LRT On-Street Operations: The Calgary Experience

J. R. Walshaw
Transportation Department
City of Calgary, Alberta, Canada

On May 25, 1981, light rail transit (LRT) returned to Calgary with the opening of the 11-km South line. This project represented a major commitment on the part of the city of Calgary and the province of Alberta to provide a convenient alternative to the private automobile. The South line is the first of a network of routes radiating from the city center (Figure 1). Construction of the Northeast line started in 1982, with a scheduled completion date of May 1985, and work will start on the Northwest line in 1985. Other legs are planned but are not yet committed to construction.

The southernmost 6.5 km of the South line were constructed parallel to the Canadian Pacific (CP) Railroad secondary main line through suburban neighborhoods. The LRT leaves the CP line at 42nd Avenue and proceeds to the downtown core on an exclusive right-of-way. For the final 1.8 km in the downtown core the LRT runs along 7th Avenue at grade (Figure 2).

The 9-km section of the line outside the core is equipped with an automatic block signal system, and the six at-grade road crossings are protected by flashing light signals and gates. The 1.8-km segment on 7th Avenue has 12 intersections, and trains must obey traffic signals located at each intersection.

The light rail vehicles (LRVs) are Siemens-Duewag U2 articulated cars, similar to those used in Edmonton and San Diego. Their design standards are as follows:

- Car length = 23 150 mm,
- Car Width = 2650 mm,
- Car height = 3620 mm,
- Passenger seats = 64,
- Standees (at 4/m^2) = 98,
- Passenger capacity = 162 to 260 per vehicle,
- Vehicle weight (empty) = 32 500 kg,
- Contact wire height = 4000 to 6880 mm,
- Service acceleration = 1.0 m/sec^2,
- Maximum acceleration = 1.3 m/sec^2,
- Service deceleration = 1.2 m/sec^2,
- Maximum deceleration = 2.7 m/sec^2,
- Maximum speed = 80 km/hr,
- Interior noise level = 65 to 75 dB(A),
- Wayside noise level (at 15 m) = 65 to 80 dB(A), and
- Train size = 1 to 5 cars.

Ultimately they will be run in five-car trains, but for the present the peak-period demands are met with three-car trains. Off-peak service is provided with two-car trains and, occasionally, single units. Stations have been constructed with platforms for three-car trains but can be lengthened in the future. The LRVs are fitted for high-platform loading only.

The LRT operates on a basic 10-min schedule with peak-period service at 5-min intervals. When the Northeast line becomes operational, the same schedule will be maintained resulting in 2.5-min headways on 7th Avenue during peak periods.

7th Avenue has been designated as a transit mall, reserved for LRT and bus operation. Emergency vehicles are permitted, of course, and service vehicle entry is controlled by a permit system because some business operations have no alternative access. Automobiles and taxis are completely prohibited. Although the transit vehicle usage in peak periods is quite impressive (176 trains and buses per hour), compared with the parallel streets, 7th Avenue is relatively underused.

The transit mall is 48 ft wide with the LRT tracks in the center. Station platforms are provided every three blocks in each direction, staggered so that there is only one station in any block (Figure 3). LRT operating rules on 7th Avenue require that trains obey the traffic signals located at each intersection; buses must not pass LRT trains.

The challenge to the traffic engineers was to devise a signal timing system that would minimize delay to trains, avoid blocking of intersections, and accommodate cross street traffic.

THE SETTING

The downtown core of Calgary can be considered to be bounded by 4th Avenue to the north, 9th Avenue to the south, 9th Street West on the west, and 3rd Street East on the east (Figure 4).

Because 7th Avenue is designated as the transit mall and 8th Avenue is a pedestrian mall for much of its length, the main east-west traffic flows are accommodated on 4th, 5th, 6th, and 9th Avenues. These roads operate as one-way couplets. Peak-period flows are as high as 2,300 vehicles per hour.

The north-south streets, though more numerous, are generally less useful as through traffic carriers. No streets cross both the Bow River and the CP rail line to the north and south of the downtown core, respectively. The streets do funnel traffic from parking areas to the avenues and the two major north-south routes: Centre Street and Macleod Trail. Most but not all of the streets are one way. Blocks are relatively short averaging 570 ft east to west and 340 ft north to south. All intersections within

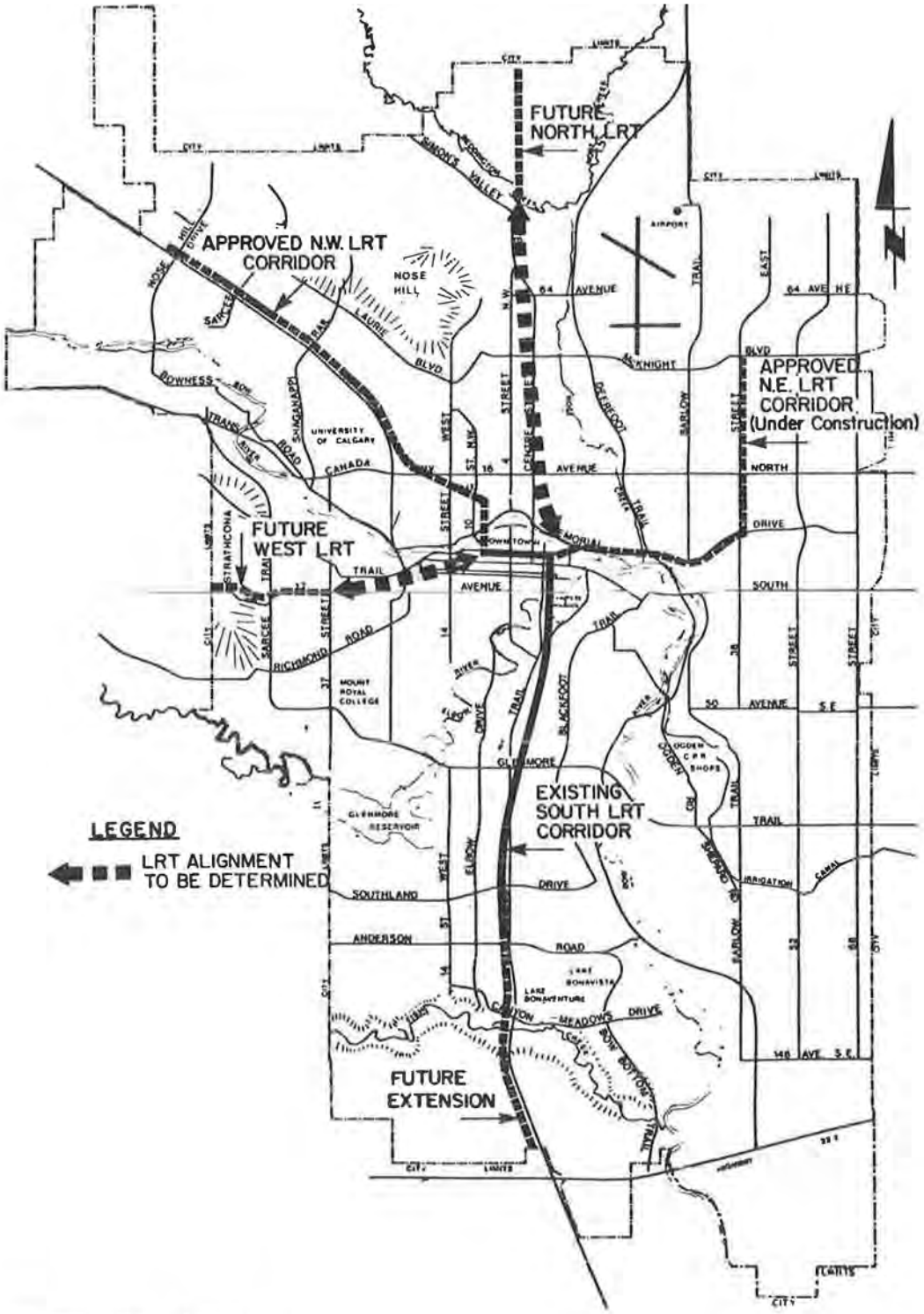

FIGURE 1 Calgary LRT system.

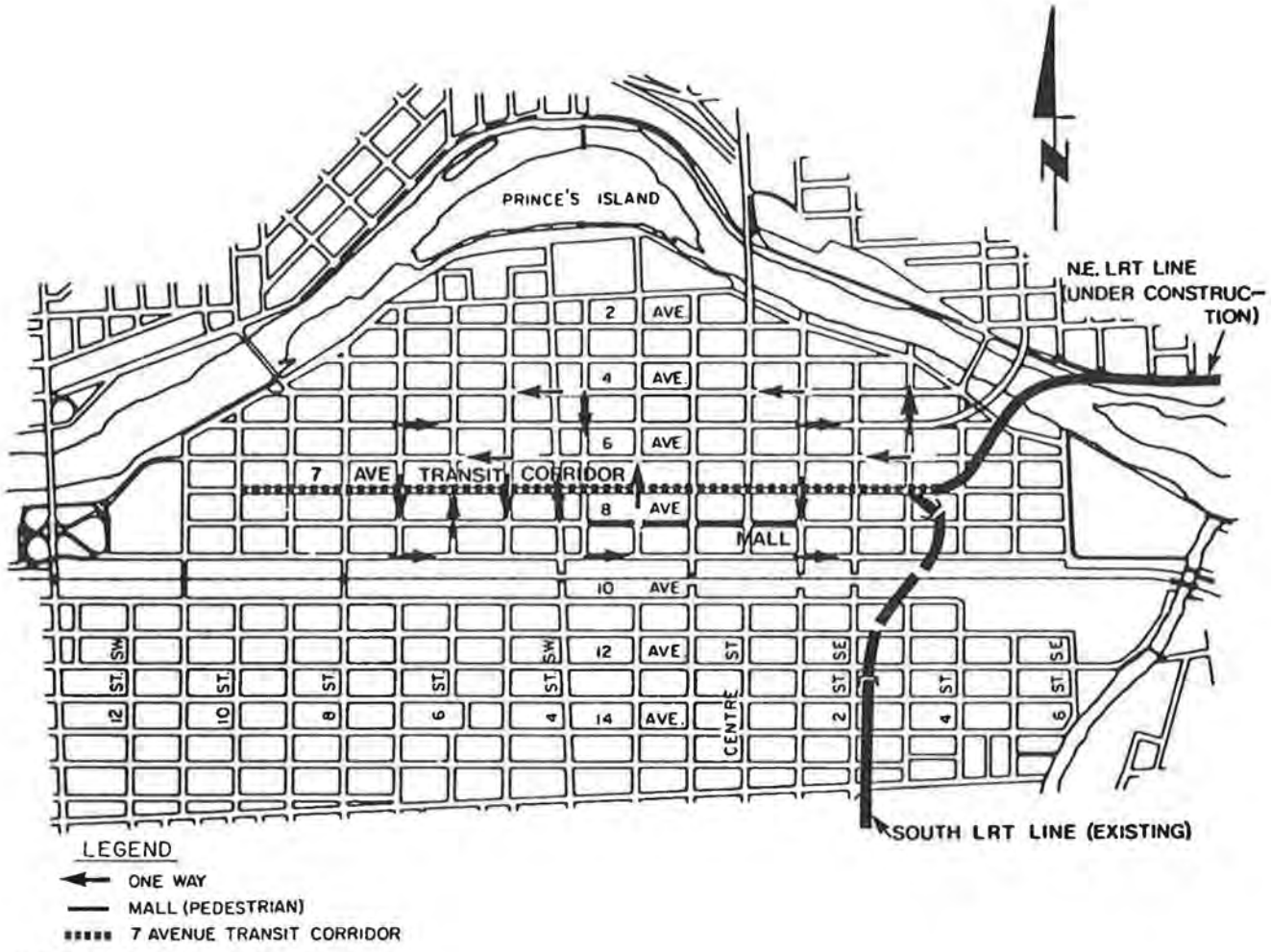

FIGURE 2 Downtown roadway network.

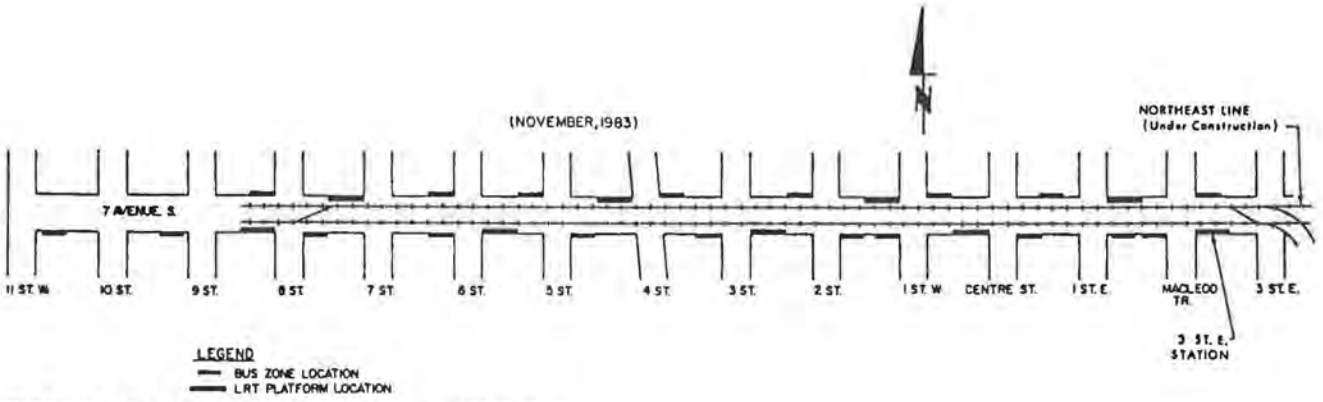

FIGURE 3 Existing South line LRT stations and bus stops.

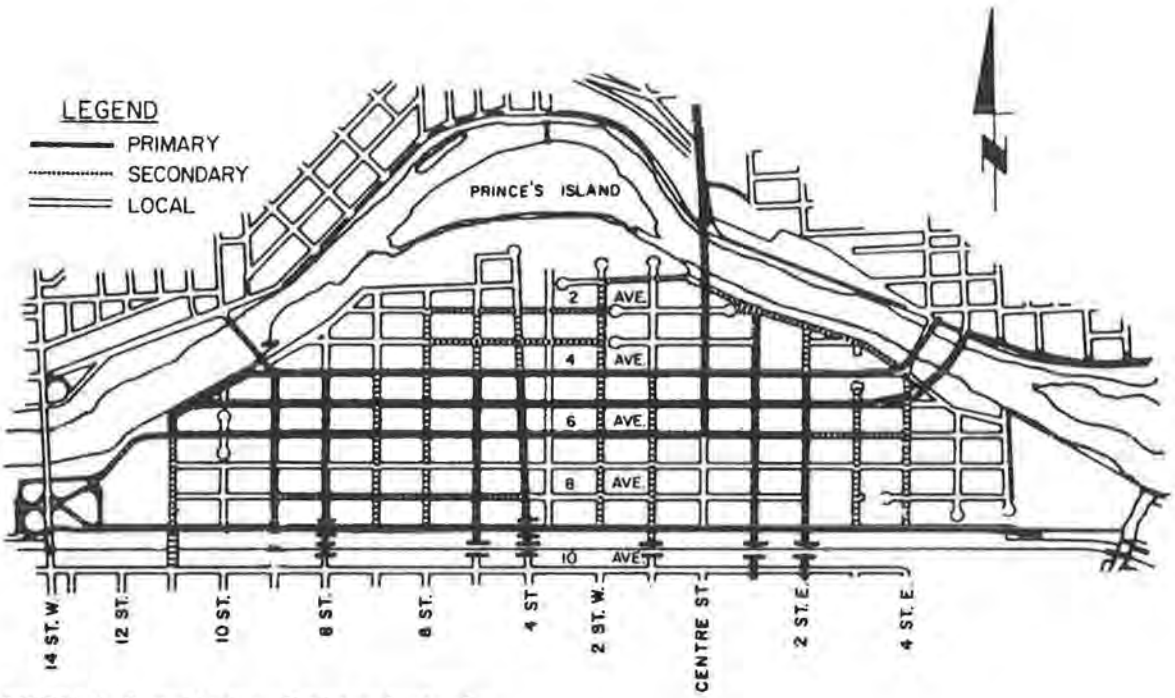

FIGURE 4 Central business district road network.

this defined core area are signalized except for two grade-separated intersections on 9th Avenue at 8th Street and at 4th Street. Traffic volumes are generally fewer than 1,00 vehicles per hour.

The 73 traffic signals in the defined core area are supervised by a Honeywell master control system (proprietary Urban Transportation Planning System software). The system uses a Honeywell Level 6 minicomputer and Honeywell HMP290 fixed time intersection controllers. Thanks to the extensive one-way system, nearly all intersections operate with two phases. At present, three time-of-day timing plans are used.

TRAFFIC ANALYSIS

Timing plans were developed using the TRANSYT-7 simulation model. Because this model is now so familiar to North American traffic engineers, little more need be said about its operation. The model is run on the Honeywell minicomputer, usually at night when the traffic control system can be shut down. To obtain faster running times, the network was broken down into two sections.

Bus traffic was handled in the standard manner. LRT trains were simulated by treating them as standard vehicles with their special characteristics coded as inputs to TRANSYT. Link travel times included allowances for station stops on the appropriate links. The highest permissible weighting factor was used to ensure that the low number of trains was not ignored in favor of the much higher cross-street volumes.

The TRANSYT simulation was relatively successful in providing quite good signal splits and offsets for buses and trains on 7th Avenue. It is likely that the high traffic volumes on the parallel streets influenced the splits for 7th Avenue because it was found that the splits generated by the model also gave greater than minimum time for pedestrian traffic along the 8th Avenue mall.

Because the inception of LRT service occurred essentially at the same time as the introduction of the traffic signal computer system, no historical data were available to assess the effect of LRT operation on an optimized signal network. The assessments given in Tables 1-3 were made recently by running the TRANSYT-7 model without allowing for train operation.

TABLE 1 Effect of LRT on Street Traffic Operation—Complete Downtown Network

	Without LRT	With LRT	Variance (%)
Distance (vehicle-km/hr)	28,574	28,913	+1
Total time (vehicle-hr/hr)	1,009	1,048	+4
Uniform delay (vehicle-hr/hr)	357	397	+11.2
Random delay (vehicle-hr/hr)	47.1	45.6	-3.3
Uniform stops (vehicle/sec)	20.9	22.2	+6.4
Performance index	432	475	
Speed (km/hr)	28.3	27.3	-3.6

TABLE 2 Effect of LRT on Street Traffic Operation—6th Avenue Corridor

	Without LRT	With LRT	Variance (%)
Distance (vehicle-km/hr)	2,752	2,752	
Total time (vehicle-hr/hr)	89.3	94.1	+5.4
Overall (vehicle-hr/hr)	28.0	32.5	+16
Uniform stops (%)	36.8	38.7	+5.1
Speed (km/hr)	30.8	29.2	-5
Degree of saturation (%)	41.5	42.5	+2.4

TABLE 3 Effect of LRT on Street Traffic Operation—Macleod Trail (2nd Street East)

	Without LRT	With LRT	Variance (%)
Distance (vehicle-km/hr)	1,073	1,073	
Total time (vehicle-hr/hr)	44.5	50.5	+13.5
Overall (vehicle-hr/hr)	16.2	22.3	+38
Uniform stops (%)	37.2	39.5	+6
Speed (km/hr)	24.1	21.2	-12
Degree of saturation (%)	52	56	+7

Overall network travel time is calculated to have risen by 4 percent due to LRT operation. On roads close to the 7th Avenue transit mall the effect is higher, as would be expected. Travel time on 6th Avenue increased by 5.4 percent; travel time on Macleod Trail (which crosses 7th Avenue) increased by 13 percent.

The results of LRT travel time studies are given in Table 4. Although it was obviously not possible to test LRT travel time under free-flow conditions, measurements of delay at traffic signals can give a reasonable approximation of what might be possible under free-flow operation.

TABLE 4 Effect of Traffic Signals on LRT Operation

	Eastbound	Westbound
Total travel time (min:sec)	6:32	6:54
Waiting time at signals (min:sec)	0:32	0:27
Net travel time (min:sec)	6:00	6:27
Delay (%)	8	7

This analysis completely neglects the impact of LRT operation on street traffic flows. When LRT operation began in 1981, Calgary was at the peak of an unprecedented period of growth. Much of this growth was occurring in areas served by the LRT line. From 1975 to 1981 traffic volumes on Macleod Trail grew rapidly. Between 1981 and 1982 the traffic volumes on Macleod Trail stabilized, and late in 1982 they had decreased due to the declining economy. However, LRT passenger volumes remained stable at about 40,000 passengers per day.

OPERATIONAL PROBLEMS

Following the introduction of LRT service, extensive field observations were made, and a number of fine-tuning adjustments were made. Some major problems were identified that required special attention.

Intersection Blockage

The first problem was that of ensuring that trains did not encroach into the cross-street green time while clearing intersections. A three-car train takes about 10 sec to cross an intersection, so a train entering an intersection at the start of the amber interval would not clear it until 6 sec of side-street green had elapsed. This problem was resolved by the introduction of a longer clearance interval for trains only. Initially, train operators were required to treat the flashing "don't walk" pedestrian clearance interval as an indication to stop. This solved the problem of blocked intersections but led to continuing complaints from operators that the pedestrian signals were too hard to see. Eventually, the expedient of displaying a flashing yellow indication concurrently with the flashing "don't walk" and solid green to indicate a train clearance interval was adopted. No complaints have been received from the operators since this was introduced.

It was found that one block on 7th Avenue was shorter than a three-car train. If a train was required to stop at one end of the block, the rear end would still occupy the intersection at the other end. Under normal conditions, the signal timing plans and offsets would make it unnecessary for a train to stop in that block, but that possibility had to be taken into account. Accordingly, the signal controller hardware was changed so that one controller is used for the two intersections. The interval sequence plan ensures a fixed relationship between the two signals on a more secure basis than the offset parameters.

Delays to Trains

At the west end of 7th Avenue, westbound trains leaving the 7th Street station use a crossover to the eastbound tracks to reach the 8th Street station (Figure 5). Because the crossover movement must be made at restricted speed, a relatively long green time was needed at the 8th Street signal, far longer than required for the eastbound movement. Delays to traffic on 8th Street led to complaints from the public, especially during off-peak periods.

The response to this problem was to set the normal green time for 7th Avenue to that required for all traffic except westbound trains. The fixed time signal controllers have the capability of recognizing two detector inputs, assigning time to designated intervals when the input is active, and adding the

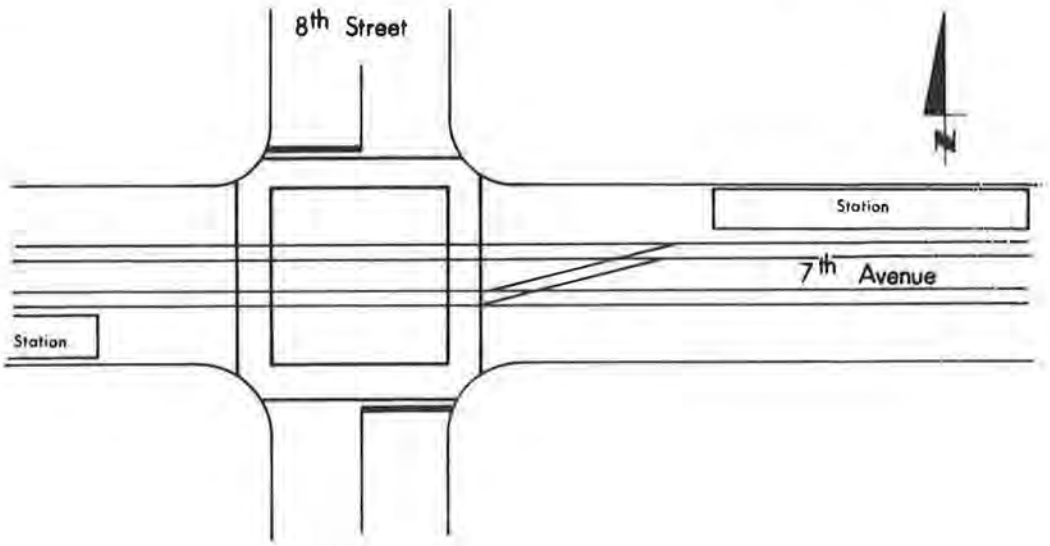

FIGURE 5 LRT west terminus (1984).

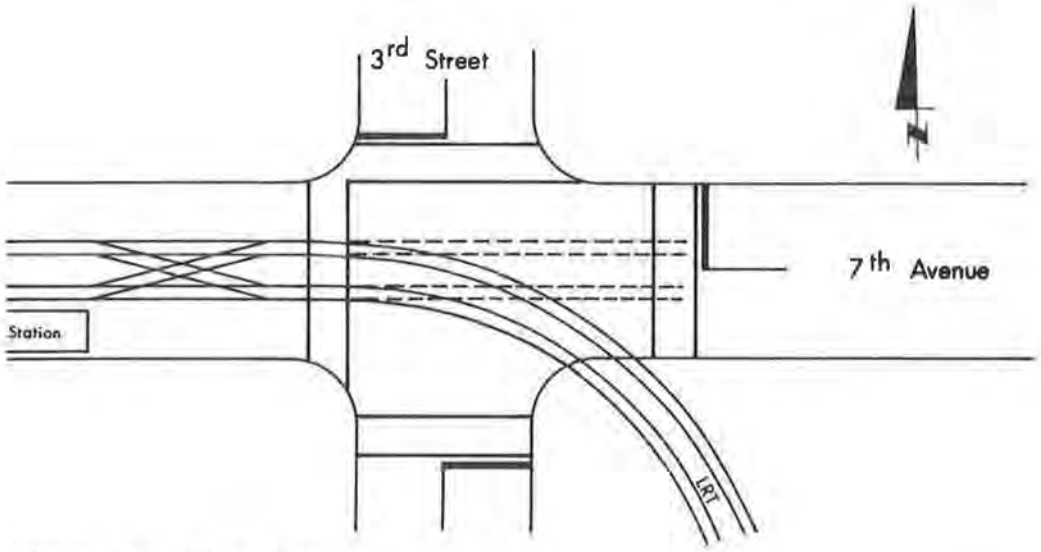

FIGURE 6 3rd Street interlocking.

time to another interval when the input is not active. The position of the crossover switch points was used as the detector input; when lined for the crossover movement the detector input is active, lengthening the 7th Avenue green. When the switch points are lined for the through movement, the input is inactive and the time is assigned to the 8th Street green.

A similar situation exists at the east end of 7th Avenue at 3rd Street East (Figure 6). The LRT tracks swing southward off 7th Avenue in the intersection, creating a fifth leg to the intersection. A three-phase signal plan was established with a fixed time operation. Again complaints were received, mostly from transit operators, about delays. The signal phasing was modified to a standard two-phase fixed-time operation with an actuated phase added to serve trains entering 7th Avenue.

This modification has reduced delays to all traffic in the intersection except inbound trains. These trains arrive at relatively regular intervals, but completely at random relative to the signal cycle. In the worst case, a train would be forced to wait a full signal cycle (70 to 90 sec) before entering 7th Avenue.

CONCLUSIONS

In Calgary on-street operation of LRT has been accomplished with a minimum of disruption to downtown traffic, and satisfactory train operations have been maintained. Road traffic delay is somewhat greater than would have been the case if LRT had not been operating. However, because the LRT reduced the number of buses using the street system and made possible an increase in total transit ridership, the impact of LRT is believed to be much less than that of the traffic congestion that would have occurred without LRT.

LRT operation is thought to be satisfactory, and the additional LRT traffic generated by the new Northeast line will be accommodated without changes in the signal control system.