Edmonton's Light Rail Transit from Concept to Operations

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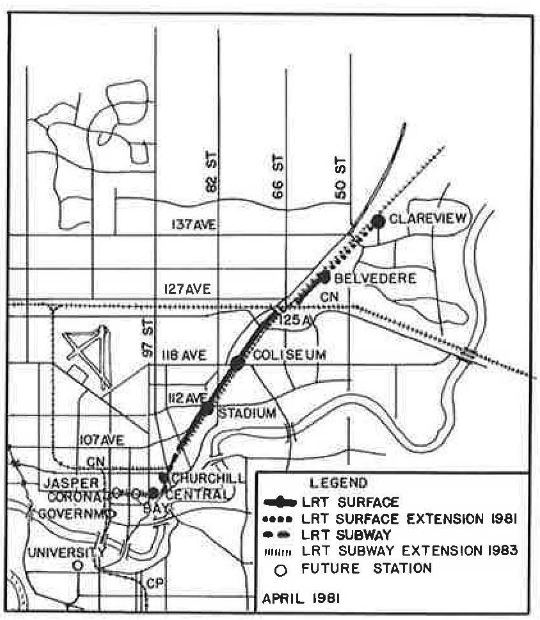
An overview of the light rail transit (LRT) operation in Edmonton, Alberta, from construction through operation, is presented. Edmonton's LRT proved to be very cost effective in the construction phase. Edmonton had few institutional constraints at the time of construction, and it also had excellent construction conditions and a small project management staff. This small staff provided oversight for the project, using consultants, architects, contractors, and other city departments to complete the work. The project managed to stay within budget and was completed ahead of schedule. Since these conditions were unique, no comparisons should be made with other cities or other countries or even with conditions as they will be in Edmonton in the future. The operating phase has so far proved to be less cost effective. The LRT operation has not produced the labor savings expected, primarily because of the fare-collection system adopted. Although there are problems in computing an operating ratio for the system because of revenue allocation formulas, it can be said that this ratio lies between 0.43 and 0.60, depending on the assumptions made. It is shown that the operating ratio will improve due to the proof-of-payment system that went into effect in November 1980. Further development in the northeast sector of the city should further improve the operating ratio in the next five years.

The Edmonton, Alberta, light rail transit (LRT) line (see Figure 1) was officially opened on April 22, 1978, ahead of schedule and within budget. It is no longer usual for public works projects to be ready ahead of schedule or to be within budget. This paper attempts to review what happened in Edmonton. There are several components that should be looked at, such as the institutional constraints, the project management, Edmonton's natural conditions, and what can be expected in the future.

INSTITUTIONAL CONSTRAINTS

In Canada, there is always some doubt as to which government is responsible--federal, provincial, or municipal. Responsibility is usually associated with the fiscal ability to finance a project. The federal government of Canada does not involve itself in any financial support for urban transit projects, nor does it support any transit system with operating subsidies. As will be described later in this paper, there was some federal involvement in the approval process for LRT in Edmonton, but the federal government was not a factor in the decision to proceed with the project.

Figure 1. Edmonton LRT line.



In Canada, the municipal governments are the creation of the provincial government. The control that the provincial government exerts is primarily by means of conditional grants and the requirement that borrowing for capital funds be approved by a provincially appointed board, the Local Authorities Board. Municipalities derive their income from property taxes, conditional and unconditional grants from the province, fees, fines, and income from municipally owned utilities.

In 1974, the provincial government of Alberta recognized that it had no experience in urban transit and that funding for transit was a desirable policy. The provincial government displayed a great trust in the cities by giving capital grants for transit that would be paid annually and were guaranteed for six years. In the case of Edmonton, this grant was $7.5 million/year for a total of $45 million (1). It is no coincidence that the original estimated cost of LRT in 1973 was also $45 million. The provincial government exercised no control over the planning, design, or construction details of the project. In addition, the capital grant was paid at the start of the financial year on April 1. Any interest earned from the grant had to be spent on transit as well. At the end of each year, an accounting of the funds was required. A surplus could be carried forward and temporarily invested. In addition, an operating subsidy was provided that paid up to 50 percent of an operating deficit with a maximum per capita grant of $3. The province of Alberta also helps municipal governments through the Alberta Municipal Finance Corporation, which is funded by the province and lends money for capital projects at an interest rate below the market rate (8 percent during the LRT construction period, when the market rate was 10-12 percent). Early in 1979, the provincial government allocated an additional $140 million spread over six years (1979-1985) on the same unconditional basis.

There are a number of unique situations in Edmonton. The city owns the electricity, telephone, water, sewer, and transit utilities. All of these utilities except transit make a profit, part of which is used to reduce property taxes. Planning in the city is coordinated through the Municipal Planning Commission (MPC), in which the managers of the various utilities as well as city departments are represented. The city can therefore, through development agreements, keep paths open for LRT--as it did, for example, by controlling the location of piles under the Edmonton Plaza Hotel so that LRT tunnels could be bored later without interfering with the hotel foundation.

In 1974, the transit system was part of the Edmonton Transportation and Engineering Department, which was responsible for roadways, traffic operations, and transit as well as transportation planning. The transportation plan was developed by this department and became the transportation chapter of the general plan in August 1973. The first manager of the transportation planning section was D.L. MacDonald, who had been manager of the transit system and later became the manager of the LRT project.

The Edmonton City Council decided to proceed with LRT in 1973 regardless of the absence of provincial funding because of the three possible transportation solutions for the northeast area (LRT-bus integration promised the lowest annual cost to the city). The provincial grant came later in 1974, partly because the determination of the city convinced the provincial government that LRT was really needed. The provincial grant improved the least-cost alternative (2).

When construction was approved, the project manager reported to the director of transportation and engineering, who in turn reported to the commissioner of utilities and engineering (an appointed position), who reported to the City Council. The LRT project was therefore a separate section just as transit operations was a separate section. Coordination between the sections was relatively easy.

The city water and sanitation utility had extensive experience in tunneling as part of the construction of storm drains and intercept sanitary sewers. This utility was later able to act as the contractor for the tunnels between Churchill Station and Central Station. The electrical utility had already had experience with the construction and maintenance of the overhead wire system for the trolley buses. The power supply for LRT uses the same 660 V (direct current) as the trolleybuses, which allowed future savings with spare rectifiers. The electrical utility could therefore assist in the design of the LRT electrical supply system.

The traffic operations section of the department was able to integrate train control and level crossing with a computerized traffic control system (3). The result was that, after the start of LRT operations, traffic flow improved and there were fewer delays at level crossings and at intersections near these crossings (4,5).

The fact that transit was a utility did have a legal benefit as well. After the City Council approved a borrowing bylaw to finance the difference in cost between the actual cost (allowing for inflation) and the provincial government grant of late 1974, a number of citizens challenged this bylaw in court. (A bylaw in Canada is the same as an ordinance in the United States.) For public works projects, the Municipal Government Act provides that the city has to advertise the bylaw and, if 5 percent of the population signs a petition requesting a vote, a vote must be held. This procedure does not apply, however, to the extension of a utility. The city of Edmonton argued in court that the LRT project was an extension of the transit utility and that, although it used a different technology, it was not different from other extensions of the network, such as a trolleybus line or a diesel bus route. The city won its case, and the LRT project was able to proceed.

The federal government was involved in the LRT project in a number of nonfunding ways. Since the LRT operation uses a railway right-of-way for part of its length, the Canadian Transport Commission (CTC) was involved in the approval of the signal system and the at-grade crossing protection (4). The signal system used is a red and green modified block system with a clearance overlap, which is different from the standard railway signaling procedures. The level-crossing protection is integrated with the traffic signal system and again has some unique features (the system has operated safely in Europe for many years and has proved to be safe). CTC sent one investigator to study the proposals and then a second investigator, both of whom no doubt submitted reports to CTC. Then an outside consultant looked over the situation and wrote a report for CTC. Finally, approval was given. It was, of course, realized by all that refusal meant that the Commonwealth Games would not have the benefit of LRT service and that the question could therefore become a political issue.

The city signed an agreement with the Canadian National (CN) Railway to lease the rail right-of-way. CTC approved this agreement when it was discovered that such an agreement required CTC approval. The federal government also waived the requirement for most of the import duties on the LRT equipment, which came from Germany and was finished in Edmonton. There are indications that pressure from industries in Ontario may cause duties to be levied on additional LRT cars in the future. It is probably mere coincidence that an Ontario organization was importing prototype light rail vehicles for Toronto at the same time as Edmonton, but from Switzerland, and therefore also benefited from the waiving of import duties. No doubt these import duties will also be a political issue in the future.

The federal government also contributed to the 118 Avenue and Santa Rose grade separations under the grade-separation-crossing fund program. This program of assisting in grade crossings was abandoned by the federal government in 1978.

Overall, therefore, it can be said that the federal government cooperated with the city in giving the necessary approvals, contributing to funding grade separations, and waiving most import duties. This kind of intergovernmental cooperation should be normal procedure, and it is hoped that it will continue.

The city enjoys a good relationship with the engineering faculty of the University of Alberta. Faculty members have been advisors to the transit system and the rapid transit project. The faculty has taken advantage of this opportunity to initiate research projects in transportation planning, traffic management, soil mechanics, tunneling, and the structural design of tunnels. It was possible, therefore, to monitor the performance of the tunnels during construction with extensive instrumentation.

Although the institutional constraints were favorable in 1973 when the project started, changes had occurred by 1978. The provincial government now has an expanding section dealing with urban transit; however, the grants are still unconditional. At every opportunity, the city has been requesting federal involvement in urban transit. It is unlikely that the federal government will actually get involved in a time of cutbacks and restraints, but one never can tell. Under Canadian arrangements, any federal funding would be channeled through the provincial government and would no doubt require extra staff at the federal, provincial, and municipal levels. It is difficult to estimate what additional government involvement will mean in costs or time delays.

The city itself reorganized in 1977 in that transportation planning was made part of the city planning department, which reports to the city commissioner of public affairs. The transit system was made a separate department, and traffic control remained with the engineering department. The previously existing coordination within one department is now dependent on committees and the willingness within separate departments to work together or even to inform others of what is being done. Any differences of opinion or conflicts now can only be resolved at the commission-board level instead of at the department level. If conflicts are not resolved early, voluntary cooperation may suffer. An outsider does not get the impression that the process of going from planning to implementation will be speeded up by these reorganizations. It is rumored that further reorganizations will take place during 1980.

PROJECT MANAGEMENT

The Edmonton LRT project had a small management team. The manager, D.L. MacDonald, reported to the director of engineering and transportation until 1977 and then to the manager of the transit system. The other principal members of this team were R. Yacyshyn, construction manager, and W. Mitchell, who was in charge of financial control. The entire staff, including secretaries, numbered 11 persons.

The small staff allowed quick decision making. The general philosophy was to discourage or veto any proposals for costly extras but to encourage proposals that might produce reductions in project costs. Extras that were nonessential to LRT but were included in the project had to be separately funded. For example, the mezzanine floor serves as a pedway and is part of the undercover pedestrian system being developed in downtown Edmonton. The finishing of this system within the structural shell required for the LRT was funded by the pedway project. Facilities such as elevators for the aged and the handicapped also required separate funding by the City Council. An example of cost reduction was the reactivation of an old streetcar barn as the maintenance facility for LRT.

Local consultants were used from the beginning for the various project phases. The structural design used for the subway stations dictated to a large extent what could be done architecturally. Architects had to work within severe limitations and were retained on a per diem basis. Consultants were also controlled by strict budgets. Because of the small project management staff, there was very good coordination among the city, the consultants, and the architects and contractors.

The contracting philosophy was to use small, manageable contracts of about \$1.5 million to \$4.0 million each (1). The smaller contract size made it possible for local contractors to bid. Contractors were encouraged to produce more economical alternative designs. These designs were then evaluated by the consultants to see that they were true alternatives and indeed more economical.

All contracts were on a fixed-price basis. In a time of inflation, profits can easily disappear, particularly if there are undue delays. Many contracts were completed ahead of schedule, which in fact provided a bonus to the contractor. Progress payments were processed fast so that contractors would not be faced with excessive interim finance charges. The knowledge that progress payments were fast also meant lower bid prices on subsequent portions of the work. The small management team provided for easy communication between the construction manager and the financial manager.

Because of major construction, excavation, and tunneling in the downtown area, there is the possibility of litigation later in regard to real or imagined damage to buildings. From the outset, one consultant (independent of all other consultants) was retained to monitor the effect of construction on the surrounding environment (6). The existing condition of structures was documented prior to construction, and copies of the reports were signed by the owners of the buildings. Vertical and horizontal deformations were monitored during and after construction, and the effect of vibration and noise during construction was measured and compared with the previously measured, normal situation. The fact that building owners knew that there was an inspection report and that there was monitoring reduced the possibility of irresponsible claims. A second benefit was the public relations aspect in that the owners and tenants knew that they were being looked after. As a result of the vibration measurements, a vibratory pile-driving hammer was replaced with a diesel pile-driving hammer. Although the noise level during construction increased by about 20 dB, no litigation was initiated. With the evidence collected, it has been possible to settle the few disputes that have arisen (2).

The city was also able to do some advance buying of components, materials, or equipment. For example, the precast, prestressed concrete girders used in the downtown station construction were ordered well in advance so that the concrete manufacturing plant could schedule production during an otherwise slack period. The mole for the tunnel was purchased by the city and then made available to the successful contractor for the tunneling.

The project was constantly monitored as regards financial control. In 1974, some changes had to be made in the plans so as to reduce costs. A run-out track with a crossover switch west of Central Station was eliminated from the plans. In addition, a new maintenance facility for the LRT equipment was not built; instead, an old streetcar barn was renovated and converted for LRT use. The articulated cars made it possible to reach this facility, since the route has some sharp curves.

The cost of construction of a subway is often dependent on the number of utilities that have to be relocated as well as the soil conditions in the area. Edmonton is a young city and therefore did not have too many utilities to relocate. In addition, the soil conditions are ideal for tunneling and excavation. The water table is low and well below the subway grade. Cost comparisons with other cities are therefore not meaningful, since each city is unique.

Since the completion of the project in April 1978, the management team has been disbanded. The newly approved LRT extensions required that a new team be formed.

EQUIPMENT

In regard to equipment, the specifications stressed performance rather than detailing the car features. Because the requirements of Edmonton would not justify a specially designed model, the aim was to use the production and design developed for other customers. The second aim was to select a simple, proven vehicle.

It was also desirable to have as much local input as possible. The contract was on a fixed-price basis with Siemens Canada Ltd. for 14 cars. The price was therefore unaffected by rate-of-exchange fluctuations. The shells and trucks were made in Germany by Düwag, and the final outfitting, wiring, and interior finishing were done in Edmonton. Mechanics and electricians of Edmonton Transit were invited to apply for the job of electrical mechanic, for the task of maintaining the equipment. These men were then seconded to Siemens Canada for the assembly and finishing work in the city-owned LRT maintenance shops, where they worked under the supervision of Siemens Canada personnel. This process helped in increasing Canadian content in the cars, a factor that was used in the request for exemption from import duties.

The cooperation of the supplier and the city also provided excellent training and a thorough familiarization with the equipment for maintenance personnel. This group of people now consider themselves a selected elite and take great pride in their work. The result has been that 12 of the 14 cars can be scheduled daily for service.

OPERATING COSTS

As described earlier, the construction of the Edmon-

Table 1. Total capital costs of Edmonton LRT.

Cost Element	Cost ($)
Underground stations and subway sections	
Central Station	4 417 217
Churchill Station	9 279 782
Precast beams for Central and Churchill Stations	1 814 976
Elevators and escalators	804 300
Portal underground section	3 003 996
Underpinning	1 745 897
Properties and acquisitions	1 172 094
Utilities and relocations	3 155 468
Mined subway from Churchill to Central	2 732 601
Fire lines in underground section	100 000
Connection, Coliseum	245 000
Edmonton Telephone, telecommunications system	375 000
Total	28 846 331
Surface stations and sections	
112 Avenue Station (Stadium)	1 448 784
118 Avenue Station (Coliseum)	2 200 817
118 Avenue overpass	598 823
129 Avenue Station (Belvedere)	200 000
CN relocations	984 093
Rail transit track work and crossings	6 393 074
Santa Rosa underpass	250 000
Structure underpass under CN at 66 Street to 129 Street	2 410 300
Total	14 485 891
Electrification	3 093 702
Signaling	2 271 300
Total	5 365 002
Other	
Design and engineering	3 358 713
Maintenance yards and shops	561 000
LRT cars (14)	7 396 796
Interest during construction	1 420 796
Miscellaneous	750 000
Total	13 487 305
Total for construction and design	62 184 529
Administration	1 299 000
Advisory consultants	1 135 000
CN lease costs	130 000
Total	2 564 000
Grand Total	64 748 529

Table 2. Edmonton Transit revenue and passenger statistics.

Item	1978	1979	1980
No. of systemwide passengers	61 414 000	62 724 000	66 282 000
Systemwide revenue ($)	18 511 288	23 268 464	24 418 398
Average fare per passenger ($)	0.30	0.37	0.37
No. of LRT passengers	4 263 496[a,b]	6 255 944[b]	6 500 000[c]
LRT passengers (percentage of total)	6.9	9.9	9.8
LRT revenue from fare boxes ($)	652 162	903 569	1 026 695
LRT revenue ($)			
Based on percentage of total	1 277 279	2 303 578	2 393 003
Based on 75 percent of average fare per passenger	959 286	1 736 024	1 803 750

[a]April 22, 1978, to December 31, 1979.
[b]From counts made by fare collectors.
[c]Calculated from sample counts.

ton LRT project was in capable hands and great care was taken not to waste funds. The total capital costs of the project are given in Table 1.

The operations of the LRT system are the responsibility of Edmonton Transit. At first glance, it appears that the LRT operation has been overstaffed. The personnel consist of the following:

Category	Position	Number
Operations	Director	1
Operations	Training supervisor	1
	Dispatcher	1
	Security supervisor (part-time to LRT)	1
	Inspector	10
	Relief inspector	3.5
	Operator	14
	Fare collector (plus two supervisors)	29
Equipment	Shop supervisor	1
	Electro-mechanic, including foreman	8
	Serviceman	7
	Cleaner	7
Plant	Supervisor	1
	Track foreman	1
	Subforeman	1
	Laborer	4
Power	Signal maintenance	2
	Overhead crew	4
Building maintenance	Janitor	12

In addition, there is a contract with a security firm to provide four men on duty 24 h/day, 7 days/week (a total of 13 guards). Since the start of operations, security has been reduced. The monitoring of closed-circuit television is now done by the central control staff.

It is expected that the maintenance personnel will be able to handle more than the initial 14 cars. A further 3 cars were ordered for the extension of the line to Clairview and were delivered in 1980. The major overstaffing occurs in the area of fare collection. It should be realized that about 60 percent of the passengers travel on passes and, of the remaining 40 percent, half will already have paid a fare on a feeder bus and use a transfer; so 31 people are employed to collect a small portion of the fares. If ticket machines were used with a proof-of-payment (POP) system, then these 31+ positions could be eliminated at a saving of $621 500/year. Several consultants and study groups have recommended this change. The Edmonton City Council approved POP on October 10, 1978. In November 1980, the POP system was instituted. The violation rate has since been about 0.26 percent of people checked (there is a $25 fine if a passenger has no proof of payment).

The costs of the transit system are operating costs only. Debenture interest, other interest, lease-back charges, and depreciation charges have been omitted. In Alberta, the provincial government gave a grant of $500 per capita in 1979 to municipalities to pay off past debts; therefore, including these charges would distort the comparison between years.

The revenue is even more difficult to estimate in an integrated system. The following assumption has therefore been made--namely, that every ride on LRT contributes 75 percent of the average fare collected on the system. It is easy to argue with this assumption, but it is based on geography and on the total distance traveled by an LRT passenger (on the average, 25 percent is on a feeder bus and 75 percent on LRT).

Table 2 gives the systemwide and LRT revenue and passenger statistics for 1978, 1979, and 1980. LRT costs for 1979 are given below:

Item	Cost ($)
7 electro-mechanics	204 640
7 LRT servicemen	128 190
7 LRT cleaners	105 610
Parts men performing for LRT	18 910
Equipment, repair, and maintenance	316 700

Item	Cost ($)
10 LRT inspectors	336 160
1 LRT dispatcher	22 760
14 LRT operators	286 230
≥29 transit fare collectors	609 905
2 transit fare supervisors	36 950
Administration	52 000
Building, station, right-of-way, signal maintenance	1 438 595
Total	3 556 650

The total transit costs for 1978-1980 are given in Table 3; Tables 4 and 5, respectively, give the recent fare history and the computation of operating ratios depending on the fare-collection method used.

In 1979 and 1980, the LRT system was as efficient in its operating ratio as the total transit system. The LRT did operate during 1979 and 10.5 months of 1980 with station attendants. Without station attendants and POP system, the operating ratios would have been substantially better than those for the rest of the transit system.

RIDERSHIP TRENDS

Ridership trends can only be measured if accurate before-and-after data are available. In this regard, there are two counting programs in Edmonton. Edmonton Transit makes counts of problem locations for operational needs and has the fare collectors count at the LRT stations. The transportation planning section has made periodic counts at a large number of locations in the city. Unfortunately, counts taken on the same day at the same location on the LRT by the different agencies vary by as much as 20 percent.

In order to measure trends on the entire transit system, I have used the counts from one agency only--the transportation planning section of Edmonton Transit. The basis here is the assumption that over the years the sign and percentage of error (if any) should be the same. Again, unfortunately, counting locations were changed before and after the initiation of LRT service, which makes comparisons difficult. The results given should therefore be viewed as preliminary. For LRT patronage, the fare collector's counts have been used.

In the northeast sector--namely, the area north of 127 Avenue (or the CN-Calder tracks) and the Beverly-Highlands area (east of the LRT track, north of 111 Avenue, south of the CN main line)--subsectioning can be used. Table 6 gives the changes in patronage over the years and illustrates the effect of LRT. It should be noted that both population and patronage in the Beverly-Highlands area decreased, although the rate of patronage increased.

It is clear from Table 6 that there is scope for a passenger increase in the northeast sector. So far, there has been little promotion, since the LRT service in the peak hours has standing room only. The city has yet to order more equipment to lengthen peak-hour trains to three cars each.

The advantage of LRT is that there is spare capacity for standees and additional patronage can be accommodated. There is, however, a need for more seated capacity in the peak hour, which would make LRT more marketable in the northeast sector. Adding an additional car would not increase operating costs significantly. The reason for constructing LRT was to be able to handle the increased peak-hour movement expected due to the development of new residential areas in the northeast sector.

The northeast quadrant is expected to grow to a population of 175 000 by 1985, or 15 percent more than in 1978. If one combines the transit trip-generation potential under current plans (26 percent versus a current 21.1 percent) and the growth of 15 percent, there is a potential market for another 8500 passengers in the northeast sector. On top of that, there is the potential of park-and-ride and land redevelopment.

CONCLUSIONS

The cost-effectiveness of LRT in Edmonton can be viewed from two viewpoints: the construction phase and the operating phase. Several factors made the Edmonton LRT project unique: There were few institu-

Table 3. Edmonton Transit revenue and expenditures.

Item	1978	1979	1980
Revenue ($)			
Cash fares			
Bus	8 643 351	9 753 851	10 487 669
LRT	652 162[a]	903 569	1 026 695
Tickets	74 938	97 691	131 505
Passes	9 145 459	12 513 353	12 772 529[b]
Total	18 506 910	23 268 464	24 418 398
Expenditures[c] ($)			
LRT	3 503 113	3 556 595	4 151 035
Other transit	39 320 887	41 591 204	51 100 349
Total	42 824 000	45 147 799	55 251 384
Operating ratio of system	0.43[d]	0.51	0.44

[a]From April 22 to December 31 only.
[b]Senior citizens travel free. Prior to 1980, compensation was paid by the Social Welfare Department. To keep revenues comparable, a charge of $0.50/senior citizen was added.
[c]Excludes depreciation and capital charges.
[d]The low operating ratio in 1978 was caused by lower fares and by higher costs due to the Commonwealth Games.

Table 4. Recent fare history of LRT.

	1978			
Type	1/1-3/31	4/1-12/31	1979, 1/1-12/31	1980, 1/1-12/31
Adult	0.35	0.40	0.50	0.50
Child	0.15	0.25	0.25	0.25
Monthly pass	14.00	15.00	17.50	18.00

Table 5. Estimates of operating ratio for LRT.

Time Period	Fare Collection	Revenue Assumption 75 Percent of ($)	Revenue[a] ($)	Expenditures ($)	LRT Operating Ratio	Systems Operating Ratio
1978	No POP	0.37	959 286	3 503 113	0.27	0.43
	POP	0.30	959 286	3 200 000	0.30	0.43
1979	No POP	0.37	1 736 024	3 556 595	0.48	0.51
	POP	0.37	1 736 024	2 905 295	0.60	0.51
1980	No POP	0.37	1 803 750	4 151 035	0.43	0.44
	POP	0.37	1 803 750	3 383 373	0.53	0.44

[a]Passengers x 75 percent x average fare.

Table 6. Transit trip generation in northeast Edmonton.

Item	Year	Northeast Sector[a]	North of 127 Avenue[b]	Beverly-Highlands[c]
Transit passengers	1975	NA	10 313	6 360
	1976	25 499	11 313	6 014
	1977	28 292	13 688	7 028
	1978	31 942	17 415	6 923
Population	1975	139 985	66 003	27 905
	1976	143 135	74 037	27 147
	1977	150 218	81 042	27 202
	1978	151 529	84 791	26 525
Trips generated as percentage of population	1975		15.6	22.8
	1976	17.8	16.2	22.2
	1977	18.8	16.9	25.8
	1978	21.1	20.5	26.1

Note: All passenger counts are based on data from the transportation planning section of Edmonton Transit.
[a]East of 97 Street and north of the North Saskatchewan River.
[b]East of 97 Street and north of 127 Avenue.
[c]East of LRT, north of the river, south of the CN tracks.

tional constraints, and that there were favorable construction conditions. Any comparisons, therefore, should take these unique factors into account, since it may not be possible to duplicate these conditions again, not even in Edmonton.

The operating phase shows that the promised labor saving from LRT was not realized initially in Edmonton. The main reason for this lack of productivity is the type of fare collection adopted. With the adoption of the POP system, the operating ratio for LRT should improve in the coming years in comparison with the remainder of the transit system.

The real value of the LRT system will not show until the new areas in the northeast sector have been fully developed and the trains have been lengthened. Although costs are expected to increase because of the lengthening of the line, revenue should also increase. The prospect, therefore, is that the operating ratio will improve for LRT whereas that of an all-bus system cannot improve at the same fare levels.

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Abridgment

Management Decision Model for Light Rail Vehicle Service: Development and Application

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A vehicle reliability methodology to aid in the determination of an operating service policy or maintenance schedule for a light rail transit system is presented. A decision-theoretic approach is developed to balance the costs of troubleshooting and regular maintenance against the risks of breakdown, repair, and passenger delay. The reliability of a vehicle is compared with a critical vehicle reliability obtained from the decision-theoretic approach to determine the suitability of a vehicle for service or to determine the optimal scheduling of the next regular maintenance to minimize expected cost. This expected cost includes the cost of passenger delay in addition to operating and maintenance costs. To provide an example of how the methodology is used, reliability distributions were fitted to the miles between discrepancies for the propulsion, electrical, brake, and door subsystems based on data from the Massachusetts Bay Transportation Authority. Flexibility in applying the technique is illustrated in a sensitivity analysis. Changes in the decision process are shown with respect to changes in five key parameters.

Vehicle procurements throughout the past decade have brought about dramatic changes in the design and complexity of rail transit vehicles. Increased complexity, however, often causes total equipment reliability to decrease (1, p. 5).

The American Public Transit Association (APTA) has been developing a program that identifies the scope and estimated acquisition and maintenance costs of information and data, including hardware components critical to system availability and dependability. Problems with maintenance scheduling and fleet availability have also resulted from equipment complexity. The application of reliability techniques has evolved to reduce the escalating costs of maintenance; to assist in this regard, the federal government has recently begun to collect and organize vehicle failure data through the Transit Reliability Information Program (TRIP) (2). Within specific systems, reliability assessment of the Bay Area Rapid Transit (BART) system includes "analyzing the slope of the failure rate trend, following preventative maintenance, to be used as a guide for