Light-Rail Transit in Calgary, 1981–1995: A Retrospective Review

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In the past 14 years, the city of Calgary has invested approximately $543 million (Canadian) in developing a three-leg radial light-rail transit (LRT) system. Currently the LRT system consists of 30 km (18.6 mi) of double track, 31 stations, and 85 light-rail vehicles and carries approximately 100,000 passengers each weekday. Approximately 87 percent of the system is composed of surface operation in the right-of-way of city streets and an existing rail corridor. The present transportation and land use policies for downtown Calgary reinforce the importance of public transit for downtown work travel. Access-mode planning at the LRT stations also provides for a comprehensive range of access modes and effective coordination of feeder bus and LRT transfers to optimize the development of the transit market. Strategies have also been developed to integrate surface LRT operations within a shared right-of-way with private automobile, pedestrian, and bicycle traffic while giving priority to LRT operations through traffic signal preemption. These factors have enhanced the attractiveness of the LRT system for travel to downtown and suburban employment and educational and retail centers. The impact of LRT on travel behavior in Calgary and the planning and design lessons that can be learned from the first 14 years of LRT operation are examined. The lessons learned encompass systems planning and design, access-mode planning, personal security, and fare collection, in addition to overall experience gained with LRT operations.

With more than 14 years of light-rail transit (LRT) construction and operating experience, Calgary Transit has a substantial knowledge base regarding planning, design, and operation of LRT systems. The experience gained from construction and operation of successive stages of the LRT system has been used to adapt LRT operations to a variety of surface operating environments. Experiences with station design, access-mode planning, fare collection, and safety and security have also been used to improve operations.

Background

Calgary is a city of approximately 738,000 situated at the base of the Rocky Mountain foothills in southern Alberta. The city's economy has been built on an economic base of agriculture, energy, and tourism. Since the 1960s, Calgary's history has been one of overall steady growth from 400,000 in 1971 to almost twice that amount. The city has developed around a concentrated commercial core with a crescent of residential development radiating away from the downtown to the north, west, and south and an industrial district to the east. Approximately one-third of the present employment is located in the downtown and inner city, one-third along

the east industrial area, and one-third throughout the city.

Calgary is a "unicity" in the sense that it is an urbanized area surrounded by agricultural or country residential areas. This situation allows the Calgary City Council to exercise almost complete control over its urban environment, including the transportation system. This combination of strong, continuous growth and unicity jurisdiction contributed to the advent of a successful LRT system in Calgary.

System Development

Discussion

In 1967, Calgary City Council adopted a balanced plan of freeways and heavy-rail transit, that was to be implemented over the subsequent 20 years (*1*). Projected expenditures showed an expected emphasis on freeways, with estimates of $450 million and $80 million for roads and transit, respectively. The freeway network plan adopted in principle met quick opposition with respect to plans for individual sections, and the momentum for a revised approach to urban mobility began in 1971 when a section of a major north-south freeway was relocated.

In 1972, the Calgary City Council took advantage of its unicity status and established a Transportation Department, which brought together a number of transportation functions previously administered by separate city departments. Traffic operations, public transit, and transportation planning (both transit and roads) were included in this department. The Transportation Department was placed under the jurisdiction of a Commissioner of Planning and Transportation, who has similar management responsibility over the City Planning Department. Coordination of the activities of transportation and land use planning under a unified administrative structure facilitated the integration of transportation modes (e.g., transit, roadways, parking, pedestrians) and development of mutually supportive land use and transportation policies.

Also in 1972, the province of Alberta initiated a new funding program for transportation in urban areas. Labeled as "responsive" to the right needs, the program provided financial assistance to municipalities for planning and construction of public transit and arterial roads. Receipt of funds was conditional on a municipality's passing a Transportation Bylaw based on a comprehensive study and on provincial approval of funded projects.

Initially, after abandoning much of the freeways proposed for the inner city but retaining some peripheral and suburban radial routes, Calgary concentrated on rehabilitating the public transit bus system. New equipment was purchased and a new express bus service was developed, forming a prototype system for the eventual rail system proposed. The express bus system promoted the development of transit corridors and included park-and-ride facilities and supporting feeder bus routes.

In 1976 the Transportation Department initiated several studies on the feasibility of LRT for Calgary. Light rail versus bus was compared for the south corridor, and transit versus roadway expansion was analyzed (*2*). While maintaining a substantial suburban roadway expansion program, Calgary City Council adopted the concept of LRT. After further review, implementation of LRT began in 1977, and in May 1981 the 10.0-km (6.6-mi) south line opened for revenue service.

With the downturn in the economy in the early 1980s, the city's perceived need for rapid implementation of LRT and its ability to finance the system were altered. A new staging schedule was adopted, and in 1984 the province announced a restructured assistance program providing continued financial support for the city's objectives.

Implementation of a northwest extension was delayed by controversy over its alignment. Although this line had been advocated by a Transit Commission in 1964, no action had been taken on right-of-way acquisition through the inner city. While extensive community consultation on this issue was being undertaken, implementation priority was switched to a northeast line whose right-of-way had been protected in the median of roadways planned for the area. The 9.8-km (6.1-mi) northeast line opened in 1985, sharing a downtown section with the south line.

The impending 1988 Winter Olympics gave impetus to resolving community opposition to the northwest line, which served important venues at the University and McMahon Stadium for the games. The 5.8-km (3.6-mi) line was opened in 1987 and connected to the south line. A further 0.8-km (0.6-mi) extension of the northwest line was opened in 1990, providing improved terminal connections to bus routes and park-and-ride facilities.

The existing LRT system (Figure 1) is operated as two lines—Anderson to Brentwood (south to northwest) and Whitehorn to downtown (northeast). On weekdays, LRT carries approximately 100,000 passengers (378 boarding passengers per operating hour), including 20,000 passengers within the downtown free-fare zone on 7th Avenue S. W. Average weekday bus ridership is approximately 161,800 (45 boarding passengers per operating hour).

To accommodate future system expansion, right-of-way has been protected for extension of the LRT system to the northwest, south, and northeast. Route location studies have also been undertaken to protect the right-

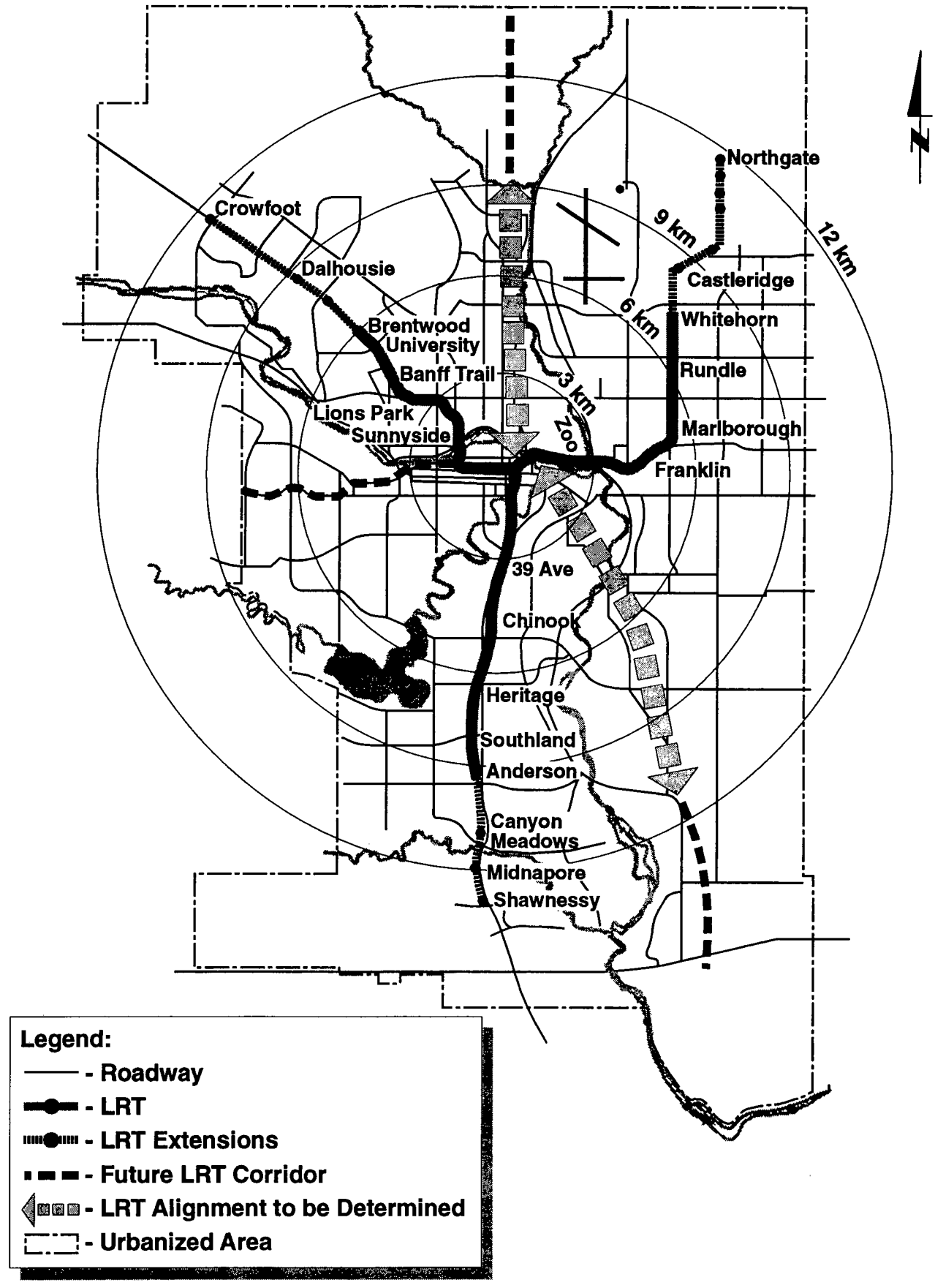

FIGURE 1 Calgary roadway and LRT networks.

of-way for future LRT lines to the southeast, west, and north.

Lessons Learned

1. Long-range plans should be developed to protect LRT right-of-way, including station areas and adequate land for park-and-ride and feeder bus facilities. Because the land is required well in advance of actual use, it is advisable to consider potential interim land uses to lower the overall capital investment. In addition, at this stage it is worthwhile to assess the potential of adjacent properties for compatible shared parking.
2. An LRT system prototype with express bus service and park-and-ride facilities should be developed to promote ridership in future rail corridors.
3. Transit planning should be integrated with transportation (roads, parking, pedestrian) and land use planning by creating multidisciplinary project teams under the control of a single administrative entity.
4. If possible, LRT expansion should be implemented in successive stages to continue momentum and develop expertise among the project management team and construction contractors.

Performance and Downtown Transportation Policies

Although Calgary may be characterized as being typical of western North American cities with high automobile ownership and low-density suburban neighborhoods, it differs from many similar-sized cities in that it has a well-defined, intensively developed downtown. With 86,700 employees, 10,000 residents, and 8.94 million m^2 (31 million ft^2) of office space plus hotels and retail space concentrated in only 3.6 km^2 (approximately 1.4 mi^2), downtown Calgary has one of the more concentrated central business districts (CBDs) in North America.

Calgary's present transportation policies are designed to alter the modal split in favor of public transit, particularly for work travel to downtown. The cornerstone of the policies for downtown transportation is the gradual reduction in availability of long-term parking relative to downtown growth. Current Land Use Bylaw requirements for office buildings in the CBD specify one parking stall per 140 m^2 (1,500 ft^2) of net floor area. For the downtown core area, which has restricted vehicular access because of the exclusive LRT-bus corridor on 7th Avenue and a pedestrian mall along 8th Avenue, the city has a cash-in-lieu program of on-site parking. The Calgary Parking Authority utilizes funds collected through this program to construct parking structures in designated corridors on the periphery of the downtown core. These structures have been connected to the office and retail core by an extensive, elevated walkway system known locally as the Plus 15 network.

To complement the downtown parking policies, the city has made a major investment in improving transit service by developing a radial system of LRT lines and mainline bus routes leading to the downtown. Complementary policies such as suburban park-and-ride, traffic management, roadway capacity restrictions, improved pedestrian environments, and downtown residential development complete the strategy.

Figure 2 summarizes the changes in parking supply, employment, and modal split to the CBD between 1964 and 1992. The period of greatest growth in the modal split occurred between 1971 and 1981, when parking supply lagged behind employment growth. Since 1981, transit usage has declined as parking supply has increased in proportion to downtown employment. The contributing factors to this situation are high office vacancy rates and the existence of a large supply of parking in office buildings and on temporary surface parking lots awaiting development. Of the approximately 45,000 downtown parking stalls, approximately 63 percent of the total supply is included in the category of bylawed parking (required under the Land Use Bylaw) and the remainder, non-bylaw parking is composed of on-street parking (5 percent) and surface parking lots (32 percent).

LRT has generally had a positive effect on transit usage, particularly for travel to downtown. Since the inception of the south LRT service, the line has carried between 38,000 and 40,000 passengers on weekdays, with the most notable impact being the attraction of nearly 20 percent of this ridership from previous automobile users (*3*). Between 1981 and 1985, the peak-hour modal split to transit for trips to the downtown increased from 37 to 47 percent but has since declined to approximately 42 percent.

Since its initial year of operation in 1985, the northeast LRT ridership has increased from 23,000 to 28,000 weekday passengers. Again, approximately 20 percent of these riders were previous automobile users (*4*). The peak-hour modal split for downtown work travel increased from 42 to 52 percent from 1985 to 1988 in the northeast corridor.

Because of funding constraints, the northwest line has been constructed in stages and does not extend into the center of the catchment area. This factor has limited ridership development. Currently, daily ridership is approximately 24,000 weekday passengers, and the modal split has remained at approximately 35 percent since the line opened in 1987 (*5*).

In general, public reaction to the introduction of LRT has been very favorable in each of the LRT corridors. Customer surveys indicate that 90 percent of LRT riders

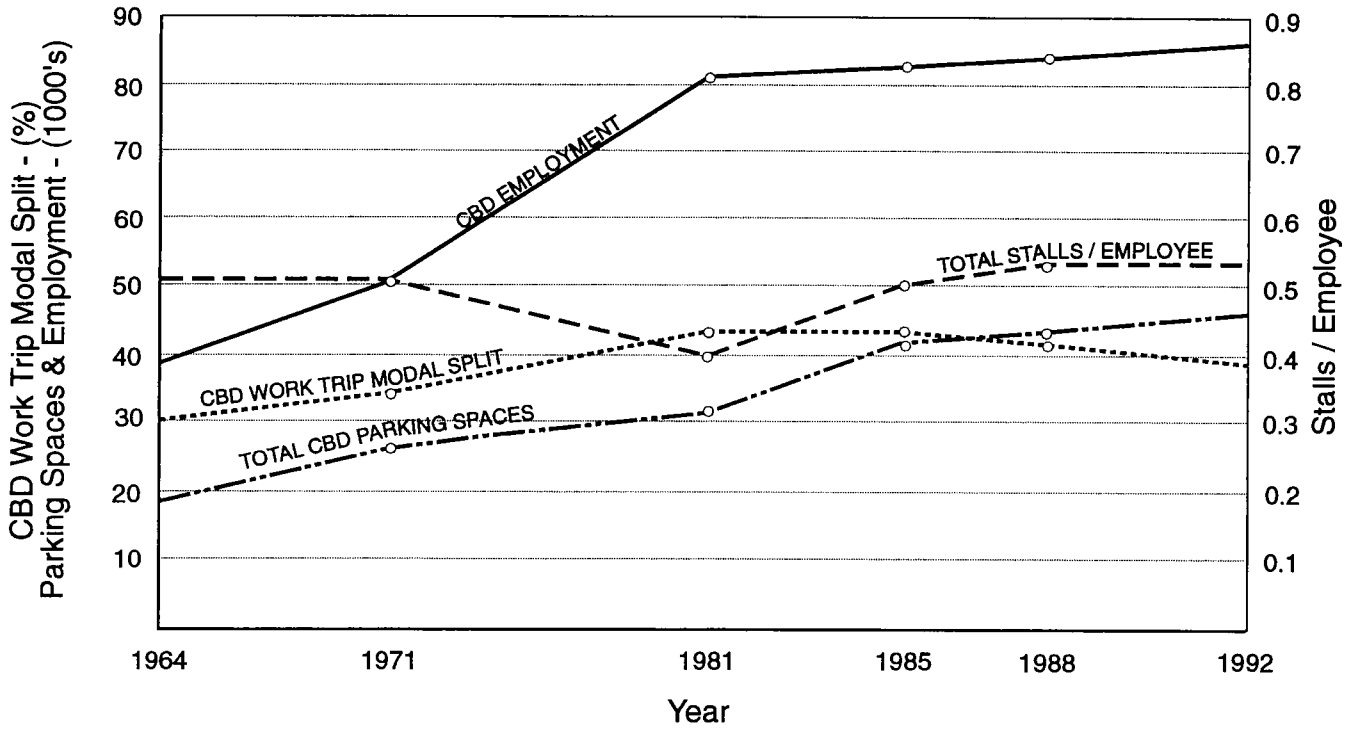

FIGURE 2 CBD work trip modal split.

are satisfied with the service. The qualities most often mentioned by transit customers who have switched from their private automobile to LRT relate to convenience and reliability of LRT travel, travel time savings compared with automobile travel, and the reduction of out-of-pocket costs for travel to downtown. Market research surveys also indicate strong support among transit users and nonusers for further extensions of the LRT system.

Future Situation

A recent study (*6*) has confirmed that there is a strong statistical relationship between the supply of long-term downtown parking and the amount of transit usage. In general, the more stalls per employee, the lower the propensity to use transit.

To manage future downtown growth, recommendations have been developed to match the supply of long-term parking to a desired modal split for transit travel to downtown. The matching policy for long-term parking is based on increasing the peak-hour work trip modal split from 40 to 50 percent within a 30-year period and higher beyond that time frame. An important part of the strategy to match parking supply to the modal split goal is to encourage further residential development within the downtown. Taken together, these initiatives and additional investment in public transit improvements (i.e., LRT and bus) will contribute to the achievement of the city's goals to provide a balanced transportation system and maintain a strong, viable downtown.

Lesson Learned

1. LRT has had a positive effect on increasing the modal split for downtown work travel when supportive parking policies are working to restrain long-term downtown parking.

System Design and Operations

Calgary's LRT system now consists of approximately 30 km (18.6 mi) of double track, of which 87 percent is for surface operation, 5 percent is on grade-separated bridges, and 8 percent is underground. Surface LRT operations have been adapted to operate in city streets (e.g., downtown Calgary), within an existing railway corridor (e.g., the south corridor), in the median of an expressway and major arterial roadway (e.g., the northeast corridor), and within existing communities and educational institutions on an exclusive right-of-way or parallel to existing local streets (e.g., the northwest corridor). In total, there are 43 grade-level roadway crossings on the LRT system.

Outside the downtown, train movements are controlled by an automatic block signal (ABS) system that

allows only one train to occupy each section, or block, of track. At grade-level crossings outside of the downtown, trains preempt the normal operation of traffic signals to allow uninterrupted movement between stations. Grade-level roadway crossings are protected by LRT gates, bells, and flashing lights. Currently the gate warning time is about 22 sec, with an additional 10 to 15 sec for the gates to ascend and the warning lights and bells to turn off. In the northeast corridor, the operation of the traffic signals at the 10 grade-level intersection crossings along 36th Street N.E. is designed so that preempted traffic movements (e.g., north and south left turns) are reserviced if a preset green time has not been met once the train clears the intersection.

Within the downtown, the LRT operates along the 7th Avenue transit mall under line-of-sight operation with buses and emergency vehicles. Cross-street traffic and train and bus movements are controlled by conventional traffic signals. Although LRT trains are not given special priority at downtown traffic signals, a signal progression has been designed along 7th Avenue to minimize delays as the trains travel between stations.

Since the opening of the LRT system in 1981, there have been an average of 4.9 vehicle and pedestrian collision accidents per 1 million km. This compares with 17.3 collisions per 1 million km for the bus system. From a passenger safety perspective, there has been 0.56 passenger injury per million passengers on the LRT system compared with 3.5 passenger injuries per million passengers on the bus system. In comparison, a recent study of European and North American LRT systems revealed that LRT accident rates are similar to those for buses per vehicle kilometer and that on a passenger-kilometer basis, LRT is generally safer than bus, which, in turn, is safer than car (7).

Operating Experience Within Downtown

In examining temporal trends in collision accidents involving private vehicles and pedestrians, there is clear evidence of a learning curve with respect to LRT operations in the downtown. In the initial years of LRT operation, the system experienced over 22 vehicular accidents per year in comparison with the more recent average of 10 per year. However, no similar trend has been noted with respect to pedestrian accidents as the system continues to experience an average of six incidents per year (i.e., contact of any type).

The majority of accidents involving other motor vehicles in the downtown have occurred as a result of failure by private vehicles to obey traffic control devices at the streets intersecting 7th Avenue and 9th Street. Most pedestrian-LRT accidents are a direct result of persons jaywalking or disobeying signals at intersections.

New features and signage have been developed to increase the level of safety along the 7th Avenue transit mall. To summarize,

- LRT trains are restricted to a maximum speed of 40 km/hr along 7th Avenue, 15 km/hr through the turn at 7th Avenue and 9th Street S. W., and 25 km/hr on 9th Street S.W.;
- Pedestrian gates, signals, and railway crossing bells have been installed at the intersection of 7th Avenue and 3rd Street S. E. where the south and northeast legs merge; pedestrian bedstead barriers have also been installed at specific intersections to channelize pedestrian flow;
- Posts and chains have been erected along a one-block area on 7th Avenue where there are a number of taverns and at other locations where jaywalking has presented a problem;
- No Jaywalking signs have been installed along the 7th Avenue corridor, and support has been solicited from the local police to enforce the jaywalking bylaws; and
- A public awareness campaign has been established to develop a greater level of safety consciousness regarding the LRT system.

With the implementation of these improvements, there has been a gradual reduction in the number of accidents along 7th Avenue and 9th Street.

Operating Experience Outside of Downtown

A review of vehicle and pedestrian collisions for the outer sections of the LRT system indicates that the accident rate is substantially less than that for in-street operation within the downtown, which has experienced an average accident rate of 13 collisions per 1 million vehicle-km. In general, the northeast corridor, which incorporates median running in a major arterial roadway, has a slightly higher vehicle accident rate (0.33 collision per 1 million vehicle-km) than the south or northwest corridors (0.16 and 0.08 collision per 1 million vehicle-km, respectively). This difference is attributable to the concentration of commercial land uses and the heavy volume of cross-street and left-turn movements at the 10 grade-level intersections along 36th Street N.E.

Lessons Learned

1. Surface LRT operations can be safely integrated into city streets and other environments by using existing traffic signals, railway crossing equipment, and other pedestrian and traffic control techniques.

2. Use of LRT signal preemption provides travel time savings for transit travel and can be accommodated in major arterial roadways without compromising safety.
3. On the basis of Calgary Transit's experience, LRT accident rates are lower than those for the bus system, per vehicle kilometer. On a passenger-kilometer basis, LRT is also generally safer than bus.

Station Design

Discussion

The experience gained from construction and operation of each of the LRT lines has resulted in changes in the scale and design of Calgary's LRT stations.

The initial south LRT line includes six center-load stations fed by enclosed stairways and a single set of escalators at the north end of the platform. No provision was made for elevators or ramp facilities to accommodate persons with disabilities; however, equivalent funds were committed by City Council to upgrade the specialized door-to-door Handi-Bus service. In the downtown, short stairways and access ramps were constructed at the 11 side-load stations on 7th Avenue.

The design of the second leg of the LRT system to the northeast incorporated the LRT alignment in the median of an expressway and major arterial roadway. The seven center-load stations on this line are fed by stairways and ramps spanning the roadways. Within the station, an elevator and two sets of escalators were provided to accommodate access between the fare process area and the platform. Access to the platforms incorporates alternate end loading at successive stations. This revision emanated from a review of loading patterns on the south LRT stations, which showed that customers tend to cluster near the end of the platform closest to the only access point (*8*). Placement of the access points at opposite ends of the platform at adjacent stations has improved the evenness of passenger loads in the three-car train sets, resulting in better equipment utilization and passenger comfort compared with the same end-loading pattern on the south LRT.

Unlike the first two LRT lines, where limited community interface problems were encountered, the northwest LRT line presented a major challenge in integrating the stations and track alignment within established neighborhoods. To facilitate this process, Calgary City Council allocated $4.1 million to the $107 million capital budget specifically for aesthetic upgrade purposes and appointed an urban design consultant to work with community representatives and project management staff on the integration of the line within each affected community (*9*). Although the vertical and horizontal alignments were held as "givens" for this process, the scope of the review allowed the communities to influence decisions affecting pedestrian access and circulation, buffering for noise and vibration, landscaping of the right-of-way, and appearance of the stations, bridges, tunnel portals, and ancilliary structures.

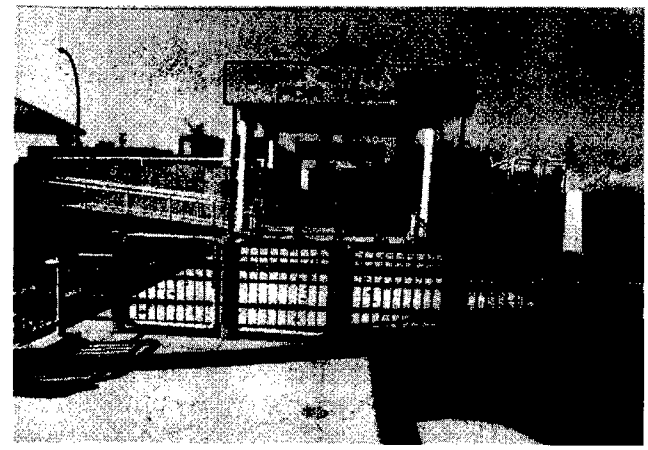

FIGURE 3 LRT station grade-level pedestrian crossing with gates, railway lights, bells, and large warning signs.

The alignment of the northwest LRT readily accommodated grade-level pedestrian access to the meter-high, side-loading platforms and presented an opportunity to design low-scale "local stations." Because the station design represented a major community concern from both aesthetic and functional perspectives, the philosophy adopted was that the stations should reflect the local urban character of the community both in design and materials and need not have a profile greater than a single-family house. To accommodate customer access, railway signals, pedestrian gates, and staggered bedstead railings are used to provide crossing protection at designated access points (see Figure 3). These grade-level crossings enhance customer access and also have been linked with the community pathway and bicycle network, which connect the northwest communities. Standard railway crossing signals, bedstead barriers, and pedestrian gates have been effective in providing protection for the volume of pedestrian and bicycle traffic crossing the tracks.

On the basis of the experience with grade-level access to the northwest LRT stations, new grade-level pedestrian connections are being constructed to accommodate handicapped access to the south LRT stations. The new connections incorporate a new set of stairs and a ramp and concrete apron linking the open end of the station platform with the park-and-ride lots. There is a single grade-level crossing of the southbound LRT track, which is controlled by a system of railway signals and staggered bedstead railings.

Lessons Learned

1. Station access walking time should be minimized by keeping the station design simple, and, if possible, direct grade-level access to the platforms should be provided.
2. Where appropriate, "local station" concepts should be considered to integrate LRT within established residential areas. The scale of the station should be minimized and urban design elements that complement adjacent land uses should be incorporated. Efforts should be made to integrate station access with the local pedestrian-bicycle pathway system. As a general rule, major park-and-ride lots should not be located at local stations except possibly on a shared-use arrangement with a land use such as a community center.
3. Barrier-free access should be incorporated in station design to accommodate persons with disabilities and other transit customers (e.g., persons with parcels, baby strollers, or small children).
4. Alternate end loading should be incorporated at successive center-load stations to balance passenger loads between cars in the train consist and achieve more efficient use of available capacity.

Access-Mode Planning

Access-mode planning for Calgary's LRT system accommodates a comprehensive range of access modes (*10*). In suburban areas, access is by feeder bus, park and ride, automobile drop-off, walking, and cycle. The predominant access mode to LRT stations for the inner city, University of Calgary, Southern Alberta Institute of Technology, and the Zoo is pedestrian (Figure 4).

Suburban Stations

The access-mode guidelines for suburban stations are as follows:

Access Mode	*Modal Share (%)*
Bus	60–65
Park and ride	15–20
Kiss and ride	15
Walk	5

The policy target is to accommodate two-thirds of total a. m. LRT boardings by feeder bus. This strategy recognizes that feeder buses are best able to supply the required capacity for customer access to the LRT system and addresses community concerns regarding the traffic and environmental impact of developing large parking facilities adjacent to residential areas.

To ensure the provision of a high-quality feeder bus service, public transit requirements are reviewed and incorporated at each stage in the development process as a condition for development approval. Through this process, the collector road system is molded to maximize transit coverage and enhance directness of travel. In developing feeder bus networks, every effort is made to provide direct bus service to and from the LRT to accommodate trips leaving the catchment area, serve a range of community-oriented trips (e.g., school, shopping), and, where possible, increase the potential for crosstown and intercommunity trips. Together, the LRT system and connecting feeder bus network form a citywide network of transit services.

To provide for private automobile access to the LRT system, park-and-ride and automobile passenger drop-off facilities have also been developed at suburban LRT stations. Currently there are more than 7,000 stalls at 11 stations and an additional 5,900 stalls are planned in extensions of the system. Accommodating 15 to 20 percent of peak-hour demand by automobile access represents a strategy to strike a balance between satisfying the demand for park and ride and maintaining a viable feeder bus service.

Inner-City Stations and Educational Institutions

The main access mode to inner-city stations and large institutions is pedestrian and, to a much lesser extent, the bicycle. Planning guidelines for these stations emphasize the pedestrian mode.

Lessons Learned

1. The feeder route network and LRT are mutually dependent for their success. Integration of LRT and feeder bus services substantially enhances the attractiveness of transit for travel to downtown and also utilizes opportunities that LRT presents for meeting non-CBD-oriented transit trips.
2. Public participation is required for access-mode planning at suburban stations to allay the fears of local residents with respect to increased automobile and bus traffic and spill over parking. The Calgary experience is that there is no substitute for detailed planning and public participation to gain public acceptance of feeder bus routes and park-and-ride facilities in close proximity to residential areas.
3. It is essential that an appropriate balance be maintained between park and ride and other access modes to sustain a viable feeder bus system and minimize traffic impacts in adjacent residential areas. Experience has demonstrated that parking expansion programs may

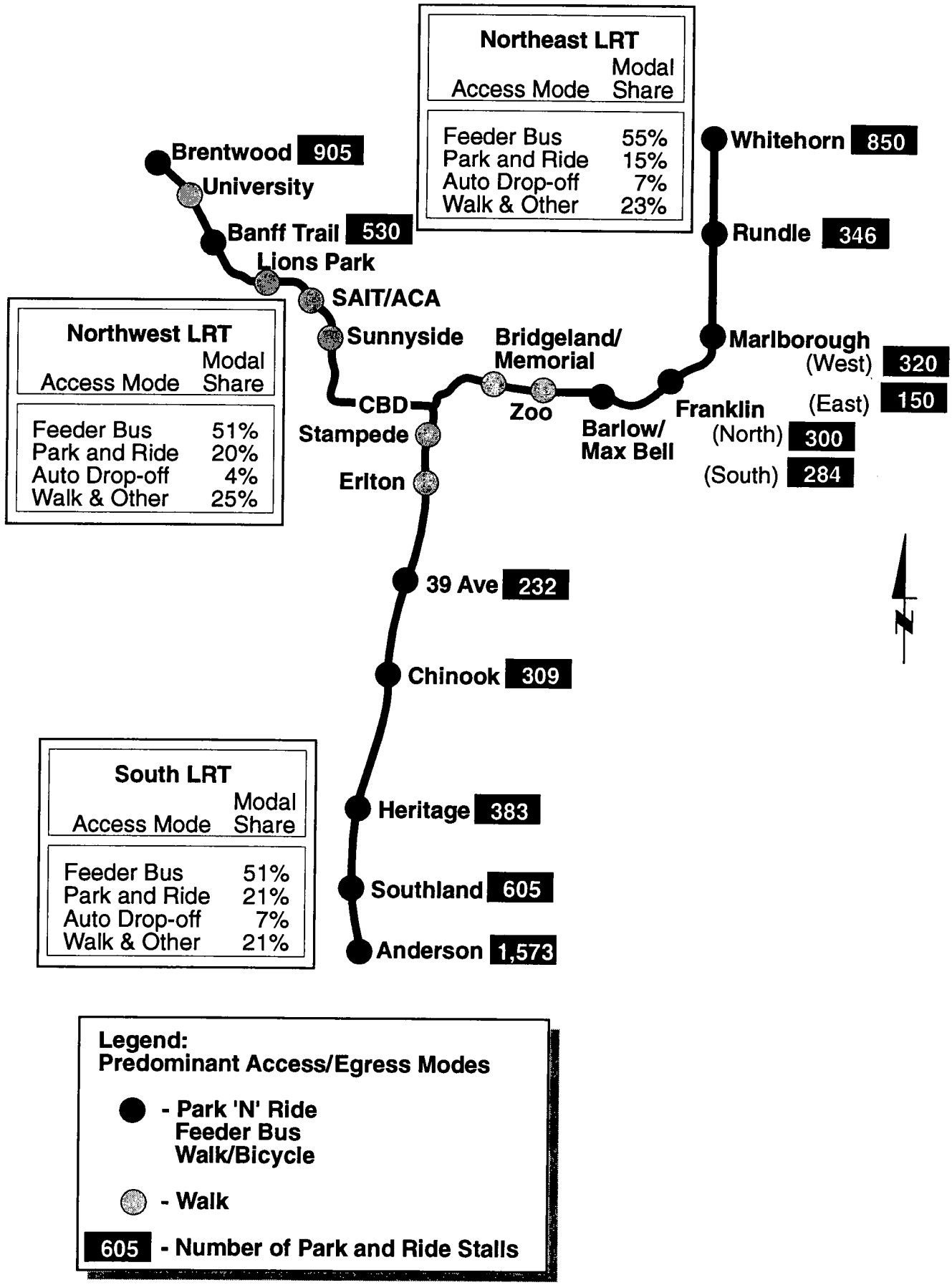

FIGURE 4 LRT access modes (a.m. peak period).

trigger some shift from other access modes such as feeder buses to park and ride rather than generating entirely new ridership (*11*). Oversupply of park-and-ride stalls not only is economically undesirable but also could result in unacceptable environmental and community impacts. Undersupply of park and ride can also result in unacceptable impacts such as spillover parking on adjacent streets and discourage public transit patronage by commuters now driving to work downtown. Part of the lesson learned is that the commutershed concept (*12*) is very useful for estimating the demand for park and ride as well as the trip generation to and from park-and-ride facilities (*13*).

Personal Security

The number of criminal acts against persons on transit property is low in relation to the number of customers who regularly use the system and the total crimes against persons reported citywide. In 1992 there were 112 crimes against persons involving C-Train passengers among approximately 70,000 Calgarians who use the C-Train regularly. This represents less than 2 percent of the total crimes against persons in Calgary.

Although 90 percent of transit customers report that they feel safe when using the LRT system (*14*), Calgary Transit is concerned that any perception that the LRT system is not safe from a personal security perspective may cause customers to use the system less frequently or not at all. To enhance public security and customer confidence in the LRT system, the following initiatives have been undertaken.

Equipment Enhancements

In 1992, Calgary Transit implemented HELP telephones on all LRT platforms and an intercom system in all light-rail vehicles. This system allows customers to communicate directly with Calgary Transit personnel in the event of an emergency or threat to their personal security. A multi-year replacement program has also been initiated to upgrade the 40 television monitors in the LRT control center and the 190 cameras located at LRT stations.

Crime Prevention Initiatives

Calgary Transit and the Calgary Police Service jointly endorse the concepts of Crime Prevention Through Environmental Design (CPTED) and have conducted facility audits to determine where CPTED principles could be applied to deter criminal activity and encourage greater confidence in the security of the LRT system. CPTED concepts include the design of buildings and surrounding areas to provide natural surveillance and natural access control. Integrating natural crime prevention approaches into the design of public buildings and property encourages greater use of facilities and reduces the need for intervention by traditional enforcement personnel.

Staffing Initiatives

To provide greater visibility of uniformed personnel patrolling the LRT system, additional uniformed employees have been assigned to assist existing Calgary Transit Protective Services officers in enforcing the Transit Bylaw. The Protective Services unit also continues to assign plainclothes officers to deter criminal activity and threats to personal security. As well, Calgary Transit deploys staff from the Transit Operator Spare Board to increase surveillance of park-and-ride lots.

Lighting Standards

The LRT system has been developed in phases over a 12-year period with no uniform standards for lighting at the stations and park-and-ride lots.

Calgary Transit has recently developed design guidelines for lighting levels at LRT stations (see Table 1) and has taken steps to address deficiencies in the downtown and the older south line stations. Lighting levels at downtown stations have been increased from 54 to 215 lux (5 to 20 footcandles). Work has also begun to correct lighting deficiencies at suburban stations and park-and-ride lots, particularly on the south LRT line.

TABLE 1 Design Guidelines for Lighting Levels at LRT Stations

Area To Be Lighted	Minimum Levels	
	Footcandles	Lux
1.1 Outlying platform	10 avg	108
1.2 Downtown platforms	15–20 avg	161–215
1.3 Interior stairs	8–10 avg	86–108
1.4 Lobby	8–10 avg	86–108
1.5 Ticket area	20 min	215
1.6 Parking lots	0.9 min	10
1.7 Above-ground building	8 avg	86
1.8 Sidewalks, bridges	4 avg	43
1.9 Ramps, exterior stairs	4 avg	43
1.10 Bus waiting areas	4 avg	43
1.11 Sidewalks in parking lots	2 avg	22

NOTE: 1 footcandle = 10.76391 lux. Lux is defined as the illuminance produced by a flux of 1 lumen uniformly distributed over 1 m^2.

Liaison with Calgary Police Service

Calgary Transit has increased liaison with the Calgary Police Service and other security units of organizations that operate in close proximity to the LRT line (e.g., educational institutions, shopping centers) to share information and coordinate public security efforts.

Customer Information

A communications program has been initiated to promote public awareness and confidence regarding the personal security features on the LRT system.

Lessons Learned

1. A visible, uniformed security presence and good customer information regarding personal security features are essential to maintain public confidence in the safety of LRT systems.
2. A variety of approaches may be employed to deter criminal activity and reinforce public confidence in transit travel, including environmental design to preventing crime, effective training and use of staff resources, up-to-date security equipment and lighting standards, ongoing liaison with police and other security agencies, and regular monitoring of crime trends and customer perceptions.

Fare Collection

Discussion

Calgary's LRT system uses a barrier-free, self-serve fare system that has been widely adopted by Canadian and American LRT systems. This system was chosen because it offers the highest potential savings in labor and equipment costs, provides the greatest flexibility in station design, and controls the level of fraud by regular fare evasion checks and issuance of fines to customers who do not pay.

In May 1993, Calgary Transit conducted a survey of fare evasion on the LRT system and found that 7.4 percent of riders failed to produce proof of fare payment when requested to do so. This level of fare evasion represented a loss of $2.3 million in annual revenue. Surveys before this time indicated a substantially lower fare evasion rate.

On a time-period basis, higher levels of evasion were reported during off-peak hours and on weekends than during peak periods. The highest levels of evasion were associated with stations closest to the downtown. High levels of fare evasion were reported on both inbound (to the downtown) and outbound directions of travel.

To reduce the incidence of fare evasion, several actions were initiated:

- The specified fine for fare evasion was increased from $35 to $150. This decision reflected the belief that the penalty for failing to produce a valid fare should be no less than three times the cost of a monthly adult transit pass (i.e., $46 per month).
- Additional staff resources were assigned to enforce the payment of fares, and regular "fare blitzes" have been conducted.

Subsequent fare evasion surveys have revealed that fare evasion levels have been reduced from 7.4 to 1.5 percent, which is considered a very satisfactory industry standard.

Lessons Learned

1. Calgary Transit continues to believe that the self-serve honor system is the most efficient and economical for LRT systems.
2. Fines for fare evasion must be set at a level that serves as an effective deterrent to avoid paying a transit fare. Calgary's philosophy is that the fine for fare evasion should be no less than three times the cost of a monthly adult transit pass.
3. Regular surveys must be conducted to monitor the rate of fare evasion and assign staff resources to address locations where fare evasion problems persist.

Conclusion

On the basis of more than a decade of operating experience, Calgary Transit has demonstrated that an LRT system can be successfully integrated within the right-of-way of city streets. Adoption of traffic signal preemption for LRT operations at grade-level crossings; a comprehensive, balanced range of access modes; and an integrated package of policies for managing downtown growth (e.g., emphasis on public transit, long-term parking restraints, deemphasis of the road system, enhanced pedestrian environment) have contributed to a greater than 40 percent modal split for downtown work travel and created an environment that supports further development of the transit market. Other lessons relating to station design, personal security, and fare collection have also improved the safety and operation of the LRT system.

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