Transit Costs During Peak and Off-Peak Hours

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This paper discusses the relative costs of providing peak-hour and base transit service in Albany, New York, during a 3-month period between January and March 1976. It concludes that the total cost (operating and capital) per passenger was $0.480 during the peak period and $0.746 during the base period. It cautions against the application of these results to other properties because of differences in peak and base service requirements, demand profiles, and union work rules and concludes with a discussion of the implication of the results for transit fares by contrasting an economic viewpoint and a transit-operator viewpoint.

The Capital District Transportation Authority (CDTA), like nearly all other transit properties in the country (1), is subject to far greater passenger demands during the weekday rush hours than during the midday, evening, and weekend hours. To accommodate this demand profile during the morning rush period (the largest of the two at the CDTA) requires 143 vehicles in service. The base requirement for midday weekdays, however, is only 68 vehicles. (The vehicle requirement by time of day is shown in Figure 1.)

Although much of the system revenue is collected during the peak period, a large portion of the costs are borne during these times. While buses tend to be more crowded during the rush hours and are, therefore, at least superficially more productive, in order to produce a high level of capacity during only a portion of the day, a significant amount of human and physical resources must be idle for a large segment of the day. The purposes of this paper are to explore the costs and revenues of peak service in contrast with those of off-peak service and to make some inferences regarding peak and off-peak pricing of urban transit service.

BACKGROUND ON TRANSIT COSTS

There are two adverse effects on the transit industry caused by the time-of-day distribution of service demand. The first effect is that the peak demand requires significant expenses for vehicles and operators that are in use for only a small portion of the day. The second effect is that the peak requirements dictate the number of bus operators and, to some degree, the conditions under which they work. This paper is primarily concerned with the first effect, although additional investigation has shown that unit labor costs increase with the scale of the operation even after correction for cost-of-living differences. This may be due to the greater power held by larger union locals.

The peaked nature of transit demand and, hence, supply also causes extremely complicated contracts with labor bargaining units (2). Hence, proper categorization of costs into peak and off-peak costs is quite difficult, and, on the part of the transit industry, interest in cost assignment has been limited. Although many attempts have been made to ascertain costs of specific routes for the entire day, there has been little work on the aggregate costs of an entire transit system for different time periods within the day.

DRIVER ASSIGNMENT

A brief explanation of industry practice and local union rules regarding driver assignment will be given before the methodology used to assign costs to peak and off-peak service is explained. Since driver wages account for about 55 percent of the transit operating budget, this may explain why the peak-hour service is more costly to provide on a unit basis than is the off-peak service.

Three times each year the drivers select their assignments for a 4-month period. This is done on a seniority basis. There are two types of assignments: regular runs or assignment to the extra board. Regular runs are duty assignments of approximately 8 h for 5 d/week. A driver who has a regular run keeps it for the 4-month period. The extra board is for extra trips during the rush hour, nonscheduled trips, and to cover for sick days and attrition of the regular run drivers. A driver on the extra board may have a different run each day. All drivers work full time, as the labor agreement prohibits the use of part-time operators. Not all regular runs are continuous 8-h tours. Some are split runs consisting of two pieces of work, usually one in the morning and one in the afternoon. During the May 1976 peak at the CDTA there were 37 extra operators out of a total of 208 drivers.

There are three basic rules for determining operator wages.

1. All drivers are guaranteed 40 h/week.
2. Overtime (paid at time and one-half) is paid under the following conditions: (a) more than 8 h work in a single day and (b) work that lasts more than 11 h from the first time the operator reports to work. (This provision affects mainly those drivers with split runs.)
3. Extra operators work 5 d/week and are guaranteed 40 h of work/week. During each day they work, they are guaranteed 6 h of work.

The ability to reduce labor costs lies in skillful manipulation of runs while paying minimal overtime and spread-time penalties. Figure 2 shows the tours of duty on the route that require the largest number of peak-hour buses, the Western Avenue route.

METHODOLOGY OF THE INVESTIGATION

This investigation was carried out by determining the costs and ridership of the peak and base service for the first 3 months of 1976 for the portion of the system that serves Albany and Troy by a study of the CDTA financial records. The major effort of the analysis was the distribution of labor costs to the peak and base periods.

The major problem was that of estimating the additional cost of the peak-hour service above that of the current level of nonpeak service.

Determination of Peak and Base Hours

The peak and base hours are defined by bus assignments on the system throughout the day. The morning peak is defined as the hours between 7:00 and 9:00 a.m., and the afternoon peak is defined as the hours between 2:45 and 5:15 p.m. The longer afternoon peak is due to the fact that school discharge hours do not coincide with normal work discharge hours. On the other hand, the morning school and work starting times are similar. (All hours on Saturdays, Sundays, and holidays are considered to be base hours.)

Determination of Peak Versus Base Service Costs

To assess the performance of each route, the CDTA uses a cost-allocation model, derived by Simpson and Curtin (5), that assigns all authority operating costs to the number of peak vehicles, the service distance, and vehicle (platform) hours of service. The overhead and administrative costs are distributed according to the number of peak vehicles assigned to the route. The hourly costs include driver and field supervision sala-

Figure 1. Vehicle requirement by time of day.

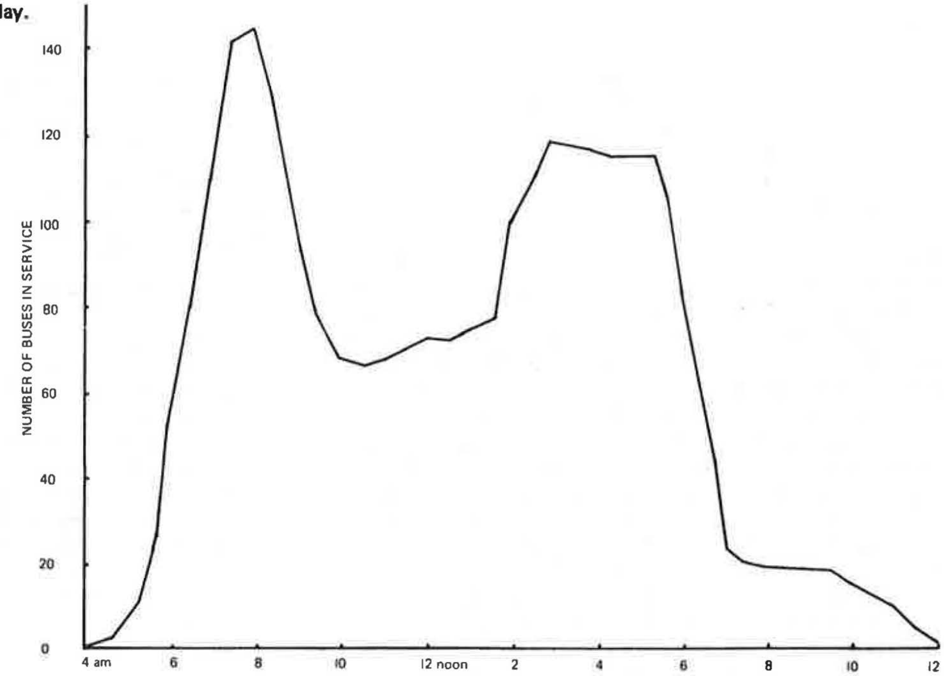
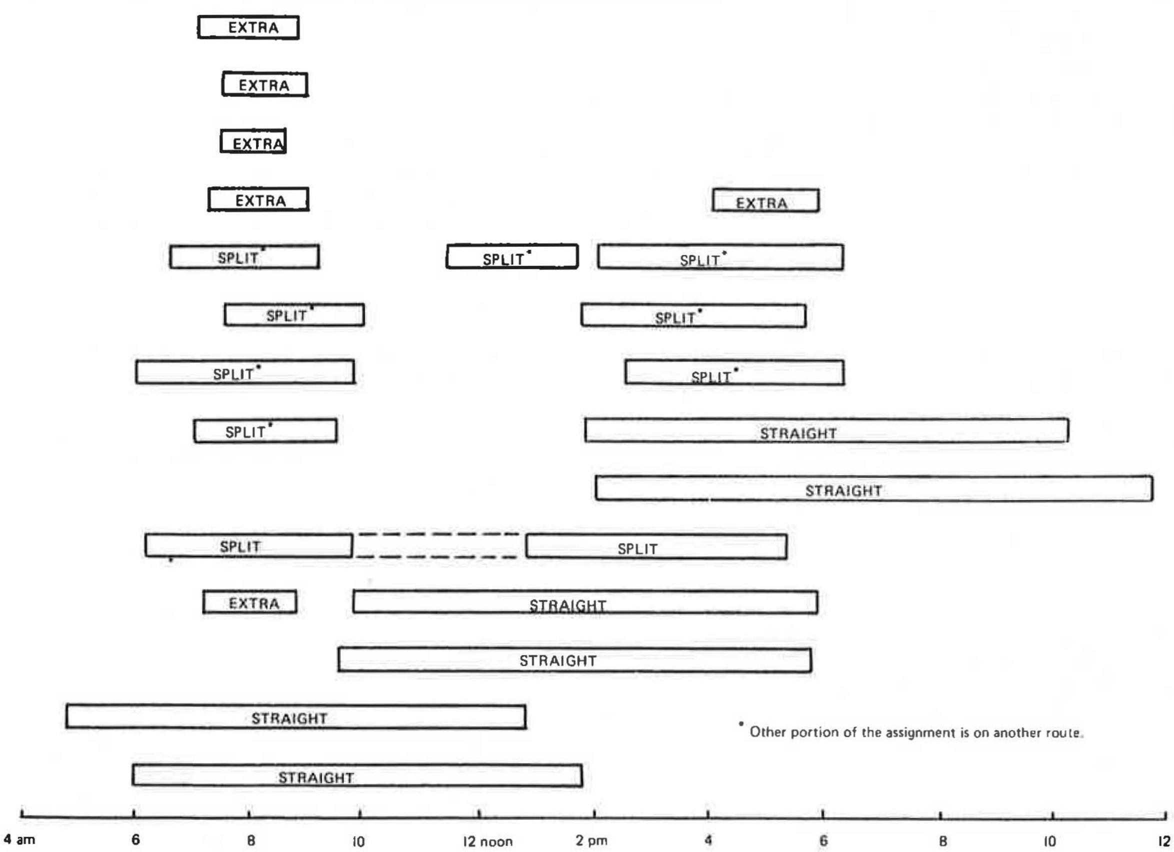


Figure 2. Assignment of runs on route 10 (Western Avenue) on a typical weekday.



ries and insurance and the distance-related costs include maintenance and consumables such as fuel and tires. For the period of the study (January 1, 1976, to March 31, 1976) $161 805 was assigned to the number of peak vehicles, $911 553 to the vehicle-hours, and $344 497 to the service distance. The cost-allocation equation has the form

$$C(x) = K_1V + K_2M + K_2H \tag{1}$$

where

$C(x)$ = cost of service x,
V = number of peak vehicles assigned to the service,
M = miles of service,
H = bus hours of service, and
K_1, K_2, and K_3 = constants.

(SI units are not given for the variables of this model inasmuch as its operation requires that they be in customary units.) For the period of the study, this was $C(x) = \$1131.50V + \$0.31M + \$9.70H$. This formula will allocate costs to a certain route correctly if the route requires the system average amount of overtime and the system average amount of peak to base time. However, since the efficiency of labor, measured as a ratio of actual bus hours to paid driver hours, is not uniform for peak and base service, the $9.70/h cost is higher than the actual cost of labor during the base period but lower than the actual cost during the peak period. The unit cost per mile ($0.31) is probably independent of peak or base operations since it reflects the cost of maintenance and consumables. Similarly, the peak vehicle charge is used to allocate fixed administrative costs and probably adequately reflects the extra administrative costs caused by the peak fleet size.

The peak hourly cost versus the base hourly cost could be estimated by adjusting the unit cost of labor ($9.70) upward during the peak and down during the base period and then multiplying each by the number of peak and base hours. This would ensure that the peak service is charged with the inefficient use of labor caused by the peaked demand that dictates that some drivers will be paid for a full day's work but may work only a few hours. This allocation model would be

$$C(x) = K_1V + K_2M + K_3H_p + K_4H_b \tag{2}$$

where

H_p = peak bus hours,
H_b = base bus hours, and
K_1, K_2, and K_3 = constants.

In this formula, K_3 would be greater than $9.70 and K_4 would be less than $9.70, reflecting the more efficient use of labor during the base period. To determine these constants (K_3 and K_4) the hourly costs were divided into operator and nonoperator costs.

Operator Cost

CDTA financial records showed that, for the 3-month study period, the cost for operators was $622 200 for salaries and $132 000 for fringe benefits, for a total operator labor cost of $754 200. The number of pay hours for straight time and overtime for regular and extra operators is shown below.

Drivers	Straight Time	Overtime	Total
Regular	75 468	7 869	83 337
Extra	24 826	4 345	29 171
Total	100 294	12 214	112 508

The operator labor cost (L) is then

$$L = A_1H_s + A_2H_o \tag{3}$$

where

A_1 and A_2 = constants,
H_s = pay hours for straight time, and
H_o = pay hours for overtime.

A_1 and A_2 represent the unit labor costs of straight and overtime respectively and were $6.47 and $6.80. A_2/A_1 is not 1.5 exactly (reflecting the 50 percent bonus for overtime) because the fringe benefits for overtime are less than the benefits for regular time. The labor-cost formula then becomes $L = \$6.47H_s + \$8.60H_o$. All of the driver pay hours were then assigned to straight time, overtime, peak hours, and base hours. The following time was assigned to the peak hour: all actual driving time during the peak hours, deadhead time between the garage and the route terminal on extra runs during the peak, and the nonproductive time of drivers that is caused by the fact that some are required for only a few hours each day but are paid for a full day's work. Most of the overtime was assigned to the peak periods since overtime is generally a result of using a driver to work both the morning and evening peak hours. The distribution of pay hours is illustrated below.

	Straight Time		Overtime	
Drivers	Peak	Off-Peak	Peak	Off-Peak
Regular	27 923	47 545	5965	1904
Extra	14 505	10 321	3916	429
Total	42 428	57 866	9881	2333

Nonoperator Costs

Not all hourly related costs, however, are due to driver wage and fringe benefits. Some hourly costs are for supervision, training and safety, and other categories. For the study period, these costs were $157 353.

Assignment of Hourly Costs to Platform Hours

The bus hours, the hours of actual driving time, were assigned in a manner similar to the assignment of the labor hours. As with the labor hours, all platform time on Saturdays, Sundays, and holidays was considered to be off peak. The peak versus off-peak distribution of platform hours is shown below.

Period	Weekdays	Saturdays	Sundays and Holidays	3 Month Total
Peak	659	–	–	42 173
Off-peak	685	525	108	51 788
Total	1344	525	108	93 961

Thus, the operator cost was $L_p = \$6.47(27\,923 + 14\,505) + \$8.60(5965 + 3916) = \$359\,486$ during the peak and was $L_b = \$6.47(47\,545 + 10\,321) + \$8.60(1904 + 429) = \$394\,457$ during the base period. The unit operator costs per platform hour during the peak and off-peak hours were $8.53 and $7.63 respectively.

The unit cost per platform hour of nonoperator hourly costs (N) was \$1.675 (\$157 353 ÷ 93 962), and the adjusted unit hourly costs were $K_3 = (L_p/H_p) + N$ = \$10.21 and $K_4 = (L_b/H_b) + N$ = \$9.31. Thus, the adjusted allocation equation for the operating costs is $C(x) = \$1131.50V + \$0.31M + \$10.21H_p + \$9.31H_b$.

Inclusion of Capital Costs

This analysis does not consider the capital costs associated with operating the transit system during the 3-month study period. Essentially, capital costs are in two categories: depreciation or the allocation of a prepaid cost to future time periods, and interest charges. The interest charge, although not an accounting cost, is indeed an economic cost, since the money spent on fixed facilities or vehicles could have been placed in alternative investment. The money that could have been earned by this investment should be allocated to future time periods, but the fact that nearly all CDTA equipment has been purchased largely with capital funds contributed by the federal government obscures this subtlety even further. For the study period, the vehicle and plant depreciation was about \$103 900 while interest charges (at a miminal 6 percent) would be \$91 860. The total capital cost is thus about \$195 760.

The proper assignment of these costs to peak and base operating periods is not readily apparent. Clearly, the interest cost and plant depreciation are peak-vehicle-related. However, it is not so evident whether or not vehicle wear is caused by the passage of time, as the accountant's ledgers view it, or by the accumulated distance driven. The common industry practice of assigning buses to runs so that buses of equal age have been driven similar distances supports either assignment method. In actuality, the reason for bus replacement is probably a combination of the effects of age and use; the allocation used here is on the basis of vehicle requirement. The total cost (operating and capital) then becomes $C(x) = \$2492.60V + \$0.31M + \$10.21H_p + \$9.31H_b$.

Cost Split Between Peak and Base Periods

The cost of service during the peak and base was determined by use of the adjusted allocation formula to be \$774 900 and \$839 200 respectively.

Determination of Peak and Base Patronage

Detailed ridership on a trip-by-trip basis was not easily available during the time of the study. However, based on a consultant's on-board questionnaire (3) administered in 1971 and verified by a more recent staff investigation, a time-of-day profile of ridership was established. The expected distribution of peak and base ridership is shown below.

Period	Weekdays	Saturdays	Sundays and Holidays	3-Month Total
Daily				
Peak	25 640	–	–	–
Off-peak	14 860	11 800	2 400	–
3-month total				
Peak	1 615 320	–	–	1 615 320
Off-peak	936 180	153 400	36 000	1 125 580

Per Passenger Cost During Peak and Base

The cost per passenger during the peak period was therefore \$0.480 while the base cost per passenger was \$0.746, a substantial difference. Since the system average revenue per passenger is \$0.38, it is probable that the added cost of providing peak-hour service is almost balanced by peak-hour revenue. The off-peak service, on the other hand, requires most of the non-fare-box support. The base period was not disaggregated into categories such as midday, evening, Saturday, and Sunday service, and there is no reason to suspect that the per passenger costs for each of these periods would be similar. There is no evidence that the peak-period patron is cross-subsidizing the off-peak patron, or the converse.

APPLICATION OF RESULTS TO OTHER PROPERTIES

The conclusions of this research may not apply to other properties for a variety of reasons. First, the ratio of peak to base units in service will certainly affect relative costs. A property with many long-haul commuter and park-and-ride services will probably have lower labor productivity, which may or may not be offset by higher physical productivity (passengers per unit of service). Second, the CDTA use of certain types of driver assignments reduces the number of extra operators required, which is a key determinant of peak-hour labor efficiency. In addition, work rules such as the hours after which spread-time penalties become effective and the maximum number of percentage of split runs will affect the relative costs of peak and base service.

Finally, a large proportion of the CDTA passengers are school children. Their school hours combined with the work hours of the general labor force provide a profile of demand that has a shorter but sharper peak in the morning but a longer, flatter peak in the afternoon. The absence of substantial school transportation would influence the magnitude, length, and time of occurrence of the two daily peaks so that relative costs might vary significantly from those presented here.

POLICY IMPLICATIONS

This paper provides some insight into transit policy, particularly in the area of urban transit pricing. The issue is whether the current practice of identical peak and off-peak pricing is proper. The transit operator is inclined to apply private business cost-recovery principles to the problem, while an economist is concerned with the proper allocation of resources to activities. The following discussion highlights the two viewpoints.

Economic Perspective

An economic approach to transit-fare policy would be to ensure that the service policy is efficient in that it is related to the marginal cost of the service and equitable in that the income transfers that result from any subsidies are positive. While the analysis above indicates that the average cost per passenger during each period (peak and base) is unequal, there was no inference about the marginal cost of carrying additional patrons. The incremental, not the average, cost is the key to efficient pricing.

During the peak hours, a small increment of passengers would either require additional resources to transport them or cause uncomfortable crowding on the existing vehicles in service. This cost of additional service, including both the out-of-pocket cost of additional resources and the cost imposed by congestion of the vehicle, distributed over the additional passengers, is an efficient price. An efficient price for transit during the peak hour, however, should be considered only if all segments of the urban transportation market during the peak hours are efficiently priced. Since the marginal social cost of driving in cities, particularly during the rush hours, is significantly higher than the price, primarily due to uninternalized costs such as congestion and pollution, attempts to efficiently price the transit sector of urban transportation will be counterproductive. However, this situation will continue until there are realistic attempts to bring automobile prices into line with automobile costs, which will make the entire urban transportation sector efficiently priced and, therefore, properly allocated by mode and time of day.

During the off-peak hours, since there is a substantial excess capacity in the number of vehicles in service, a similar small passenger increment would probably require no additional buses or operators. In fact, since transit fares, even during the off-peak hours, are quite inelastic, a fare reduction would increase passengers without increasing costs. In the capital district, even if the off-peak fare were reduced to zero, the requirement for vehicles and operators would not increase and excessive crowding and congestion in vehicles would not be likely. A truly efficient fare would be one that would just fill the bus. A fare below this amount would result in extra riders and cause additional vehicle requirements while a fare above this amount would be suboptimal in that extra output (ridership) could be produced at no increment in cost.

In effect, transit service in the capital district during the off-peak hours is a public good, in that additional output, within limits, can be produced at no additional cost. The appropriate efficiency-based charge is thus zero or nearly zero. Paying off-peak transit costs from tax revenue would be more efficient than direct user charges since the marginal cost of net revenue due to taxes spent would be less than the marginal cost of net revenue due to transit fares received. That is, the cost to society of transit financing through taxation (measured as the sum of collection, compliance, and excess burden costs) is significantly less than the net cost to society of transit fares priced above the marginal cost (measured as the ratio of the increased consumer cost to the extra revenue created).

As a second-best alternative, if it were considered desirable for users themselves to pay for the cost of service, a system of monthly or annual passes sold to off-peak patrons would be appropriate. The fee for this pass would represent a charge for the option to ride the bus, not unlike the fixed monthly charge to telephone subscribers (4).

These efficiency-based charges could have the effect of shifting some of the transit ridership from peak to nonpeak hours. This could reduce the cost of producing transit service by diminishing the excess off-peak capacity and the need for a large reserve of underused peak-hour resources.

Transit Operator Perspective

An historical perspective is required to fully appreciate the operational viewpoint of transit prices. During the period in which private ownership dominated public transit systems, prices were established on a cost-recovery basis by regulation of various utility and public service commissions. Although most of the urban transit properties in the country are now in public hands, they still tend to be operated with certain vestiges of their former private ownership. Even today, a key performance measure by a transit operator on a specific route is the operating ratio, which is the inverse of the percentage of costs that are covered by passenger revenue. The economist, however, measures efficiency by the cost per passenger trip or per passenger mile, regardless of the source of the revenue.

Governed by a fixed budget derived from fare-box revenue and external subsidies, a transit operator wants a fare policy that provides a politically tolerable subsidy and an easy-to-explain and simple-to-administer fare structure. The current practice of identical peak and off-peak pricing with flat-base fares is ideally suited to meeting these two objectives. An efficiency-based fare, on the other hand, is difficult to explain, hard to rationalize in terms of cost recovery, difficult to enforce, and could yield politically intolerable deficits.

Resolution of Conflicting Viewpoints

There is no easy resolution of these viewpoints, particularly because of the price inelasticity of urban public transportation during both the peak and off-peak hours. If off-peak transit demands were elastic, reducing the fare (to price the service efficiently) would result in increasing revenue for a given supply of service. This would satisfy the operator's requirement for revenue recovery and the economist's requirement for efficient pricing.

For the future, transit policy will probably be a compromise between the two positions. For example, the National Mass Transportation Assistance Act of 1974 requires half-fares for the elderly and handicapped during off-peak hours for Section 5 grant recipients. Second, the percentage of transit costs that is recovered by fare-box revenue is decreasing and so it is probably not considered to be as important as it was formerly. Finally, the utility industries are recognizing that the additional costs of peak-hour power generation are in excess of the nonpeak costs, which will soon be reflected in consumer utility bills. Once this procedure is established and accepted, mixed pricing for transit will be easier to explain to the public, which could lead to more efficiency-based prices for services.

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