LRT's urban development potential by aligning segments along abandoned railroad rights-of-way and freeways. Although the record on LRT in the United States and Canada is still rather short, experiences with rapid rail transit are sobering reminders that a strong regional economy, supportive local policies, and a hospitable station environment are essential if positive and substantial land use outcomes are to occur.

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The Impact of Light Rail Transit on Travel Behavior in Calgary

ARCHIE CHUMAK and DAN BOLGER

ABSTRACT

In May 1981 light rail transit (LRT) was introduced in Calgary between the downtown and the southern part of the city. An extensive 2-year monitoring program of the impact of LRT on the transportation system has been conducted by the city, the results of which are reported. The methodology consisted of a series of before-and-after surveys, which included conventional traffic counts, speed and delay studies, and an on-board survey. An important component of the study was a home interview survey. LRT has had a significant impact on travel downtown. Transit modal split across the south downtown screen line has increased from 35 to 40 percent to 50 to 55 percent in the a.m. peak period. The study also examined the public's attitudes and perceptions of the transportation system as well as the reasons for mode choice. The majority of residents believed that both transit service and overall traffic congestion had improved with the introduction of LRT. Most travelers indicated that convenience is the critical factor in choosing between the automobile and transit. A significant portion of the population, however, identified travel time as the most important factor.

The purpose of this paper is to outline the effects that the implementation of a 12.5-km light rail transit (LRT) line and associated feeder-bus system has had on travel behavior in the rapidly growing city of Calgary, Alberta, Canada.

The line opened in May 1981 using a downtown transit mall (mixed bus and LRT) and seven suburban stations; 27 Siemens-Düwag U2-type cars are operated, usually in two- or three-car trains with 6-min peak-hour frequency. Feeder-bus routes and levels of service were substantially revised with the introduction of the LRT line.

The collection of data on travel behavior before and after the change in the transit system covered the period between April 1981 and May 1982. This period coincided with the leveling off of a vigorous decade of growth in Calgary (about 4 percent per annum), and the findings largely represent conditions that preceded any significant reduction in employment due to the economic downturn.

BACKGROUND

Figure 1 shows a plan of Calgary. A simplified representation of the geography of the city would show a concentrated commercial core with a crescent of residential areas spreading around its west side and a band of industrial land stretching down the east side. About one-third of the city's employment is in the central area, one-third in the east industrial area, and one-third spread throughout the city.

Although the downtown accounts for less than 20 percent of all vehicle trips in Calgary, the intensity of this travel is concentrated. In addition, crosstown traffic from the predominantly residential west side of town to east-side employment in industrial locations exacerbates downtown and inner-city congestion. Therefore, a number of the city's objectives emanate from a desire to manage traffic in the downtown and the inner city. The thrust of many of these objectives is to improve the physical environment of the downtown and the inner city, and they can be simply translated into one objective: to reduce unnecessary vehicular traffic in this area (1). However, although the objective can be simplified, the issue addressed is most complex, and the

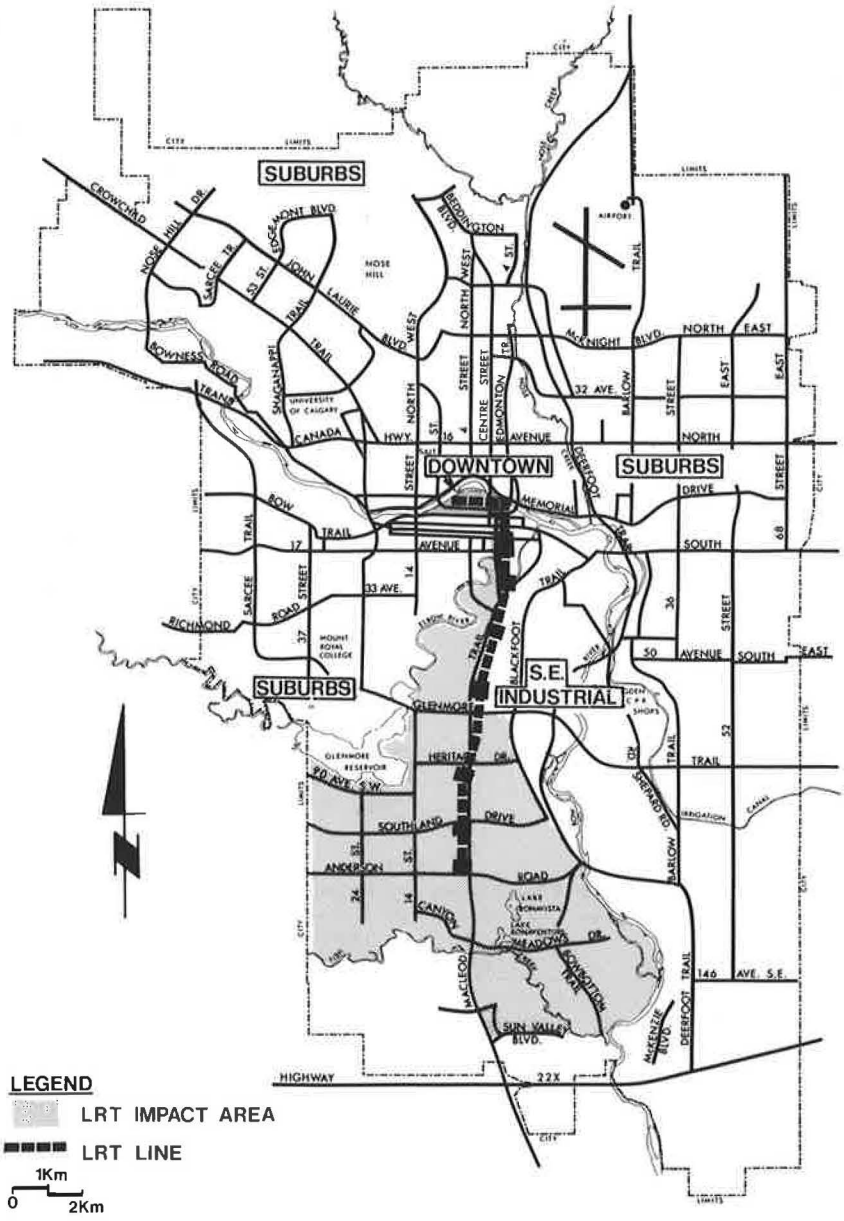

FIGURE 1 Calgary and LRT impact area.

strategies and policies that the city applies to it must be comprehensive and coordinated. These techniques include downtown parking and pedestrian schemes, roadway restraint, and suburban transit planning.

BUS SYSTEM BEFORE LRT

The major transit corridors leading to the downtown had their beginnings with the Blue Arrow express bus system, introduced in the early 1970s. The Blue Arrow system acted as its own feeder in the farthest suburbs and interconnected with crossing feeder routes as it approached downtown. Limited stops between the outer suburbs and the downtown gave it some of the characteristics of an express service; within the downtown, exclusive transit lanes were implemented to increase speed and schedule adherence. A series of free park-and-ride lots were developed with particular emphasis on proposed future rail corridors. Thus the Blue Arrow and its feeder-bus systems combined with park-and-ride facilities to form a prototype for the development of the LRT system that began service in 1981.

The improvements in the bus system have already had a significant impact on travel behavior. Figure 2 shows the impact on downtown-oriented travel during the p.m. peak hour. Total growth, represented by the circle sizes, has increased significantly. In the decade 1971-1981, the p.m. peak-hour work trip modal split to transit increased from 34 to about 50 percent. Citywide annual transit rides per capita changed from 60 to 93 in the same period.

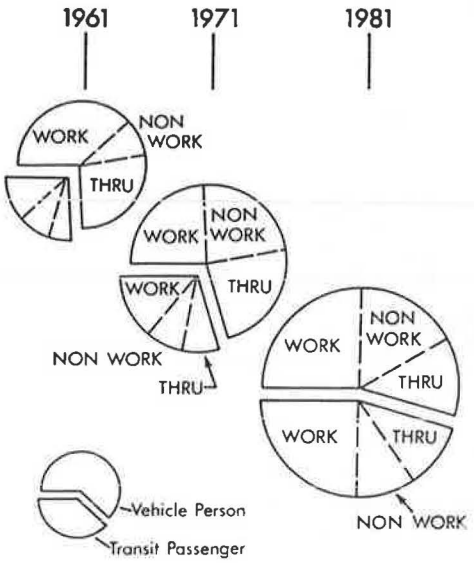

FIGURE 2 Composition of p.m. peak-hour downtown travel.

THE LRT SYSTEM

The patron catchment area for the Calgary LRT line encompasses approximately 95 km² with a population of 150,000 (approximately 1,600 persons/km²). The rail line runs adjacent to a major arterial roadway that serves abutting commercial land containing an employment population of 65,000.

The LRT alignment south of the downtown parallels an existing freight rail line for the majority of its length. The alignment was selected because of its location and ease of acquisition. It provides good access to the southeast industrial area and bisects the residential catchment area.

A total of 15 feeder routes and 8 connecting or crosstown routes were developed and approved to serve the south LRT catchment area. The complementary bus network was designed to serve the largest possible transit market. During the a.m. peak period, transit travel times to the downtown have been reduced approximately 20 percent throughout the suburbs. Total feeder-route operating hours were increased 72 percent, from 492 to 846 hr for weekday operation. This increase is the result of major improvements in transit service in new developing areas (2).

TRAFFIC IMPACT

Table 1 is a summary of transit use change after the implementation of LRT in the south corridor (3). These traffic counts were conducted across the south downtown screen line. The screen-line data indicate that there has been a significant increase in transit travel ranging from 59 percent during the a.m. peak period to 80 percent during the p.m. peak period. The major reason for this growth has been an increase in transit modal split from 36 to 48 percent during the a.m. peak period and from 23 to 39 percent during the p.m. peak period.

It should be noted that this transit ridership growth occurred over a period of time during which a number of fare increases took place. In January 1980 the transit fare was $0.50. By the time LRT was inaugurated in May 1981, the fare had risen to $0.65. The fare was further increased to $0.75 in 1982, which was when the post-LRT impact surveys were conducted.

TABLE 1 Traffic Volume at South Downtown Screen Line

	Two Way (7:00 a.m.-11:00 p.m.)		To Downtown (7:00-9:00 a.m.)		From Downtown (4:00-6:00 p.m.)	
Parameter	Volume	Percent	Volume	Percent	Volume	Percent
Before LRT						
Vehicle occupants	141,759	86	11,008	64	14,930	77
Bus passengers	23,461	14	6,080	36	4,599	23
Total	165,220		17,088		19,529	
After LRT						
Vehicle occupants	153,327	79	10,322	52	13,124	61
Bus passengers	12,172	6	2,240	11	1,838	9
LRT passengers	28,324	15	7,394	37	6,424	30
Total	193,823		19,956		21,386	
Change in transit use		73		59		80

Travel time studies were performed on the major north-south roads in the impact area. Generally the southern part of the corridor did not experience an increase in average speed during the peak periods (7:00 a.m. to 9:00 p.m., 3:00 to 6:00 p.m.). Increases in operating speeds were observed, however, between the downtown and a distance of approximately 2.4 km from the downtown. In this part of the corridor two major roadways, Macleod Trail and Elbow Drive, experienced increases in operating speed in the range of 1.6 to 9.6 km/hr. Contributing factors to the increased roadway speeds included reduction of transit buses in peak periods (between 40 and 80 percent fewer than before the implementation of LRT); widening of a bottleneck section of Macleod Trail (a primary artery); modest reduction in vehicle traffic, particularly in the inner city; and upgrading of traffic signal coordination.

INVESTIGATING TRAVEL BEHAVIOR

Survey Methodology

In the previous section the considerable impact that LRT has had on roadway traffic and transit volumes was identified. It is also important to understand the underlying changes in travel behavior and the reasons for this increase in transit use. This information would be very useful for planning future LRT lines.

Two surveys were used to evaluate the changes in travel behavior. A conventional on-board survey was conducted (4). The survey had a response rate of 50 percent and provided a reliable measure of LRT travel patterns during the a.m. peak period. It was also decided that a home interview survey was necessary (5). In the Calgary situation, this type of survey was the only feasible method of examining the travel patterns of the entire population, especially the automobile travelers. The home interview survey also provided an opportunity for an in-depth analysis of attitudes and perceptions about the roadway and transit systems and their reasons for choice of mode.

The remainder of this paper concerns the results of the home interview survey. The survey was conducted in March 1982, approximately 9 months after the implementation of LRT service. This delay was required in order to ensure that post-LRT travel patterns had stabilized. The survey sample consisted of approximately 5 percent of the households in the LRT corridor. The expanded survey results were compared with the census data to ensure that the survey had no inherent biases.

Existing Travel Patterns

Figure 3 shows the travel patterns in the study area after the introduction of LRT service. This overall perspective of travel patterns should always be remembered when the significance of various impacts is evaluated. These data refer only to trips that had an origin and destination within the south LRT corridor or downtown. The south LRT corridor is shown in Figure 1. It is on trips in this corridor that LRT had its greatest impact. External travel, trips originating outside the study area, or through trips were not included.

Travel characteristics are presented for the a.m. peak period (7:00 to 9:00) and the off-peak period. The off peak is defined as all travel outside the a.m. and p.m. peak periods (4:00-6:00 p.m.). P.m. peak-period travel has not been included in this

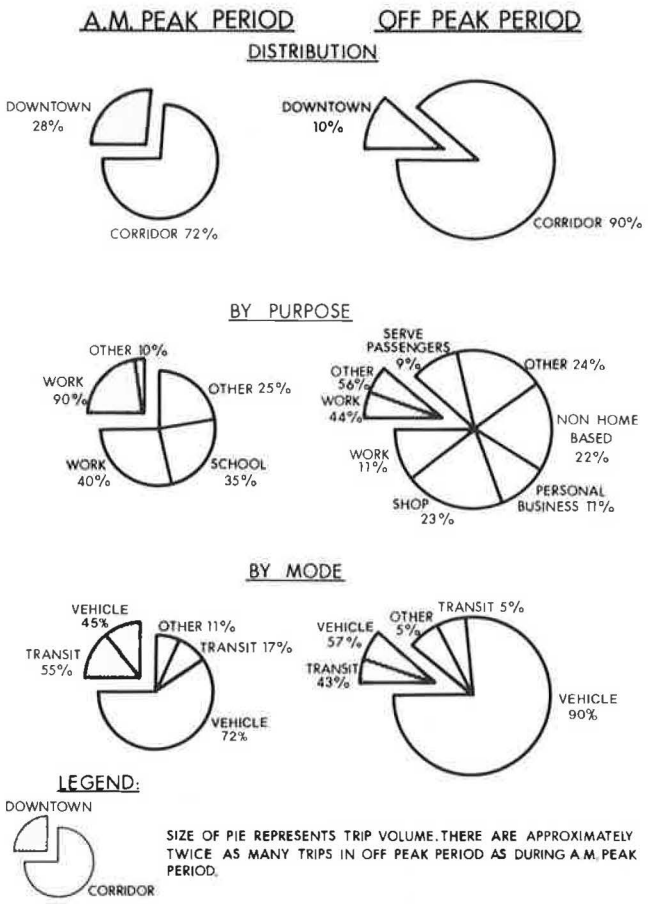

FIGURE 3 Travel in LRT impact area after LRT.

presentation. There were approximately twice as many trips in the off peak as during the a.m. peak period.

During the a.m. peak, 28 percent of the trips were to the downtown. This travel consisted almost entirely of work trips (90 percent). Corridor travel accounted for 72 percent of the volume and contained mostly work and school trips.

During the off peak only 10 percent of the travel was to the downtown of which 44 percent was work trips. Corridor travel was much more predominant and had a much more varied distribution of trip purposes: work, 11 percent; shop, 23 percent; and personal business, 11 percent.

The highest transit modal splits were to the downtown. The a.m. peak modal split was 55 percent. Off-peak downtown travel also had a high modal split of 43 percent. The automobile was clearly the dominant mode for corridor travel and accounted for 72 percent of travel in the a.m. peak and 90 percent in the off peak.

Changes in Travel Patterns

The traffic count data indicate that there has been a considerable increase in transit modal split. In Table 2 the changes in modal split for various types of travel in the impact area are summarized.

LRT was designed to provide service primarily for downtown work trips. It was in this market that LRT has had its greatest impact. Downtown transit modal split during the a.m. peak period increased from 42 to 55 percent. This travel consisted almost entirely

TABLE 2 Changes in Transit Modal Split

Type of Travel	Before LRT (%)			After LRT (%)			
	Private Vehicle	Bus	Other	Private Vehicle	Bus	LRT	Other
Morning peak							
Downtown	57	42	1	45	7	48	0
Corridor	69	20	11	72	14	4	10
Off peak							
Downtown	67	31	2	57	4	38	1
Corridor	92	6	2	89	3	2	6

Note: Confidence interval = ±5 percent.

of work trips and accounted for a significant portion, 28 percent of all travel in the study area. It should also be noted that these changes in modal split are similar to those observed in the south downtown screen-line traffic counts.

A somewhat more surprising result was the significant increase in transit modal split, from 31 to 42 percent, for off-peak downtown travel. This increase in transit travel has occurred primarily with the work trip, which still accounted for 44 percent of the off-peak travel. The modal splits for other trip purposes such as shopping and personal business have not been influenced by LRT. It should be noted that downtown travel represented only 10 percent of all off-peak travel in the impact area.

LRT has had virtually no impact on corridor travel during the a.m. peak. There has been no measurable diversion to transit for any of the major trip purposes. The bus mode continues to remain more popular than LRT. Neither has LRT had any impact on off-peak corridor travel. Transit modal split remained at a very low level of 5 percent. Of the four types of travel considered, off-peak corridor travel had the highest volume.

Table 3 presents a more detailed analysis of the dynamics involved in this change in modal split.

TABLE 3 Diversion of Travel

Pre-LRT Mode	Post-LRT Mode	Percentage of All Travel	Post-LRT Modal Split (%)
Automobile	Automobile	42	
Bus	Automobile	3	
		45	45
Automobile	Bus	1	
Bus	Bus	6	
		7	7
Automobile	LRT	13	
Bus	LRT	35	
		48	48

Note: Data are for a.m. peak period downtown. Confidence interval = ±3 percent.

These results are for downtown a.m. peak-period travel, where LRT has had its greatest impact. The analysis examines the importance of each diversion from one mode to another in relation to all travel. Travel diverted from automobile to LRT represented 13 percent of all travel. At the same time there was a diversion from bus back to automobile of 3 percent. The volume of this diversion is significant because it represents 25 percent of the volume diverted from automobile to LRT. This diversion to automobile may be due to a perception of an improvement in traffic congestion after LRT was introduced.

The survey also investigated whether LRT had a significant impact on the other components of the travel process--trip generation and trip distribution. Travelers were asked, "Would this trip have been made before LRT?" The following results were obtained:

Response	Percentage of Travelers
Same trip	96
Same trip purpose, different location	2
No trip	2

LRT appears to have had a minimal impact on both trip generation and distribution.

Attitudes and Travel Behavior

Another important objective of the study is a detailed analysis of the population's attitudes and perceptions of roadway and transit systems. This information should provide a better understanding of travel behavior in relation to the introduction of LRT.

Each person was asked to identify which factors were most important in his or her choice to use automobile or transit. The results are presented in Table 4 and refer to all travel in the study area.

TABLE 4 Most Important Factor in Mode Choice

Factor	Percentage of Respondents	
	Automobile	Transit
Convenience	60	34
Total travel time	14	16
Out-of-pocket cost	-	12
Parking at destination	-	7
No response	10	20
Other	16	11

Note: Confidence interval = ±4 percent.

Convenience, or the flexibility to travel whenever one wants, was clearly the most important factor for the majority of automobile travelers (60 percent). Respondents were also asked to rate their degree of satisfaction with each of the factors on a scale of 1 to 5: 1, very unsatisfied; 3, neutral; 5, very satisfied. The degree of satisfaction with the convenience of automobile travel was ranked 5 and the convenience of transit travel was ranked 3 by automobile travelers. Convenience was also the factor most frequently mentioned by transit travelers, who indicated that they were very satisfied with the flexibility of automobile travel and satisfied with the flexibility offered by transit.

Total travel time was the second most important factor for automobile travelers. More important is the large spread between those who indicated convenience (60 percent) and those who indicated travel time (14 percent). These results should be considered in view of what kind of transit service is feasible. It is possible for transit travel times to be comparable with those of the automobile for downtown travel. It is very difficult to match the convenience of automobile with transit. No other factors were mentioned by a significant portion (5 percent) of the automobile travelers.

Three factors were mentioned by transit patrons: total travel time, 16 percent; out-of-pocket cost, 12 percent; and parking at destination, 7 percent. It appears that policies such as improving downtown travel time and controlling the supply of parking influence transit ridership.

The choice factors for an important segment of the population--those travelers who shifted from automobile to LRT--are as follows (confidence interval is ± 8 percent):

Factor	Percentage of Respondents
Convenience	29
Out-of-pocket cost	22
Total travel time	16
Parking at destination	11
Rush-hour driving	6
No response	15
Other	1

For downtown-oriented travel, convenience was still the most popular factor, indicated by 29 percent. A considerable number of travelers also indicated factors such as out-of-pocket cost (22 percent), total time (16 percent), parking at destination (11 percent), and rush-hour driving (6 percent). The key feature of these results is that the perceived importance of the convenience factor is not always reflected in the actual travel behavior. Those who indicated that convenience was the most important reason in modal choice still switched to transit. The modal choice actually involves many factors. It appears that transit can be attractive when all other factors, especially out-of-pocket cost and travel time, are considered together.

Thus far the public's attitudes in relation to travel behavior have been examined. It is also important to determine the residents' general perception of the impact of LRT on the community. The public perception of what impact LRT has had on transportation in the corridor is summarized as follows (confidence interval is ± 2 percent):

	Percentage of Respondents	
Response	Traffic Congestion	Transit Service
Significant improvement	18	20
Moderate improvement	28	27
No effect	32	16
Worse	5	13
No opinion	17	24

Nearly half of the residents (46 percent) felt that traffic congestion had either improved or improved considerably. Similarly 47 percent felt that transit service had improved.

CONCLUSION

The Calgary LRT line is a substantial and tangible investment by the community in the management of its transportation system for the enhancement of the urban environment. The conversion of the prototype Blue Arrow service into a fixed rail transit line is a firm commitment to a continuing strong public transit program in Calgary.

The initial positive public reaction to the LRT has fulfilled the short-term expectations for the line. The striking change in behavior by commuters from the LRT catchment area is clear evidence of the influence that a major improvement in the level of transit service can have, even in a city where there is one automobile for every two citizens. The increase in downtown work trip transit modal split, from approximately 40 percent to the 50 to 55 percent reported in the home interview surveys, is confirmed by the downtown cordon crossing counts, which indicate increases in transit patronage of 59 percent in the a.m. peak period and 80 percent in the p.m. peak period.

Most residents believe that LRT has had a positive impact on both transit service and traffic congestion. The majority of travelers consider convenience to be the most important factor in their modal choice. A significant portion of the population, however, considers travel time to be the key factor.

LRT is performing its role in accomplishing Calgary's transportation objectives; the evidence is conclusive.

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