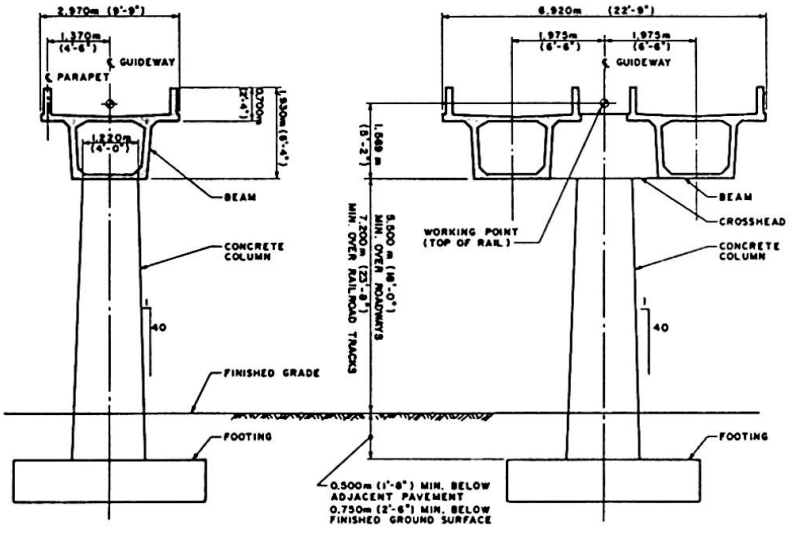


Plate I

ALRT ROUTE



ELEVATION



SINGLE GUIDEWAY DUAL GUIDEWAY

Plate II

TYPICAL ELEVATED GUIDEWAY

railway tunnel. The structure was modified to carry a two level ALRT guideway. Two underground stations are situated on the tunnel section. They were accomplished by widening out the existing tunnel. Plate III shows a tunnel crossection underground station.

The foregoing project description covers Phase I of the system. At the time of writing an extension phase has been authorised to carry the line across the Fraser River into Surrey. The total length of the extension is 7 km. The river crossing will be a cable stayed bridge structure, 450 metres in overall length. Another future extension is planned to Coquitlam. Eventually a second line is proposed from downtown Vancouver to Richmond. However, to date, the Coquitlam and Richmond lines have not been authorized.

3. OWNER'S RESPONSIBILITY

BCT as the owner of the system, has the overall management responsibility for the conduct of the project from initiation of the work to final acceptance of the operating system. The Corporation is accountable to the Provincial government for the control of the project funds. The Hon. Grace McCarthy is the Minister responsible for the project. BCT disburses funds directly in some instances but the main cash flow is disbursed through the system contractor. Budget preparation and requisitioning of funds from the government is the responsibility of BCT.

The Corporation has a direct responsibility under the system master contract to provide a cleared right of way. This entails the acquisition of land by purchase, lease or easement as well as the future disposition of surplus land. The relocation of utilities and crossings of the R.O.W. is also part of BCT's responsibility. The negotiation and legal requirements of the street closings, station approaches, etcetera, is managed by BCT.

The route of the line passes through three municipal jurisdictions and the Greater Vancouver Regional District, which consists of all municipalities in the Lower Mainland. BCT has the responsibility for obtaining consensus with the Municipalities on line location and station locations and other aspects which may impact on their jurisdictions.

Linked to the jurisdictional consensus, BCT has the responsibility for community relations and information at all stages of the project. The communication levels include governments, the business community, and the general public.

Last but not least, BCT has full management responsibility for the direction and administration of the system master contract. This includes agreement of design criteria and equipment specifications, monitoring of design, schedule and cost performance, direct management of construction, and quality assurance, in the construction and commissioning phases.

4. B.C. TRANSIT ORGANIZATION

B.C. Transit is a Crown Corporation which was established by the government of British Columbia in 1977. The general mandate is to provide the public transit

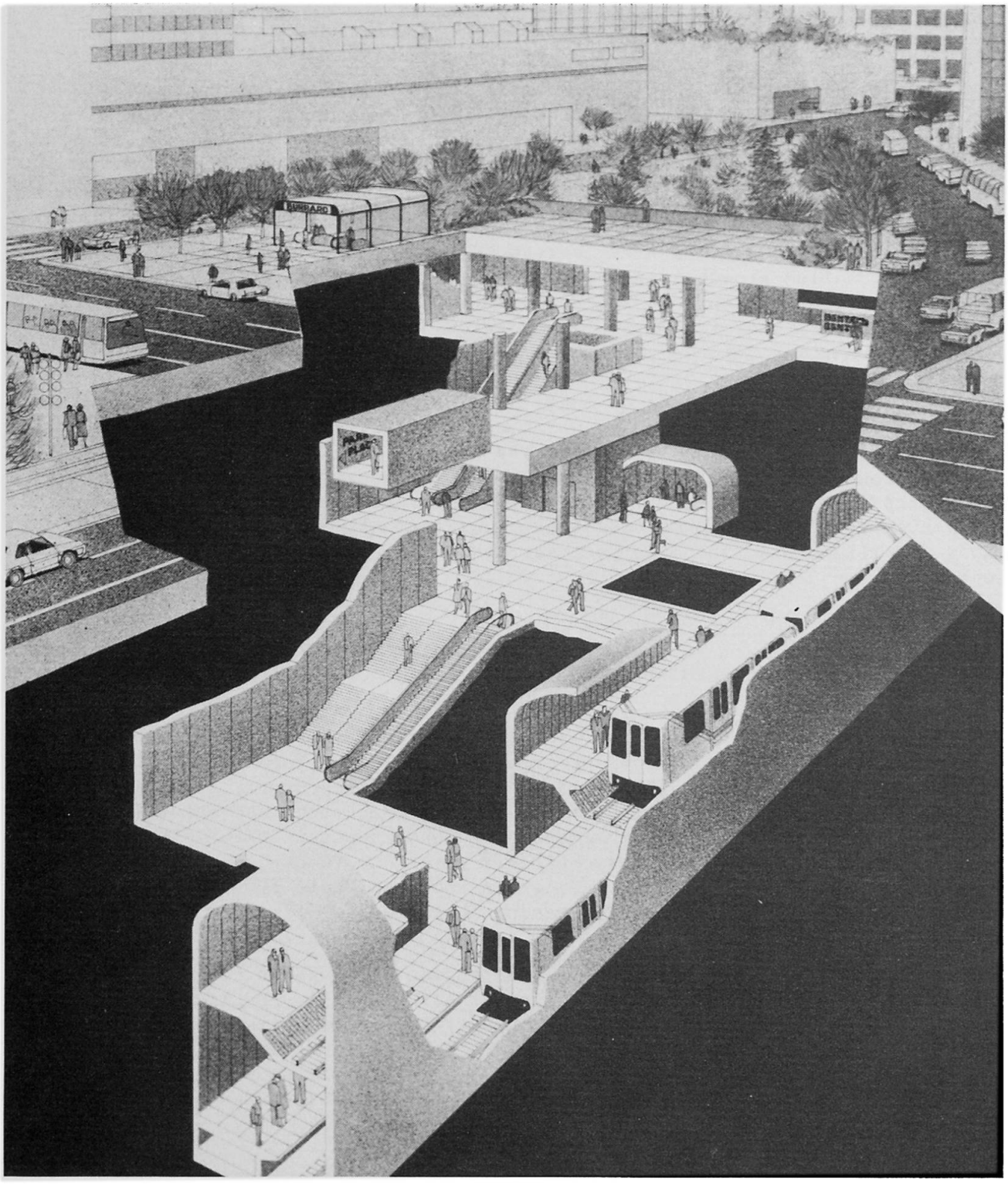


Plate III

UNDERGROUND STATION

services in the Lower Mainland, Victoria, and some smaller communities. The Corporation is governed by a Board of Directors who are appointed by the Government.

The administration of BCT is the responsibility of the General Manager, who is accountable directly to the Board of Directors. Regional Managers look after specific, geographic areas under the overall direction of the General Manager. Each region is responsible for the planning and growth of the transit system within its area.

The Lower Mainland is by far the largest region in terms of transit requirements. Population growth is continuing and the commuter traffic from the new suburban residential areas to the downtown core is expanding. By 1981 it was obvious that the road system was at and beyond capacity. Automobiles, buses and commercial vehicles were competing for ever more scarce road space during morning and evening rush hours. Rail transit systems had been under study for several years. In the spring of that year the government took the decision to implement the system which is now under construction. B.C. Transit was appointed as the executing agency for the project with full responsibility for construction of the line. A Transit '86 committee was established to coordinate the inputs from all levels of government. Under the chairmanship of the Hon. J. Davis MLA, the committee has representatives from all municipal governments along the alignment. The main contract was drawn up between BCT and the system contractor.

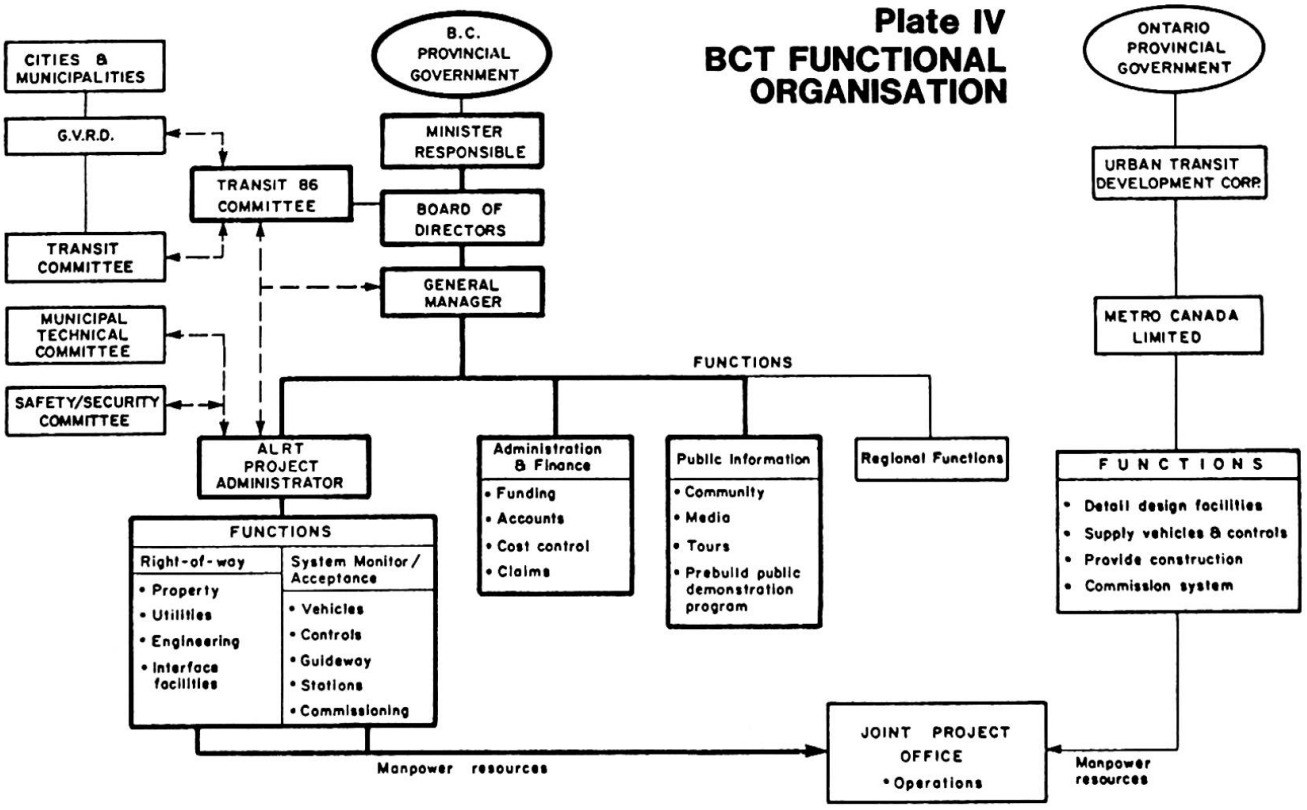
5. BCT PROJECT MANAGEMENT STRUCTURE

At the time that the system master contract was implemented, B.C. Transit did not have a major project management organizational structure in place. The opportunity was taken to tailor make a management structure to fit the project and the owners' specific responsibilities. A project team was established, reporting directly to the General Manager. The management team is headed by a Project Administrator who is responsible for the day to day operations. The management team functional organization is shown on Plate IV. The management structure stems from the basic BCT responsibilities as discussed in Section 3.

The main system contract requires BCT to provide the right-of-way for the system and to arrange for the resolution of all utilities conflicts. The BCT team structure has to include the management of land organization and related legal services and surveys, the engineering and coordination of the utilities removal and related permits. Policy level decisions are developed through the Transit '86 Committee. Working level decisions are facilitated by the Municipal Technical Committee.

Financing for the project is drawn through the BCT Controller based on annual budget forecasts and monthly cash flows. Management of the expenditures is a function of the project team. This stream includes estimating and cost control and scheduling.

The system contract monitoring management activity is a major part of the work load. Included in this stream is the approval of rolling stock specifications and the design criteria for the line and all structures. Detail design reviews were required for all stations, guideway structures and maintenance facilities.



During the construction phase BCT is taking an active role in managing the construction activities. BCT is also directly managing the communications engineering aspects of the project. As a means of managing any technical conflicts which might arise a Technical Review Board (TRB) was established. The five member TRB reports directly to the Project Administrator.

The communications activity functions as the main interface with the business community, and the general public. This includes, public presentations and media coverage and conducted tours for visitors. Also included is the preparation of information brochures and publications. During the demonstration operation period for the pre-build section, public reaction was monitored by this group.

The system contract required that the contractor provide the system detail design, including all civil, structural, mechanical and electrical engineering, and architecture for guideways, tunnel, stations maintenance yard etc. The contractor divided the project into twelve sections and appointed design consultants for each section. One of the section design consultants was also responsible for overall alignment. The system contractor provided overall co-ordination of the detail design. B.C. Transit appointed Acres Consulting Services Limited to provide monitoring and review of the contractors design work as well as the coordination of the right-of-way and utilities clearing and legal surveying. Architectural consultants were retained by B.C. Transit to provide station conceptual designs and overall architectural co-ordination.

For the first two years B.C. Transit and the System Contractor operated individually. Day to day coordination was by means of scheduled and ad hoc progress meetings and written transmittals. The principal interface for design was by submission of drawings and specifications for design reviews. This was achieved on a section by section basis and as for levels of completion 25%, 50%, 95% and 100%.

By mid 1983 major construction was well underway. Communications and coordination between the two groups had become very complex and time consuming. In order to shorten the communication links the two groups were meshed together in a single operating unit called the Joint Project Office (J.P.O.) Staff from BCT, the System Contractor and their respective consulting groups work as a single team. Contractual responsibilities between the parties remain with BCT or the System Contractor as appropriate since the Joint Project Office is not a legal entity in its own right. A specific advantage of this working arrangement is that the owner has a close relationship with the construction process. This facilitates control of budget, schedule and quality of construction.

6. MANAGEMENT STRATEGIES

Each major project has its own particular set of constraints and requirements which require management solutions. This section reviews some of the principal management strategies which have been developed for the ALRT project. For convenience the review is subdivided into the three project management areas, schedule, budget and quality.

6.1 Schedule

The overall schedule is for completion of the line in time for full operation during the Expo 86 worlds fair. The target date set in the main system contract is January 1st, 1986. In addition, a prebuild section was required to be operational during the summer of '83 as a demonstration unit.

The strategy agreed with the system contractor was to subdivide the line into sections. These were then promised to fit into the overall schedule. The centreline and station locations were established by the Contractors principal consultant and agreed by BCT, detail design was then followed up on a fast track basis according to the section priority. BCT land acquisition and utilities relocation was initiated as soon as centreline was known. Station locations tended to be on the critical path since extensive liaison with municipalities was necessary.

6.1.1 Prebuild Priority

The prebuild section was given first priority. It consisted of about 1.0 km of elevated guideway on the edge of the downtown core together with an elevated station. One guideway had to be fully operational, complete with power and controls. A two car train was to be operated and open to the public for the summer of '83. For this purpose a temporary control room and car maintenance facility was required. Apart from the R.O.W. engineering, guideway design review and construction monitoring, BCT had to review and monitor the car design and fabrication, controls and communications for the prebuild.

The prebuild demonstration exhibit was successful and 300,000 people were carried during the five month operation. The prebuild strategy was also very useful in demonstrating the guideway design and erection techniques, as will be discussed in later sections.

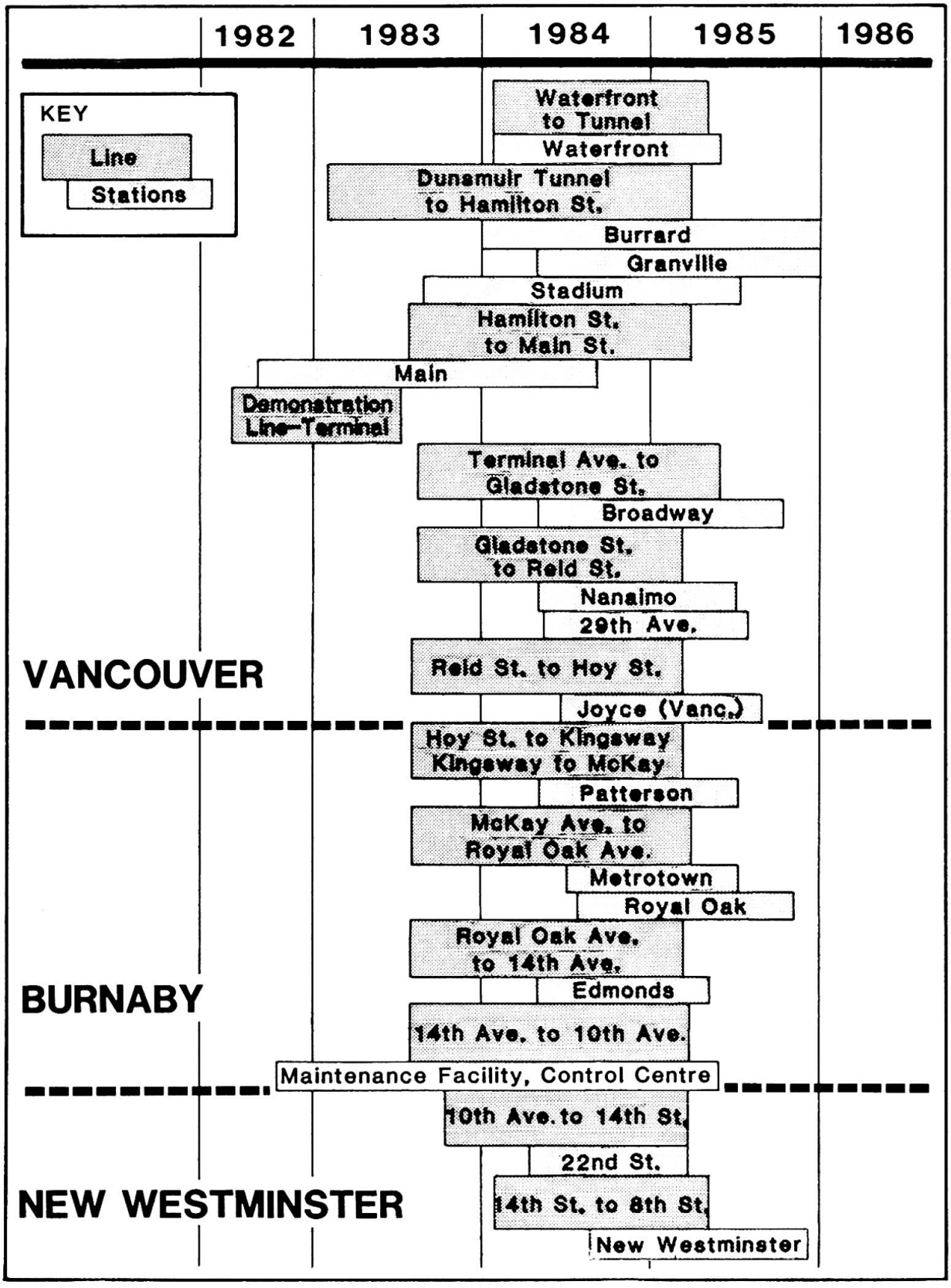


Plate V

CONSTRUCTION SCHEDULE

6.1.2 Tunnel Conversion and Underground Stations Priority

The tunnel conversion and underground stations were extremely high priority items. The tunnel, which was built in 1931, had to be acquired from the railway company and converted to double deck operation. This involved grouting behind the existing lining, rock anchoring and lowering the invert of the tunnel prior to installing the upper guideway. In addition, a short section of tunnel near the eastern portal was relocated for alignment reasons. Since the tunnel is quite shallow in depth and runs close to major buildings throughout its length BCT strategy was to carry out a detailed preconstruction inspection of all structures along the route. Station location was extremely important and full discussions were held with the City and private property owners prior to fixing the locations. Direct access to the stations from major commercial buildings was negotiated by BCT. The Burrard station was sited directly under a city owned park. The Granville station and the east portal relocation required acquisition of privately held land. Tunnel ventilation and fire safety were of particular interest to the city authorities. BCT strategy was to involve the city in the decision making process at three levels, the Transit Committee, the Municipal Engineers Committee and a Safety and Security Committee. With continuing liaison from the earliest days it has been possible to obtain all necessary agreements and concensus without incurring any substantial schedule delay in construction.

6.1.3 Public Impact on Schedule

As has been mentioned previously, BCT established a strong community relations program with a strategy of early and open information on line location alternatives. The overall concept of ALRT in Vancouver met with wide public approval. Naturally, there were specific community concerns to be met in certain areas. Full information was provided in neighbourhood briefing meetings. Wherever possible areas of potential conflict with community needs were ameliorated. In one case a section was relocated from a neighbourhood 'mainstreet' to a back-lane. Adjustments in station location were also made. By means of the timely and continuing community relations process, adverse impact on construction schedule has been eliminated.

6.1.4 Schedule Progress

At the time of writing, the construction of the guideway, tunnel, maintenance facilities and fabrication of the rolling stock and equipment is on schedule. There is every confidence that the end dates will be met. Guideway erection will be complete by December, 1984, station construction by September, 1985 and the line will be fully commissioned by January 1st, 1986. The last of the cars will be delivered by mid February, 1986. Plate V show an outline schedule.

6.2 Budget Strategies

When the project commenced in 1981 the economy was booming and inflation was high. In 1982 the economy went into a sharp decline, from which it has not yet recovered. The B.C. provincial revenue is largely derived from natural resources, forest products and mining. With these revenues at below normal levels a policy of restraint in expenditure has been necessary. At the same time, unemployment has been high, particularly in the construction industry, so that the job creation opportunities offered by the ALRT project are important in assisting economic recovery. The overall budget strategy for BCT is to make the most cost effective use possible of the project funds, while providing the maximum opportunities for job creation in B.C. The project budget approved to date is summarized in the table below:

Table I - Cost Summary

		$ x1000	
I	Vehicles, Track, Train Control		
	Vehicles	$129.7	
	Track & Equipment	104.9	
	Subtotal I		$ 234.6
II	Construction		
	Guideway	196.9	
	Stations	66.1	
	System wide	89.0	
	Subtotal II		$ 352.0
III	Design/Engineering/Administration		
	Property and ROW		$ 238.2
	Subtotal I, II, III,		$824.8
	Contingency		$ 39.6
	Total		$864.4
	Less Special Property Revenues		(10.0)
	Net Total		$854.4

6.2.1 Purchasing Policy

The policy for purchasing construction and equipment is to solicit prequalifications by public advertisement. Bids are involved from prequalified contractors and the lowest bid selected. Justification is required if other than the lowest bid is accepted. Job creation in B.C. and elsewhere is monitored monthly. The breakdown of the job creation distribution up to the end of the first quarter of 1984 is given in the table below:

Table II - Job Creation Distribution

	B.C. %	Other Canadian %	Foreign %
Equipment and Materials	13.2	51.8	35.0
Engineering and Architecture	85.0	4.2	10.8
Construction Contracts	92.8	6.9	0.3
Overall Total Contracts	70.3	17.9	11.8

Please note that this is an interim summary. The distribution may change somewhat with time.

6.2.2 Disputed Claims

In any contract of this magnitude there will be disputed items of both a contractual and technical nature. The main system contract required a referee be appointed to adjudicate in matters which could not be resolved otherwise.

BCT and the system contractor mutually agreed on the selection of an independent engineer with appropriate experience who acts as referee on contractual matters. This includes the interpretation of the contract and settlement of claims. Either party can request that the referee intervene in an unresolved problem.

6.2.3 Property Acquisition Strategy

BCT Transit had to acquire some 235 parcels of land for the purpose of locating the right-of-way. These acquisitions take many forms ranging from obtaining total ownership of title through to acquiring temporary work site easements for access by contractors during construction. Ownership of the properties varies from that of single family private ownership, to major commercial entities and finally, properties owned by cities, municipalities and major railroads.

The line was located to take advantage of the existing Dunsmuir Railway tunnel to traverse the downtown core. Further along the route, an existing railway right-of-way was utilized. Both these strategies saved significant capital expenditures. In another instance access to an underground station was arranged through the basement of a major store with advantage of bringing potential customers directly into the store. At the downtown waterfront special provision was made for a potential future building over the tracks by pre-installing the building foundations.

The purchasing strategy was to obtain two independent appraisals for the owner and BCT. A price was then agreed based on the appraisals. Initially BCT did not have powers of expropriation but these were added later. Despite a major down turn in property prices during the program negotiated settlements were reached for 98% of the parcels without resort to the expropriation mechanism.

In the course of assembling the land for the right-of-way BCT has acquired additional land. Most of this is to be sold or leased for redevelopment in due course. As can be seen from Table I this will lead to a substantial recovery.

6.3 Quality Strategies

In a project of this nature quality objectives must be pursued consistently if the owner is to obtain the best value for his capital expenditure. The quality strategy must begin with the establishment of design criteria and performance guarantees and be followed through to detail design and specification. In the construction/equipment fabrication phases, inspection and quality assurance procedures must be applied. Commissioning procedures must be quality oriented. In a 'turn key' or engineer-procure-construct (e.p.c) type contract the owner has less direct involvement in design and must rely on the system contractor's guarantees. A fast track schedule will also result in pressures on quality of fabrication and construction.

BCT requirements for quality are based on a fifty year life for the system and high degree of reliability and safety in operation. Some aspects of the quality strategy to achieve this are described below.

6.3.1 Facilities Design and Equipment Selection

The main system contract is accompanied by a detailed set of design criteria and equipment performance specifications. At the outset, BCT carried out a review of the documents. A design review process was established by BCT utilizing Acres Consulting Services Limited to carry out review at the 25%, 50%, 95% and 100% completion stages. The review covered all guideway designs, tunnel and maintenance/control facilities. These reviews were carried out on a section by section basis. They dealt mainly with conformance with the design criteria and quality in terms of the owners requirement. As the design proceeded it was found possible to reduce the frequency of reviews for the stations to a single detailed review at the 95% level. The reviews covered design drawings and specifications. Construction schedules methods and costs were also monitored.

By mid 1983 there were a number of technical items which had not been resolved, arising from the design review process or from the as-constructed experience on the prebuild section of the line. A Technical Review Board was established by BCT to resolve these items. The TRB consists of five members drawn from BCT and the system contractor staff and consultants. The board reports to the BCT Project Administrator, who determines the items for review and receives the final recommendations. The TRB is confined to determining the best overall technical solutions. The disposition of the cost of implementing a solution is dealt with elsewhere. To date all matters of substance brought before the TRB have been satisfactorily resolved.

6.3.2 Prebuild

The early commitment to the prebuild section gave the opportunity to carry out a project within a project. The prebuild contained most of the elements of the overall projects, tangent and curved guideway, elevated station, track and controls, vehicles and operations and passenger flows. The quality of design, construction, manufacture and operation were all put to a practical test. Much was learned about all these aspects which could be put to use to improve the quality of the overall project. For instance, in the guideway structures, the bearings and pier cross head designs were improved. As a direct result of prebuild experience. The Technical Review Board was also involved in this. Operationally much valuable experience was gained from the summer months of operation during which two vehicles made were in daily service. Construction methods and tolerances were extensively examined as a result of the prebuild experience. As a result the beam casting tolerances specification was changed.

6.3.3 Quality Control, Construction and Fabrication

Throughout the construction, and fabrication and manufacture there has been a high standard of quality control inspection. Detailed procedures are provided for materials and workmanship inspection. BCT staff and consultants participate directly in the construction management with the System Contractors staff. BCT staff also participate extensively in equipment and vehicle fabrication quality assurance.

In addition to inspection, there is a quality assurance program in place. This covers all aspects of fabrication of equipment, materials, and construction workmanship, the purpose of quality assurance system is to check that inspection procedures and methods are being properly and regularly applied.

In the event of disputes regarding quality of materials the matter can be referred to a Materials Review Board. Representation from BCT and the system Contractor are appointed on an ad hoc basis to form the Board. If the matter is still not resolved it could be referred to the Technical Review Board.

Commissioning procedures are not fully developed at present but it is planned that BCT staff will work closely with the Contractor's commissioning teams to facilitate the acceptance of the operational system.

7. CONCLUDING REMARKS

The ALRT project has a very short schedule compared to other contemporary similar projects. It also has unique elements in the use for the first time of LIM motor, and steerable trucks in combination with a computer controlled system. For both BCT and the system contractor, this was the first project of such magnitude which they had undertaken. For the Lower Mainland it is the first experience with rail transit. All parties were starting from scratch and had to build their teams and organizational procedures very rapidly.

It is not surprising that there were many stresses and strains within both organizations. Despite this, the project has gone extremely well so far. There is every expectation that it will continue to go well and that the system will open on time in January, 1986.