

Transit Operating Strategies and Levels of Service

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This paper discusses strategies of transit operation, differentiating between the all-day service function and the peak-hour operations of providing traffic and parking relief. A general mode split formula in which the disutility of the car is equated to the disutility of transit is used to evaluate the relevant factors in the individual choice of transit mode. Various types of networks are examined. For cities with low densities of development the timed transfer system is shown to give maximum destination opportunity. The concept of levels of service is discussed from the point of view of the passenger. It is recommended that levels of service be studied in greater depth so that these factors could also be considered.

The city of Edmonton started to use the concept of timed transfers in 1964 and has gradually expanded it. The system has to be viewed in relation to the functions of transit, particularly the service function, rather than from the point of view of providing peak-hour relief.

FUNCTIONS OF PUBLIC TRANSIT

There are four basic functions of public transit that should be considered:

1. To provide transportation to those who cannot use a car, who do not have access to a car, or who prefer transit;
2. To conserve energy based on an overall energy conservation strategy that a government may devise;
3. To provide peak traffic congestion relief, i.e., to divert transport demand to a less space demanding mode so as to avoid or postpone the construction of roadway facilities; and
4. To provide parking relief, particularly in areas of congestion and high land prices.

MODE SPLIT FORMULAS

The use of transit is dependent on individual decision

making. The mode split formula developed in Paris, which equates the total disutility of a car trip to the total disutility of a transit trip, appears to give a good explanation of this decision-making process (3). Much has been written about predicting mode split. In general, the comparison has been with the car (1, 2). The result has been the development of paratransit, which provides services similar to those of a car, namely door to door and on demand. Care has to be taken to not reinvent the car or the chauffeured car. The latter, called taxis, already exists. There is beginning evidence that the taxi industry will follow the history of transit in the 1950s and 1960s with a cycle of higher prices and less service, leading to its eventual decline.

General Formula

In the modified Parisian equation, cost of car trip equals cost of transit trip, when

$$\text{Cost of car trip} = MC_C + (t_c/60)a_1I + C_{cp} + (t_{cp}/60)a_2I + (t_{cw}/60)a_3I \quad (1)$$

and

$$\text{Cost of transit trip} = C_T + (t_t/60)a_4I + (t_{tw}/60)a_5I + (t_w/60)a_6I + (t_{tt}/60)a_7I \quad (2)$$

where

- M = kilometers traveled,
- C_c = cost in dollars of car travel per kilometer,
- t_c = travel time by car in minutes,
- C_{cp} = cost in dollars of parking,
- t_{cp} = time to find parking in minutes,
- t_{cw} = time to walk from parking to final destination in minutes,
- C_T = transit fare in dollars,
- t_t = travel time by transit in minutes,
- t_w = waiting time for transit in minutes,
- t_{tw} = walking time to stop or station in minutes,
- t_{tt} = transit transfer time in minutes between different routes, and
- I = hourly income of individual.

a_1 to a_7 are factors that evaluate time for travel, walking, waiting, and transferring in terms of hourly income. In Paris these factors were: for travel time 0.5, for transfer time 1.5, for walking time 0.875, for waiting time 1.5, and for parking time 0.25. These factors may be similar or different in Canada or the United States. More data and analysis are needed to obtain reliable factors that may even then vary among communities. For strategy purposes the formula explains the effect of various approaches. To improve the position of public transport any or all of the following could be attempted:

1. Increase the cost per kilometer for cars,
2. Increase the travel time of the car trip and reduce the travel time for transit (lane allocation, preferential signals),
3. Increase the cost of parking,
4. Reduce the availability of parking and thereby increase cost and walking distance,
5. Reduce or eliminate transit fares (the formula also explains that this factor is relatively minor),
6. Reduce waiting time at the bus stop,
7. Reduce the walking time for transit,
8. Reduce or eliminate transfer time, and
9. Decrease the hourly income (or the standard of living).

Obviously not all of these approaches are feasible, practical, or desirable. Most public transit improvement schemes have concentrated on reducing travel, waiting, walking, or transfer time. The demand-responsive schemes generally replace waiting at a stop with waiting at the place of origin, which eliminates walking time and may increase travel time (if the first one to be picked up) or reduce it (if the last one to be picked up).

Travel Time Reduction

The mode-split relationships developed in the past relied on travel time ratios or differences and used door-to-door times. The Paris equation assigns different weights to the various components of door-to-door time and shows that, while a reduction in travel time relative to the car is effective, a reduction in waiting or transfer time is more effective. Since the evaluation of time is subjective, it is most important that routes be direct and that traffic congestion be bypassed by traffic engineering measures such as exclusive lanes or priority signals.

Waiting Time Reduction

The general assumption has been to use half the frequency of service, up to a maximum of 10 min, as waiting time. Surveys in Edmonton however showed that there was often no time to interview passengers (4) on routes where the service interval was 30 min. In other words, as shown in Figure 1 (4), with good schedule information and absolute reliability in keeping to the schedule, the waiting time will be a minimum even when there is infrequent service (85 percentile, 6 min!). When the frequency of service is 10 min or less, passengers generally do not refer to timetables and the assumption of waiting time being half the frequency of service is probably correct. Schedule adherence and reliability are therefore of fundamental importance in low-density areas where the frequency of service is usually 15 or 30 min.

Walking Time Reduction

Walking time can be reduced for a fixed-route system by increasing the density of the network and by coordinating subdivision design (particularly in the provision of walk-

ways) and bus routing design. As shown in Figure 2 (4), the maximum acceptable walking distance in Edmonton is 400 m (1300 ft).

Transfer Time Reduction

To reduce transfer time the route design and schedules must be coordinated. Edmonton has changed to the timed-transfer system and transit centers have been established. By having all routes meet at these centers at fixed intervals, multiple destination opportunity is provided. Transfers are guaranteed on a regular all-day basis. While a slight delay is introduced in waiting for transfers, the public appears to accept this delay as reasonable at a transit center.

TYPES OF NETWORKS

Historical

There are still a number of networks based on former streetcar networks or developed on a piecemeal basis.

Grid

A grid system as illustrated in Figure 3 has the advantage that passengers can go anywhere with only one transfer. However, it also requires frequent service and medium to high-density service areas. Frequent service may be justified in peak hours, but such service at midday (the base period) or at low patronage periods, late at night or Sundays and holidays, can be very costly. Based on acceptable walking distances, a grid requires a route spacing of 800 m (0.5 mile). With an average speed of 18 km/h (11 mph) on a perfect north-south/east-west 800-m (0.5-mile) grid, the frequency of service would have to be 5 min if waiting time is not to exceed 5 min. However, a 5-min frequency requires a traffic generation that many low-density residential areas cannot produce, even if everybody uses transit. The grid does not allow for different densities along different routes.

If the transfers are not multidirectional but unidirectional (e.g., to and from the CBD), then a lesser frequency of service can be designed. As in subdivision design the grid is too inflexible a system for many North American cities. The grid works only if densities are uniformly high and the subdivision design has an 800-m (0.5-mile) grid.

Radial

In a radial system, as illustrated in Figure 4, the main transit routes fan out from the center of a city like the spokes of a wheel. Such a system is usually complemented with several cross-town or circumferential routes. Many radial routes exist for historical reasons. A radial system depends greatly on a strong and healthy CBD, which results from good planning control. In Canadian cities the CBD still attracts about 30 percent of the work trips and is the largest single destination. The remaining 70 percent of the work trips are more dispersed (the density factor) and are therefore more difficult to serve by transit. The need for transverse or ring routes means that the transfer locations and times must be carefully designed. To make transfers possible the frequency of service has to be increased, for transit riding cannot be accomplished without a transit service opportunity.

The Timed-Transfer System

The timed-transfer system (Figure 5) is often developed from a radial system. A number of transit centers, each

with its own feeder bus system, are established, and the CBD and transit centers interconnect to form a network (Figure 6). The basic midday schedule is generally based on 30-min intervals but could be 60 or 120 min in suburban or more rural areas. Maximum destination opportunity is provided by timing all routes to meet at the transit center at the same number of minutes past the

hour each hour (Figure 7). To minimize transfer time, the system works best with off-street transfer stations, which can best be located at shopping centers or community centers, or alternatively at commuter rail, rapid transit, or light rail transit stations. The regular basic schedule should be maintained in the peak hours, with additional service as needed. Feeder buses can then become express buses to other major destinations. The route modifications for Southwest Edmonton provide an example of how such a system evolved (Figure 8). It is relatively easy to add service on those links that generate a greater load.

In Edmonton the peak-hour service frequency is

Figure 1. Waiting time at bus stop.

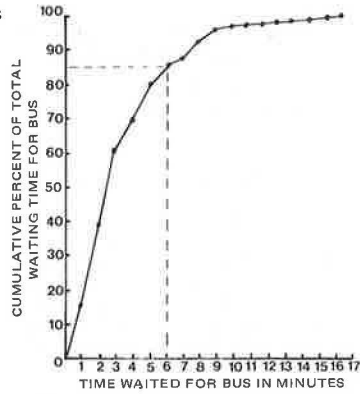


Figure 2. Walking distance from home to bus stop.

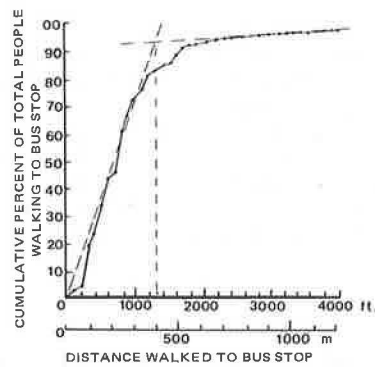


Figure 3. Grid system.

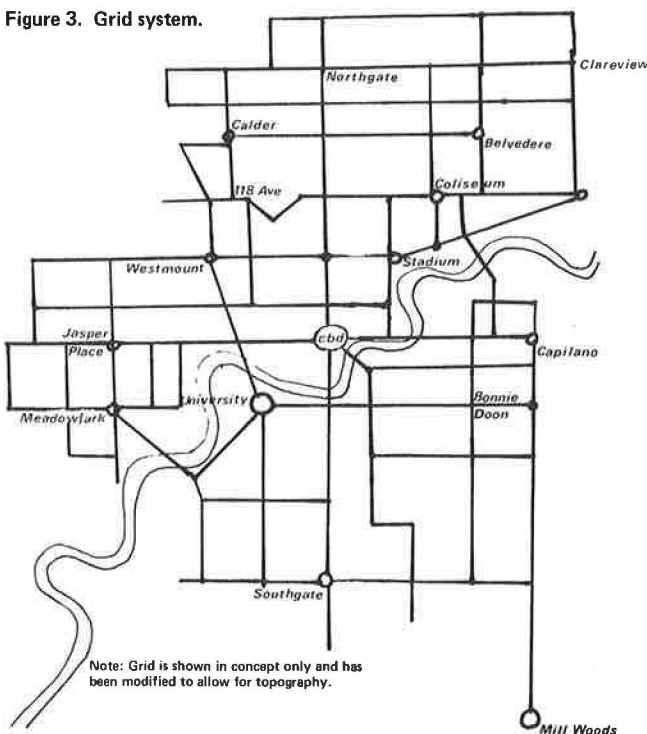


Figure 4. Radial system.

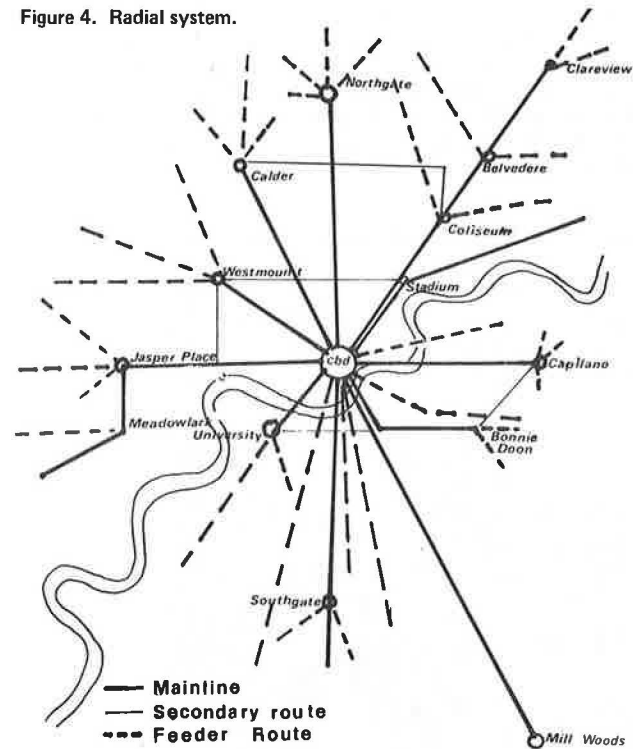
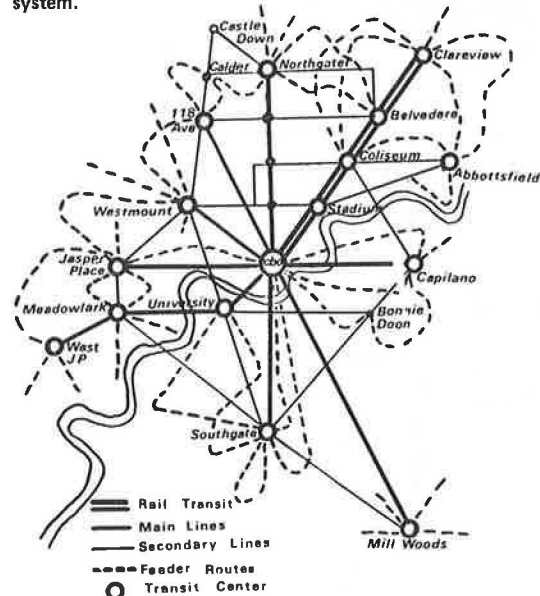


Figure 5. Timed-transfer system.



generally 10 or 15 min on the feeder routes with a 30-min express route maintained at midday. As long as the peak service fits with the critical transfer time at the centers, there is complete flexibility (i.e., 15, 10, 7½, 6, and 5-min frequencies work, but 20, 12, or similar odd service frequencies do not fit). Because several feeder routes may arrive simultaneously at a center, it may be necessary to send platoons of buses (express continuations of feeder routes) to a major destination rather than increase the frequency of service.

The basic consideration in establishing a transit network is to provide access to transit within an acceptable walking distance. The length of the route is determined by the distance between transit centers or more precisely by the time taken to cover that distance, which is (15n-2) min, where n is an integer. Sometimes the frequency of service has been increased between centers so as to provide the linkage. Sometimes the route has been deformed so as to fit the travel time between centers. The feeder bus to a center can make a collection trip that is determined by the schedule module and requires, for a 30-min module, (28n-3) min, where n is an integer. Greater efficiency is achieved by taking

a feeder route from one center and feeding it also to another center; one-way loops are therefore to be avoided.

In Edmonton the transit centers are also used as the starting points for routes to industrial areas. At present these services are provided only in peak hours, and the possibility of a demand-responsive basic daytime service is being investigated.

PATRONAGE STATISTICS

The timed-transfer system in Edmonton, together with a market analysis, has increased patronage over the years both absolutely and relatively. Patronage trends are given below and are also shown in Figure 9.

Year	Population	Passengers	Rides per Capita
1951	159 600	35 800 000	224
1956	226 000	34 400 000	152
1961	281 000	28 100 000	100
1966	376 900	32 000 000	85
1971	434 800	40 000 000	92
1972	440 900	41 000 000	93
1973	443 100	42 500 000	96
1974	443 300	45 200 000	102
1975	451 600	51 200 000	113

Figure 6. Part of transit map, showing timing points.



Figure 7. Part of transit schedule, showing timings.

LOCATION	MINUTES PAST HOUR
97 124 St./118 Ave. #3 Route	S.B. 03,13,23,33,43,53 W.B. 01,11,21,31,41,51 N6 W.B. 00,30 N7 W.B. 15,45 R3 E.B. 14,44 R4 W.B. 27,57 E.B. 13,43
98 135 St./111 Ave. #1 Route	E.B. 24,54 W.B. 19,49 N1 E.B. 07,37 N.B. 16,46 U5 N.B. 24,54 S.B. 27,57
99 127 St./129 Ave. #4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130,131,132,133,134,135,136,137,138,139,140,141,142,143,144,145,146,147,148,149,150,151,152,153,154,155,156,157,158,159,160,161,162,163,164,165,166,167,168,169,170,171,172,173,174,175,176,177,178,179,180,181,182,183,184,185,186,187,188,189,190,191,192,193,194,195,196,197,198,199,200,201,202,203,204,205,206,207,208,209,210,211,212,213,214,215,216,217,218,219,220,221,222,223,224,225,226,227,228,229,230,231,232,233,234,235,236,237,238,239,240,241,242,243,244,245,246,247,248,249,250,251,252,253,254,255,256,257,258,259,260,261,262,263,264,265,266,267,268,269,270,271,272,273,274,275,276,277,278,279,280,281,282,283,284,285,286,287,288,289,290,291,292,293,294,295,296,297,298,299,300,301,302,303,304,305,306,307,308,309,310,311,312,313,314,315,316,317,318,319,320,321,322,323,324,325,326,327,328,329,330,331,332,333,334,335,336,337,338,339,340,341,342,343,344,345,346,347,348,349,350,351,352,353,354,355,356,357,358,359,360,361,362,363,364,365,366,367,368,369,370,371,372,373,374,375,376,377,378,379,380,381,382,383,384,385,386,387,388,389,390,391,392,393,394,395,396,397,398,399,400,401,402,403,404,405,406,407,408,409,410,411,412,413,414,415,416,417,418,419,420,421,422,423,424,425,426,427,428,429,430,431,432,433,434,435,436,437,438,439,440,441,442,443,444,445,446,447,448,449,450,451,452,453,454,455,456,457,458,459,460,461,462,463,464,465,466,467,468,469,470,471,472,473,474,475,476,477,478,479,480,481,482,483,484,485,486,487,488,489,490,491,492,493,494,495,496,497,498,499,500,501,502,503,504,505,506,507,508,509,510,511,512,513,514,515,516,517,518,519,520,521,522,523,524,525,526,527,528,529,530,531,532,533,534,535,536,537,538,539,540,541,542,543,544,545,546,547,548,549,550,551,552,553,554,555,556,557,558,559,560,561,562,563,564,565,566,567,568,569,570,571,572,573,574,575,576,577,578,579,580,581,582,583,584,585,586,587,588,589,590,591,592,593,594,595,596,597,598,599,600,601,602,603,604,605,606,607,608,609,610,611,612,613,614,615,616,617,618,619,620,621,622,623,624,625,626,627,628,629,630,631,632,633,634,635,636,637,638,639,640,641,642,643,644,645,646,647,648,649,650,651,652,653,654,655,656,657,658,659,660,661,662,663,664,665,666,667,668,669,670,671,672,673,674,675,676,677,678,679,680,681,682,683,684,685,686,687,688,689,690,691,692,693,694,695,696,697,698,699,700,701,702,703,704,705,706,707,708,709,710,711,712,713,714,715,716,717,718,719,720,721,722,723,724,725,726,727,728,729,730,731,732,733,734,735,736,737,738,739,740,741,742,743,744,745,746,747,748,749,750,751,752,753,754,755,756,757,758,759,760,761,762,763,764,765,766,767,768,769,770,771,772,773,774,775,776,777,778,779,780,781,782,783,784,785,786,787,788,789,790,791,792,793,794,795,796,797,798,799,800,801,802,803,804,805,806,807,808,809,810,811,812,813,814,815,816,817,818,819,820,821,822,823,824,825,826,827,828,829,830,831,832,833,834,835,836,837,838,839,840,841,842,843,844,845,846,847,848,849,850,851,852,853,854,855,856,857,858,859,860,861,862,863,864,865,866,867,868,869,870,871,872,873,874,875,876,877,878,879,880,881,882,883,884,885,886,887,888,889,890,891,892,893,894,895,896,897,898,899,900,901,902,903,904,905,906,907,908,909,910,911,912,913,914,915,916,917,918,919,920,921,922,923,924,925,926,927,928,929,930,931,932,933,934,935,936,937,938,939,940,941,942,943,944,945,946,947,948,949,950,951,952,953,954,955,956,957,958,959,960,961,962,963,964,965,966,967,968,969,970,971,972,973,974,975,976,977,978,979,980,981,982,983,984,985,986,987,988,989,990,991,992,993,994,995,996,997,998,999,1000	

The market analysis consists of studying origin-destination data for work trips obtained from the civic census (5). The census gives, at 3 to 5-year intervals, all work trips by mode and morning destination time. Knowing the market a system has, plus the potential market that can be served, allows for better routing systems. The market analysis is then supplemented by public hearings, first an orientation meeting to identify needs, and then a meeting to discuss alternatives.

Figure 8. Route changes in Southwest Edmonton based on timed transfers.

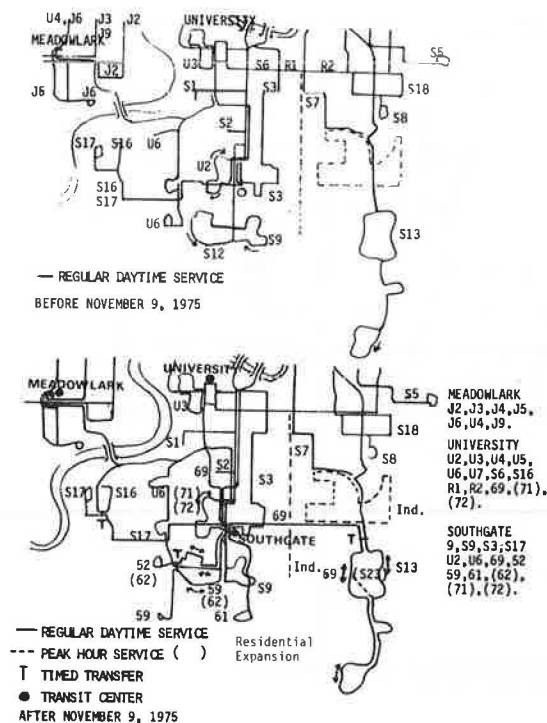
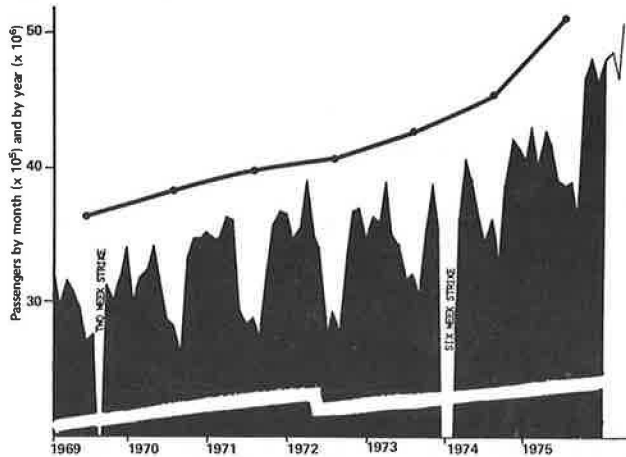


Figure 9. Patronage trends.



LEVELS OF SERVICE

Very little has been done to determine acceptable levels of service. In highway capacity the concept is used; however, in transit the concept of maximum capacity is used. Since many European systems design for standees and not for seated loads (e.g., a 12-m bus accommodates 15 seats and 102 standees), the word capacity can be misleading and a concept of level of service is needed in public transport. In most cities transit has to compete with the car, and so the base of measuring levels of service should relate to seats. The following arbitrary values are suggested:

Level of Service	Load Factor
A	0.5 x seats
B	0.75 x seats
C	1.00 x seats
D	1.50 x seats
E	1.0 x seats + 1 passenger/0.16 m ² (0.6 passenger/ft ²) of standing space

The rationale is that having a double seat available to oneself is ideal and therefore level A; level C is often used for urban service; level D is sometimes used as a maximum standard for suburban service; level E is undesirable. These levels are chosen from the point of view of the individuals to be served. The service provided is then dependent on frequency of service standards, traffic demand, and the hardware available.

In Edmonton diesel and trolley buses prevail, but on one link a light rail transit facility is now under construction (Figure 5). The choice of hardware has more to do with labor rates, productivity, right-of-way opportunities, equipment availability, and infrastructure than with level of service. At midday at least level of service B should be provided on all routes, and in the peak hours level D could be accepted (with double the frequency, four times the volume can be carried). Because of the slow delivery of equipment Edmonton has not been able to apply level-of-service standards. Additional service is based on service to new areas and on reducing overloads. Level-of-service standards will also have to be modified for other factors used in the Highway Capacity Manual such as size of metropolitan area, length of trip (standing for a short distance is acceptable), average speed, preferential treatment for transit at intersections or roads, stops per kilometer, and frequency of service.

CONCLUSIONS

The timed-transfer route system has been shown in Edmonton to contribute an increase in transit patronage because it gives increased transit travel opportunity. At the same time the system becomes simpler for the passenger to understand.

The mode-split analysis should incorporate more factors, as was done in the Parisian formula; however, research is needed to obtain more accurate quantitative factors that can be used in Canada and the United States. More study is also needed to develop meaningful concepts of levels of service that can be incorporated in transport planning objectives. These levels of service can be different for peak or midday conditions.

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