Calgary's CTrain – Effective Capital Utilization

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ABSTRACT

The City of Calgary, a rapidly growing Canadian city of nearly 1 million people, has developed a very effective and efficient public transit system with three LRT lines forming its backbone. Today, Calgary Transit carries nearly 500,000 daily passengers and nearly half of these customers use LRT for all or part of their journey. In the 1960s, foresight and planning by city leaders identified the need for a high capacity transit system to reduce the impact of building roads. Although a decision to build LRT was not made until 1976, transit corridors were reserved for some form of high capacity transit lines as major roads were planned and new communities were being built. After considerable study, LRT was selected as having the greatest potential of attracting users by providing a rapid, reliable and comfortable trip. LRT also offered lower operating costs and the ability to encourage development that would support transit use.

Today, Calgary's LRT has the highest ridership (both in total and on a per capita basis) of any North American system. This success has been achieved with a modest level of investment in comparison to costs of other recent LRT systems. Capital costs have been minimized and the effectiveness of the LRT mode has been optimized. This paper explains how Calgary has realized these achievements and become a leader in the transit industry.

CALGARY OVERVIEW

Calgary is a city of nearly one million people situated in the Rocky Mountain foothills of southern Alberta. The foundation of Calgary's economy is agriculture, energy and tourism. Today, Calgary is home to the second highest concentration of corporate head offices in Canada representing finance, oil and gas, transportation and manufacturing industries.

Figure 1 - Calgary Skyline

Founded in 1876, Calgary has experienced steady growth with the population doubling in the past 30 years. The city has developed around a concentrated downtown core that has over 112,000 jobs and 12,000 residents located within a 3.5 square kilometre (1.3 sq miles) area. Radiating away from the downtown to the north, west and south is a crescent of relatively low density residential communities. The northeast and southeast areas are home to a rapidly growing industrial sector that provides about one third of the city's jobs.

LRT DEVELOPMENT

Planning for rapid transit began in the 1960s. A number of options including heavy rail and busways were considered. In 1976 the decision was made to invest in light rail transit[1]. In advance of LRT an express bus system (Blue Arrow) was introduced in four main transportation corridors primarily to serve the downtown. The Blue Arrow service, which included park and ride lots and supporting feeder bus services, promoted the development of transit ridership in these corridors prior to construction of Calgary's current three LRT lines. Blue Arrow service still operates in the southwest sector of the city.

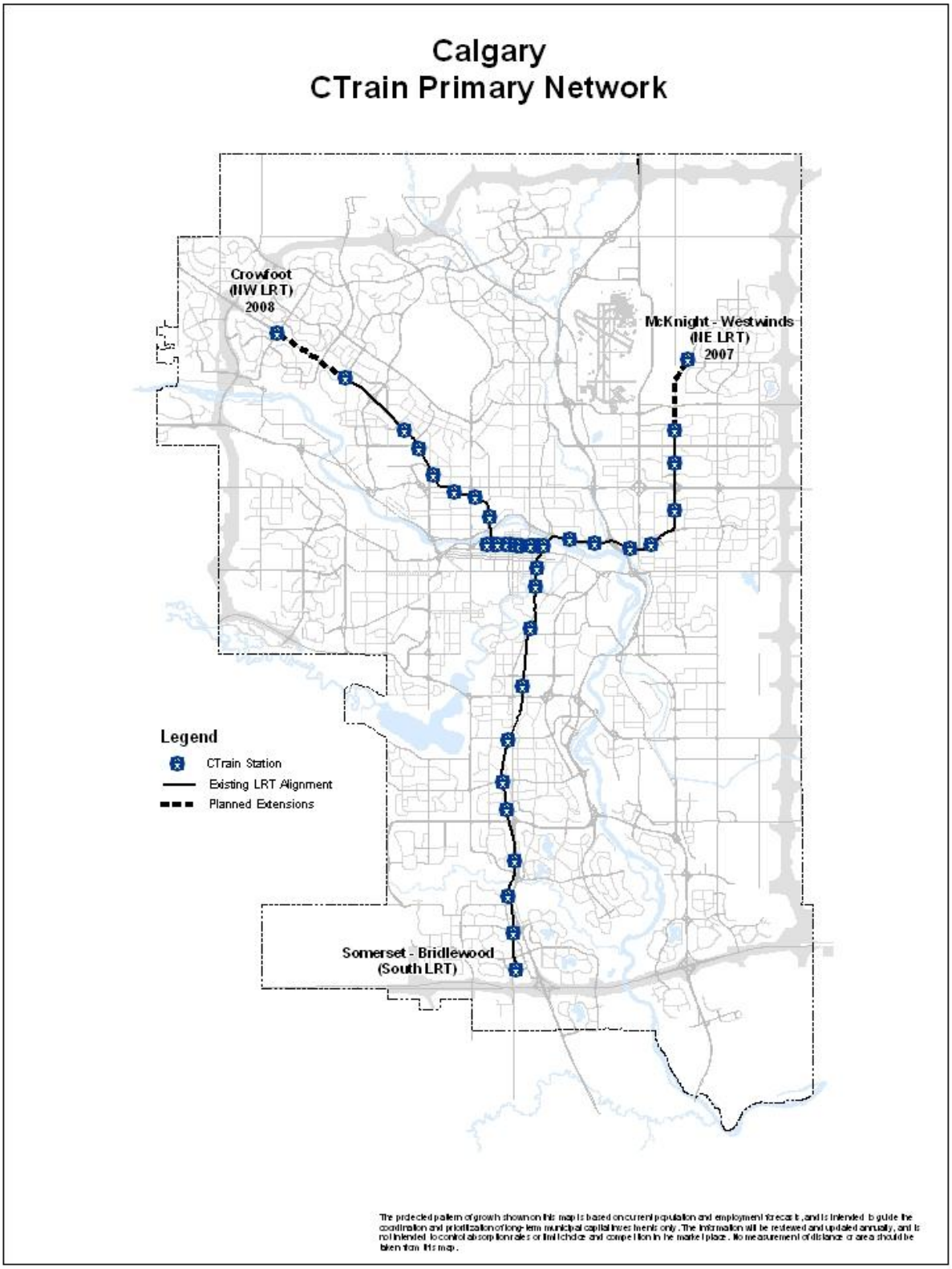

Figure 2 – Calgary CTrain Primary Network

The LRT system, or 'CTrain' as it is known in Calgary, began operations in 1981 with the opening of the 12.9 kilometre (8 mile) South LRT line. The Northeast line followed in 1985 and the first section of the Northwest line was opened in 1987 just prior to the 1988 Olympic Winter Games. Subsequent extensions of the Northwest and South lines occurred in 1990, 2001, 2003 and 2004. Today, Calgary's CTrain system stretches 42.1 kilometres (26 miles) with 25 suburban stations and 11 downtown platforms (see Figure 2). This represents a total investment of over $1 billion (CDN). The three LRT 'legs' are operated as two lines – a combined South and Northwest line and the Northeast line that currently terminates at the west end of the downtown. The three lines share the 7th Avenue transit mall in the downtown. As a result of recent rapid growth, the CTrain and bus services are currently operating at capacity during peak periods. In the next 10 years, an additional $1 billion will be invested in expanding and maintaining bus and LRT infrastructure.

LRT Operating Environment

Planning for LRT was done when Calgary's population was less than half a million. In order to maximize the length of the system with the funds available, Calgary's LRT was based on a more affordable, surface running design, common in European cities, rather than more expensive grade separated concepts.

Today, Calgary's LRT consists of 42.1 kilometres (26.3 miles) of double track, with approximately:

- 82 percent at-grade surface operation in a protected right of way,
- 8 percent in tunnel,
- 5 percent on bridges,
- 5 percent within the downtown transit mall.

Twenty five of the system's 36 stations are located in the suburban area and are spaced approximately every 1.6 kilometres (1 mile). The design and scale of suburban stations varies depending on their immediate environment and passenger volumes. Stations range from simple in-community platforms with at grade customer access (see Figure 3) to large enclosed steel and glass structures with elevators and escalators (see Figure 4). Most stations have bus terminals and park and ride lots. Of particular note is the design of the Northwest line. As it leaves the downtown it runs along side a residential street then passes through the heart of a college campus before entering the median of an expressway.

Outside of the downtown, LRT operates in a mixed environment consisting of community streets, major roads and a railway right of way. The suburban LRT right of way is generally protected with a combination of fences and barriers. LRT receives priority at all at-grade roadway crossings outside of the downtown with protection provided by traffic signals and typical railway crossing gate arms, lights and bells. Bridges and tunnels are used sparingly to grade separate some major roadways, significant features, or for alignment directional changes.

Figure 3 - Community Station – Banff Trail NW Line

Figure 4 – Brentwood Station with Park & Ride in Expressway Median

Figure 5- Downtown Platform on 7 Avenue

In the downtown, LRT operates on the 7th Avenue transit mall that is shared with buses and emergency vehicles. The 11 downtown stations are simple side loading platforms located next to the sidewalk in the curb lane with LRT tracks located in the centre lanes (see Figure 5). Downtown platforms are spaced about every other block alternating between eastbound and westbound stops. Train operation in the downtown is governed by traffic signals that are optimized to allow LRT to travel between stations without stopping.

LRT Success Story

Since the beginning of LRT service in 1981, Calgary's CTrain has proven that the significant investment was worthwhile. LRT was selected because it would provide a cost effect means of delivering an attractive, high capacity service with a higher level of reliability, speed and comfort compared to conventional bus service. As well, LRT was seen as an important tool to influence supportive, higher density land use development along transit corridors.

A high level of ridership is a key indicator of success. In its first year LRT carried over 40,000 daily passengers. This has grown significantly as the system has been extended to keep up with a rapidly growing city. Daily ridership now exceeds 220,000 averaging over 600 boardings per operating hour. During peak times, passenger boardings range between 720 and 780 per operating hour. The only challenge for the system is that current crowded conditions during peak times are detracting ridership growth. More trains will be added beginning in 2006 to address this problem.

The LRT system has contributed significant benefits to the city's urban form, particularly in the downtown. In the early 1970s, it was recognized that transit would have to play a major role in transporting workers to and from the downtown. To reduce the demand for roads, The

City of Calgary adopted a policy that limited the amount and location of downtown parking. In recent years, development has consumed most former surface parking lots in the downtown and parking space is limited. Much of the strategically located structured parking is managed by the City of Calgary. The combination of high priced long stay parking rates and limited roadway capacity encourage travel to the downtown by transit.

Today, LRT plays a significant role in allowing Calgary Transit to carry over 42 percent of Calgary's 112,000 downtown workers. Peak hour travel by LRT entering the downtown is equivalent to the capacity of about 16 free flow traffic lanes. As well, high density residential development is now occurring immediately west and south of the downtown. As a result, LRT has helped to shape Calgary's downtown and LRT ridership benefits from this high density development.

LRT does not just serve downtown travel. During peak hours, 25 percent of LRT trips are heading away from the downtown, many towards jobs in the northeast and southeast or classes at post secondary schools in the northwest. LRT reduces the roadway infrastructure required to serve these areas as well. Although transit supportive land use in the suburban areas has been slow to develop, suburban office buildings and apartment buildings have recently begun to appear next to LRT stations.

LRT Role in Calgary Transit Service

In the past ten years Calgary has experienced significant growth. Since 1995, city population has risen by 23 percent but even more dramatic has been the 45 percent increase in transit ridership. In 2005 Calgary Transit will carry over 82 million annual trips and LRT has played a major role in accommodating the increased demand for transit travel. Calgary's LRT and bus services are fully integrated with LRT lines serving a large segment of the developed area of the city. In the three LRT corridors, LRT provides a high capacity service while buses serve local destinations and provide 'feeder' services to LRT stations. Over 50 percent of LRT customers travel to and from the CTrain by bus. LRT provides an attractive mode for customers traveling to the downtown or to cross-town destinations since service is frequent (every 5 minutes in peak periods and 10 to 15 minutes in off peak) and direct with travel times that are competitive with auto travel. This overall transit system design offers significant operational efficiencies with lower capacity buses being used for shorter local trips and LRT carrying large volumes over longer distances.

CAPITAL COST OF LRT

Was LRT a wise investment? A 2001 report by the United States General Accounting Office - "Mass Transit – Bus Rapid Transit Shows Promise"[2] - suggests that for many cities, Bus Rapid Transit (BRT) may be a more cost effective alternative than LRT for providing higher capacity transit service. This report found that BRT system capital costs, in the cities under review, ranged from a low of $200,000 to $55 million per mile while capital costs for LRT systems varied between $12.4 and $118.8 million per mile. Information from the GAO report is provided in Table 1 (below). This compares the capital costs for construction of LRT in 15 North American cities since 1978. Comparative information for Calgary and Edmonton LRT systems

has been added. Capital costs shown here have been translated to year 2000 US dollars to facilitate comparison. Cost include land for rights of way, track work, stations, structures, signals, power, vehicles, maintenance facilities, and project oversight.

TABLE 1

Capital Cost Comparison of Light Rail Systems

(costs in 2000 US Dollars)

City	Total cost (year of expenditure)	Year of Line Opening	Total Cost in 2000 Million US $	Total Length Miles	Cost per mile 2000 Million US $	Weekday Boardings 2000	$ / Wk Day Passenger
Sacramento, CA	$199.0	1987 , 1998	$262.1	20.6	$12.7	28,800	$9,100
Baltimore, MD	$470.3	1992, 1997	$536.5	29.4	$18.2	25,600	$21,000
St. Louis, MO	$348.0	1993	$395.3	19.0	$20.8	31,700	$12,500
Salt Lake City, UT	$312.5	1999	$320.2	15.0	$21.4	21,300	$15,000
Denver, CO	$292.3	1994, 2000	$305.4	14.0	$21.8	29,400	$10,400
Calgary, AB	**$543 (CDN)**	**1981, 87, 90**	**$446.2**	**18.2**	**$24.5**	**187,700**	**$2,400**
San Diego, CA	$776.4	1981, 1986	$1,295.2	46.8	$27.7	82,600	$15,700
San Jose, CA	$725.0	1981, 1999	$882.6	28.6	$30.9	31,800	$27,800
Pittsburgh, PA	$540.0	1985	$780.0	25.2	$31.0	24,100	$32,400
Edmonton, AB	$310 (CDN)	1978 to 1992	$319.0	7.6	$41.7	36,000	$8,900
Portland, OR	$1,245.5	1986, 1998	$1,400.4	32.7	$42.8	71,100	$19,700
Dallas, TX	$840.0	1996, 1997	$909.6	20.0	$45.5	38,100	$23,900
Los Angeles, CA	$1,675.0	1990, 1995	$1,934.8	42.0	$46.1	81,900	$23,600
N.E. New Jersey	$992.1	2000	$992.1	10.0	$99.2	22,400	$44,300
Buffalo, NY	$510.6	1984	$760.5	6.4	$118.8	23,800	$32,000

Source: GAO-01-984 Bus Rapid Transit Shows Promise
American Public Transit Association Ridership Statistics, Calgary Transit. Edmonton Transit

Calgary's LRT ranks in the top third of these LRT systems on the basis of lowest capital cost per mile. However, this is only one measure of success. Table 1 also includes average weekday boarding passengers for these LRT systems as reported to APTA and from transit property data sources for year 2000. The last column indicates the average capital cost expended to carry a weekday passenger by dividing total capital cost by average weekday boardings. These data show that Calgary's LRT system stands out as being up to 18 times more cost effective when implementation costs are expressed on a per passenger basis!

It is evident that these cities have experienced a wide range of LRT capital costs per mile. The reasons for this wide disparity are likely associated with factors such as the type of LRT rights of way (surface, bridges, tunnel), number, scale and design of stations, types and number of vehicles, and land costs. The balance of this paper is devoted to examining the reasons for Calgary's capital cost efficiencies and high degree of effectiveness.

FACTORS CONTRIBUTING TO CALGARY TRANSIT COST EFFICIENCY

Planning and Design

As noted earlier, planning for LRT began in the late 1960s when The City of Calgary was developing a future transportation plan. It was concluded that transit would be required to play a major role if the city was to avoid the costs and environmental impacts associated with a freeway based transportation network. In 1976, after considerable study, including visits to European cities, Calgary selected LRT over a bus based transit system. LRT was selected because it offered a more cost effective, reliable and comfortable means of moving large volumes of people. As well, LRT would have a greater likelihood of attracting transit supportive development along its route.

During this time, the city was experiencing significant growth with new residential areas developing in a radial pattern away from the downtown. The need for a five legged LRT network was identified during land use and transportation planning for future city growth. As part of this process, LRT lines were planned along major transportation corridors with an emphasis on serving travel to the downtown.

LRT planning began with the reservation of rights of way in the five major transportation corridors (south, northeast, northwest, southwest, and north). The need for a sixth LRT line was identified in 1987 and planning for this future line is nearing completion. Acquisition of rights of way for LRT has come through City purchase and acquisition of land aided by the land development and building approval processes. In the Northeast and Northwest quadrants, a wide median was reserved for LRT during the construction of major roads and freeways. A lease agreement was negotiated with the Canadian Pacific Railway to allow the construction of most of the South LRT along an existing railway alignment that bisects large residential developments in south Calgary. Similar corridors have been planned in the Southwest, Southeast and North-Central areas of the city.

A policy goal to have transit carry 50 percent of all work trips to and from the downtown was adopted to limit the number and scale of roadways required to serve this high density area. This policy was reinforced by the downtown parking policy discussed previously. These policies have resulted in a concentrated, high density employment centre that is arguably the economic centre of Western Canada. Control and limitation of parking has lead to high parking prices that discourages auto trips and encourages transit use by downtown workers.

To maximize the return on investment, Calgary adopted design principles that were intended to minimize construction and operating costs while maximizing the effectiveness of service and the length of the system that could be built with the available funds. These elements are summarized below:

- **Strategic location of LRT lines.**
  - LRT lines are located to serve large residential communities and business districts.
  - LRT alignments and stations are located to intercept established and forecast travel patterns within major transportation corridors.
  - LRT stations are integrated with adjacent land use.
  - LRT stations are a focal point of local bus services.

- **Design stations to reflect the local environment and expected passenger volumes:**
  - A common, utilitarian station design was adopted. Simple side loading platforms were used where there was no requirement to protect customers from an adjacent railway or major road. Pre-cast concrete platforms with modest shelters were used in the downtown. Stations located in roadway medians are more substantial.
  - Initially, stations were built to accommodate 3-car trains but track design permits expansion to 5-car length platforms. Today, new stations are being built to handle 4-car trains and older stations are being retrofitted to 4-car lengths.

- **Provide LRT with priority over traffic outside of the downtown and maximize surface / at grade operation:**
  - Tunnels and bridges are used only where necessary.
  - Most roadways are crossed at-grade with LRT receiving priority and protection using traffic signals, gates, flashing lights and bells (see Figure 6).
  - Average station spacing is 1.5 to 2 kilometres (1 to 1.5 miles) to minimize stops, travel time and infrastructure.

Figure 6 - Suburban Roadway Crossing

- **Protect the right of way to maximize operating speed:**
  - The LRT right of way is protected from pedestrian or vehicle intrusion using fences, barriers and bollards. This concept allows LRT to operate at speeds of up to 80 kmh (50 mph) outside the downtown. The downtown transit mall is designed to restrict pedestrian crossings to signalized intersections allowing trains to operate at up to 40 kmh (25 mph).

- **Minimize infrastructure by using a downtown surface transit mall instead of a subway**:
  - An at grade transit mall was established by using an existing downtown avenue. Trains operate in conjunction with optimized traffic signals (no priority). The transit mall concept was selected to minimize construction and operating costs. Subway costs, approximately 10 times that of a surface line, were avoided.
  - LRT stations are located adjacent to or as part of the sidewalk thereby maximizing accessibility, security and minimizing cost.
  - A free fare zone along the transit mall heightens the attractiveness of the system for short trips and provides a key service to support downtown businesses.

- **Provide a feeder bus network with priority access to stations:**
  - Each station is served by a number of feeder bus routes that also serve adjacent communities and employment areas.
  - Bus stops are located as close as possible to the station entrance to minimize passenger walking distances.
  - Passenger information is generally provided through posted schedules and maps rather than electronic systems.

- **Implement a self serve fare system:**
  - Over 70 percent of Calgary Transit customers use prepaid fares (tickets and monthly passes). This is encouraged via price and convenience. Prepaid fares minimize fare collection infrastructure and costs, but, a limited number of ticket vending machines at each station allow customers to use cash.
  - Transit security personnel (Protective Services) conduct random fare inspections and provide passenger and facility security. Fare evasion rates are audited each year and are generally less than 2 percent.

- **Manage the supply of park and ride:**
  - By policy, the amount of park and ride is limited to approximately 15 to 20 percent of peak hour / peak direction transit trips leaving a community. Limiting the supply of park and ride reduces system cost, supports the feeder bus service and minimizes the amount of land required at a station.

Vehicle Procurement

The first 27 LRT cars were assembled in Calgary by Calgary Transit staff under supervision by the supplier's (Siemens-Duwag) staff. Some of the Siemens staff stayed with Calgary Transit after the cars were completed. Three of these employees are still working for Calgary Transit 25 years later! Many of the Calgary staff hired to construct the initial LRT cars are now in senior maintenance positions. This experience was invaluable for learning the intricacies of the vehicles. As well, this familiarity with the supplier has allowed Calgary Transit to maintain an extensive communications network that has enabled countless technical and supply issues to be resolved.

For new vehicle purchases, Calgary Transit does not have the facilities to continue onsite assembly. However, Calgary Transit employees are sent to oversee and participate in the assembly of new vehicles at the supplier's factory. This same practice is followed during the manufacturing of other key system components such as special trackwork and major components. The continued practice of establishing a personal network with suppliers ensures that the vehicles and parts are built to specification while maximizing quality and providing training and equipment familiarization for Calgary Transit staff.

Light Rail Vehicles (LRVs) are essentially 'off the shelf'. New vehicle purchases have been negotiated with the original supplier without a tendering process to minimize lead time and costs.

A Conservative – No Frills Approach

To enhance reliability and contain costs, Calgary Transit philosophy is to use basic, proven technology. For example, storage yards and garage track are not automated, vehicles are not air conditioned, onboard passenger information is provided using manually operated voice recordings, vehicle destination signs are not electronic, and there are no centralized onboard vehicle diagnostics. As well, there is a general policy of continuing to maintain existing technology rather than replacing items even as newer technology becomes available.

Supplier Relations and In House Teams

LRT is not a high volume industry and there are many specialized parts and equipment required to support an LRT system. Knowledge of the market place is essential to identifying areas where reliability and cost savings can be realized. Calgary Transit is able to shop the world to seek and cultivate relationships with suppliers of unique items ranging from vehicle parts to special trackwork. Trackwork, that is both standard North American and European design, is acquired from various suppliers. A small in-house maintenance team, augmented by local contractors looks after installation (see Figure 7). A network of suppliers has been established to support other specialized aspects of LRT maintenance. For example, the Munich transit system overhauls traction motors, Alstom (Calgary) is overhauling bogey frames on the older LRVs while Soiltech (German distributor) has provided a large percentage of parts for the older LRVs. Bombardier is among the companies being sought to provide other replacement parts.

Figure 7 - Calgary Transit LRT Staff Replacing Trackwork

Traction power and signals are supplied and installed by other City of Calgary departments. Use of in-house expertise permits the establishment of partner relationships and service agreements. This allows other departments to take ownership of various aspects of system construction and maintenance while maximizing The City's investment in staff training, expertise and equipment.

New Facility Design and Construction

Expansion of Calgary's LRT system has been ongoing for the past six years after a ten year pause. Since 2001, Calgary Transit has doubled its investment in LRT with extensions totaling 9 kilometres (5.6 miles) and 5 stations being constructed. A new LRV maintenance facility and two new stations are currently in the design and construction phases. The City of Calgary Transportation Infrastructure Division is a key partner in the designing and building of new facilities. An in-house LRT Construction Coordination committee provides Calgary Transit staff with input at all stages of the design, construction and final inspection of these projects. Standardization is a key objective in this process particularly when dealing with different contractors and suppliers. Materials and designs are selected to minimize cost, maximize life and utility and facilitate eventual replacement.

Figure 8 - New Fish Creek Lacombe Station on South Line in Railway Right of Way

A process of community involvement is used in new station design. Urban design and architectural principles have been used to integrate LRT within community and business areas. Involving citizens and business owners in this process enables the local community to express their needs and influence facility design. This process is critical to addressing and resolving local uncertainty and opposition. However, care must be taken to manage this process otherwise costs can escalate when unnecessary frills are allowed to creep into the designs.

Ongoing Assessment and Maintenance

A regular program of infrastructure assessment is used to develop preventative maintenance and refurbishment programs. This includes well thought out vehicle maintenance schedules, station upgrades and electrical plant refurbishing. Calgary Transit conducts regular assessments to determine the condition of all assets and infrastructure and to forecast expected life. This information is used to create budgets and programs for life cycle maintenance programs.

Operating Costs

Although this paper has focused on capital costs, it is noteworthy that the effectiveness of Calgary's LRT has resulted in a low operating cost per passenger. For 2005, the average hourly operating cost of LRT is approximately $163.00 ($139.40 USD). This figure includes operating, maintenance and utility costs. With an average of 600 boarding passengers per operating hour the average cost per LRT passenger is only $0.27 ($0.23 USD). In comparison, the average cost for bus passenger boardings is approximately $1.50 ($1.28 USD) or almost 6 times the cost of

carrying an LRT passenger. Of course buses have considerably lower capital cost and have different capabilities.

CONCLUSION

Calgary's CTrain has the highest ridership of any North American LRT system. For a prairie city with a population of just under a million, this is a significant achievement. A comparison of LRT systems built prior to 2001 shows that Calgary's LRT development costs are among the lowest of 15 North American cities. More important is that Calgary's LRT has achieved a very high level of ridership.

This very effective and efficient LRT system comes as a result of key planning, design, construction and operating principles. Rights of way were reserved as new development proceeded away from the city centre so that LRT would serve major travel corridors. A predominately at grade design with a protected right of way was implemented to optimize the length of the system, while maximizing operating speed and accessibility. Vehicles purchased were a proven design. A utilitarian approach has carried through most aspects of the system and vehicles although materials were chosen for function and durability. Calgary Transit planning, operating and maintenance staff have been an integral part of all phases of design and construction of track, stations and vehicles. Maintenance practices have followed the same philosophy.

Downtown land use and parking policies have further strengthened the role of LRT and allowed the development of a compact and vibrant city centre. As well, location of LRT lines in proximity to other major developments has enabled LRT to provide an attractive alternative to autos and reduced the environmental impact of urban travel. LRT and bus services are integrated to maximize the effectiveness of each mode.

This combination of planning, design, construction and maintenance principles has produced an LRT system that provides a tremendous return on investment. Ridership response has validated these decisions. Today, LRT is the backbone of a very successful transit service. Calgarians have embraced the CTrain and there is public and political support for continued expansion of existing LRT lines and development of the remainder of the system.

REFERENCES

1. *Light Rail Transit for Calgary,(* CALTS 38), City of Calgary, 1976

2. *Bus Rapid Transit Shows Promise,* United States General Accounting Office, GAO-01-984, 2001.