Net Costs of Peak and Offpeak Transit Trips Taken Nationwide by Mode

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Estimates are made of the net costs of trips taken during peak and offpeak periods on bus, subway, and commuter rail systems in the United States, both separately and averaged over all three of these transit modes. Net costs are defined as the sum of annual operating and maintenance expenses and annualized capital costs minus passenger revenues. Various cost and revenue allocation factors and related assumptions were used to estimate net costs using actual data for transit systems providing bus, subway, and commuter rail service. The results indicate that transit trips taken during peak periods, expressed on either a per-trip or a per-passenger-mile basis, have consistently higher net costs than trips taken during offpeak periods. Nationwide, the average net cost for a transit trip taken in the peak period during 1983 is estimated at $1.74, compared with an estimate of $1.20 for a trip taken in the offpeak. This difference occurs primarily because a relatively higher proportion of transit capital expenses is attributable to providing for the peak periods. Although passenger revenues are proportionally high in the peak, they are not of sufficient magnitude to result in lower net costs during this period. When costs and revenues are expressed on a per-passenger-mile basis, which normalizes for trips of different lengths, the disparity in net costs by mode and time of day is reduced.

Estimates are made of the net costs of peak and offpeak trips that are taken on all bus, subway, and commuter rail systems in the United States (*1*). Net costs (i.e., deficits) are defined as the sum of annual operating and maintenance expenses and annualized capital costs, minus passenger revenues received for trips taken during the peak and offpeak periods. The peak is defined as the five hours from 7:00 to 9:00 a.m. and from 4:00 to 7:00 p.m.

Average net costs per trip and per passenger-mile for both the peak and offpeak periods are estimated on the basis of data representative of all bus, subway, and commuter rail systems in the United States. This disaggregate information is useful in understanding how net costs vary by mode and time of day. However, as McGillivray et al. (*2*) note, this type of analysis is most helpful in evaluating questions pertaining to pricing policy rather than many other short-range planning applications. The latter concerns would best be addressed through an analysis of the marginal costs and revenues that would likely result from particular service changes.

Earlier cost allocation studies generally fall into one of four categories. The first, which contains the largest number of studies, is the route-level cost allocation study. These studies are typically performed for an individual or single transit agency and are intended to examine how costs vary by route and in some instances by time of day. Except for a study of the New York subway system (*3*), the vast majority of these route-level studies focus only on bus systems. The second type of study examines the issue of scale economies in the transit industry, again, usually for bus systems. The third type of study is concerned with the issue of equity in transit finance, which is usually analyzed by examining subsidies provided to users of different urban transit modes. The fourth type of study is aimed at undertaking a comparative analysis of the full costs (i.e., both supplier and user travel costs) of trips made by alternative modes. In general, all of the cost allocation studies included in these four categories have some elements (in varying degrees) in common with the present study; however, no known single study has made estimates of the net costs (as defined) of providing transit service in the United States by mode and time of day.

The analysis of transit deficits presented here builds on a Charles River Associates (CRA) study (*4*) performed for UMTA, which examined the distribution of federal operating subsidies by income group. The analysis of net operating and maintenance costs by time of day were extended to include a measure of annualized capital costs for all bus, subway, and commuter rail trips taken nationwide (*1*).

OVERVIEW OF THE NATIONWIDE COST AND PASSENGER REVENUE ALLOCATION METHODOLOGY

Allocation of Operating and Maintenance Expenses

Operating and maintenance costs for bus and subway systems were assigned to the peak or offpeak period using information obtained from UMTA's *1983 Section 15 Annual Report* (*5*) to be consistent with the earlier CRA study (*4*). The basic methodology for allocating operating and maintenance costs followed the general logic used in the route-level, accounting-based studies. Expenses in each major cost category were divided between the peak and the base period according to the amount of service supplied (e.g., vehicle-hours) and the relative productivity associated with each period. Those particular cost categories that typically vary as a function of the number of passenger-miles of service produced were then expressed on a per-passenger-mile basis. The cost of an individual trip was computed as the product of the length of the trip in miles multiplied by the appropriate (per passenger-mile) cost coefficients for the time of day during which the trip occurred, plus any per-trip fixed expenses. In general,

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the following procedure was used in making the necessary calculations:

1. Separate transit operating and maintenance expenses into accounting cost categories, by mode;
2. Assign a fraction of each cost category to the peak and base periods using various allocation measures, and determine which costs vary with the number of passenger-miles of service produced; and
3. Formulate mathematical relationships based on Step 2 and estimate peak and offpeak operating costs by mode based on observed trip length distributions by time of day.

Each of these steps is briefly described in the following paragraphs.

Step 1: Classify expenses by category and mode

The UMTA *1983 Section 15 Annual Report* (*5*) contains a breakdown of transit operating expenses by mode and by function. The functions to which costs are attributed include vehicle operations, vehicle maintenance, nonvehicle maintenance, and general administration. Vehicle operations account for the largest category of costs, because it includes expenses related to transportation labor. Because of various work rules, labor expenses per unit of service supplied are higher in the peak than in the base period and therefore need to be allocated separately. For single-mode motor bus systems, labor expenses represent about 80 percent of the costs incurred in this category (*5*).

Step 2: Determine how costs vary by peak and offpeak periods

For bus and subway modes, the procedures used for allocating operating costs by functional categories are described in the following sections (but in reverse order for presentation purposes).

General administration expenses are assigned to the peak and offpeak periods on a per-trip basis. This method of assignment was chosen because the extent of administrative functions, such as marketing, schedule printing, and service planning, are determined primarily by the number of passengers served rather than by the number of vehicle-miles produced. Furthermore, it is unlikely that these expenses, expressed on a per-trip basis, are affected by the time period in which the trip occurs. Thus, each trip is credited with a fixed expense for these overhead functions.

Total vehicle maintenance expenses first are allocated to peak and offpeak on the basis of vehicle-hours of service. Vehicle-hours are used to allocate this cost category between periods, because maintenance expenses result from the duration of actual vehicle use. This method of assignment assumes that each vehicle-hour of service results in the same maintenance expense, regardless of the time during which the vehicle is in operation.

Nonvehicle maintenance expenses include the costs of maintaining stations, rights-of-way, and other structures. This category of costs is allocated on the basis of relative passenger-miles in each period. This allocation method attempts to account for the intensity of facility use in each period. Within each period, nonvehicle maintenance expenses are assigned to a given trip in proportion to the length of trip.

Nonlabor vehicle operations expenses are divided between time periods on a vehicle-hour basis. Vehicle-hours are used because this category is dominated by fuel and tire expenses, which vary with the number of vehicle-hours of service produced. There is some justification for assigning a higher per-hour cost to the peak period on the grounds that average vehicle speeds are lower, and hence fuel consumption is higher, in the congested peak hours. However, to an unknown extent, the effects of congestion on average vehicle speeds are offset by the larger proportion of express and special-service runs in the peak. These services typically operate over limited-access roadways for some portion of the route, bringing up the average vehicle speeds for peak-period services. In the absence of solid empirical evidence concerning relative vehicle productivity, nonlabor vehicle operating expenses are assigned on a constant cost per vehicle-hour.

For *vehicle operations labor* expenses, it is well known that unit labor costs are higher in the peak period than in the base because of various work rules and labor conditions intrinsic to the peak. Previous studies of allocating costs between time periods have focused on relative labor productivity, defined as the ratio of pay hours per vehicle-hour in the peak to pay hours per vehicle-hour in the base. This statistic captures the effect of higher hourly wages for peak-period service and productivity differentials caused by split shifts, 8-hr minimum shifts, and other rules.

On the basis of a review of prior studies (*6–11*), an average of 1.20 was determined as an estimate of relative labor productivity for bus systems. [Mohring (*12*) and Boyd et al. (*13*) make use of a higher relative labor productivity figure, but one that is not based on empirical data.] No studies focusing on equivalent subway labor productivity factors were found. However, in a recent study of the New York City subway system, Hirschman (*14*) examined the way certain operating and maintenance cost items varied between peak and offpeak periods. His analysis of operating costs per train-hour—a significant portion of which includes labor (crew) costs—indicates that relative labor productivities for subway systems are likely to exceed 1.20, even after adjusting for the shorter 4-hr peak period assumed in his analysis. (If peak labor productivity factors for subway systems were greater than 1.20, relatively higher net costs in peak periods than shown here would result.)

Following the logic implicit in the route-level cost allocation studies, transportation labor costs for bus and subway systems are apportioned between peak and offpeak periods on the basis of vehicle-hours of service supplied in each period, with higher labor costs per vehicle-hour attributed to the peak. Commuter rail operating expenses by function are not available in the *1983 Section 15 Annual Report* (*5*). Consequently, each commuter rail trip is assigned the same (operating) cost per passenger-mile, regardless of the time period in which the trip was taken. To the extent that peak-period costs are higher per passenger-mile than base-period costs, this commuter rail cost assumption will underestimate the peak-period deficits on commuter rail. Although potentially significant for the commuter rail segment, averaged over all transit trips nationwide, this underestimate is likely to be small, because only 5 percent of all transit trips are made using commuter rail.

Step 3: Formulate Cost Equations and Estimate Peak and Offpeak Operating Costs

The methods described for allocating individual line items by function were incorporated into various equations that were subsequently used to estimate the cost of specific trips by time of day. The equations are described in more detail in the full CRA report (*1*).

Allocation of Annualized Capital Expenses

General Overview

Earlier cost allocation studies have presented differing points of view on how capital costs for transit systems should be allocated between peak and offpeak periods. Furthermore, even the range of capital costs considered is not addressed consistently. For example, some studies (typically those for bus systems) consider capital costs, but only for vehicles—presumably because vehicles represent the largest share of capital expenditures for bus operations. It is not uncommon to find instances in which capital expenses for bus garages and maintenance facilities are ignored. In other instances, particularly for rail transit systems, capital costs are discussed in terms of vehicles, rights-of-way, and structures (e.g., bridges and tunnels) that, because of varying useful lives, have different impacts on annualized capital costs. With respect to vehicles, some studies suggest that useful life is based on age, whereas others indicate that miles traveled, or some combination of the two, is the most important factor in replacement decisions.

A more fundamental issue that is sometimes advanced concerns whether a particular transit mode would exist at all if it were not for the singular need to provide peak-hour service. As Meyer et al. observe (*15*), "If the basis of design and justification of downtown-oriented systems is the rush-hour flow, as it usually seems to be, then it can be argued that the full costs of providing the capacity needed for that service should be charged to rush-hour travelers." The concept of charging peak users the full capital costs follows earlier studies in electricity utility pricing (*16*). Others remain unconvinced of this particular allocation concept (*17*). Coase (*18*) goes further by stating that ". . . the allocation of joint or common costs between products or services for the purpose of determining prices is without meaning." In a similar vein, McGillivray et al. (*2*) caution that any approach to capital cost allocation ". . . usually stumbles over the intractable problem of allocating the common costs . . . and hence . . . is quite sensitive to essentially arbitrary assumptions." As a middle ground to the problem of allocating joint costs between two user groups, Loehman and Whinston (*19*) propose that joint costs be computed using the different allocation methodologies possible and that a weighted average of these costs be computed.

Previous Practice in Transit Cost Allocation

Earlier studies that have considered the issues pertaining to allocating transit capital costs between peak and offpeak users can be separated into two groups: (a) those advocating that all capital costs be assigned to the peak and (b) those advocating that costs be shared in some fashion between peak and offpeak users. The studies in the first group generally base their arguments on the principle that peak demands determine the level of capital required and therefore these users should be assessed the full capital costs. Meyer et al. (*15*) not only advance this position but go a step further by indicating that all capital costs be allocated to users traveling in the peak direction. The concept of allocating annualized capital costs to peak users has been followed by Mohring (*12*), Reilly (*11*), Cherwony and Mundle (*10*), and in bus studies conducted in the early 1970s and reported by Taylor (*20*), Parker and Blackledge (*21*), and McClenahan and Kaye (*22*).

In a study of the full costs of urban transport, Keeler et al. (*23*) favor the concept of allocating all capital costs to the peak. However, as part of this larger study, Merewitz (*24*) recognizes that some may find this allocation decision to be arbitrary and therefore proposes to share capital expenditures between the peak and the offpeak, using the results of a full-cost study by Boyd et al. (*13*). The latter study is an early example of the second group of transit cost allocation studies that advocate sharing capital costs according to relative usage. Other studies that fall into this group include the works of Levinson (*25*), Cervero et al. (*7*), Lee (*26*), and Kerin (*27*).

Recommended Approach

Given that there is no unambiguous way to assign transit capital costs associated with vehicles and infrastructure by time of day, a preferable strategy would be to select a methodology that falls between the extremes of the two approaches discussed in the preceding section. This has been accomplished by assuming that 85 percent of the annualized capital cost for bus, subway, and commuter rail vehicles can be allocated to the peak period, following previous studies (*7,13*). It is likely that the size of most rail fixed facilities has been geared to meet peak demands, suggesting that 100 percent of the capital infrastructure costs be assigned to the peak. The other extreme suggests that about 70 percent of right-of-way and structure capital costs for rail rapid-transit (or approximately 80 percent for the more peaked commuter rail systems) be allocated to the peak period (*7*). Because, on average, this process would represent about 85 percent of fixed capital costs, 85 percent is used to represent the peak capital expense factor for subway and commuter rail.

A stronger case can be made that bus service, which is less peaked to begin with, would likely be offered without the presence of a morning and evening peak. Thus, a proportionately larger share of the fixed facilities for bus systems should be allocated to the offpeak. Using the Boyd et al. methodology (*13*), but assuming that only 46 percent of the bus riders (based on 1983–1984 Nationwide Personal Transportation Study data) are carried during the peak, results in a peak allocation factor of 56 percent for bus way and structure items. However, given that there are few, if any, right-of-way costs for bus systems and that vehicle expenses represent the largest share of capital expenditures, an approximate weighted average between vehicle and right-of-way of 80 percent has been estimated for allocating bus capital expenses to the peak period.

Allocation of Passenger Revenues

Passenger revenues for peak and offpeak periods were computed on the basis of the product of the number of passenger trips taken during these two time periods and average passenger fares paid by users of bus, subway, and commuter rail systems across the United States. Average fares per trip (77 and 60 cents for subway and bus systems, respectively) were calculated for single-mode systems from data in the UMTA *1983 Section 15 Annual Report* (*5*), supplemented by additional information obtained directly from transit systems operating more than one mode. Finally, fares on commuter rail systems were assumed to be proportional to trip length, with passenger revenues for 1983 obtained from the American Public Transit Association (APTA) (*28*).

ESTIMATION OF NET COSTS BY MODE FOR PEAK AND OFFPEAK TRANSIT TRIPS

The following sections summarize the results obtained in estimating operating and maintenance costs, capital costs, passenger revenues, and net costs by mode and time of day for trips taken on all bus, subway, and commuter rail systems in the United States.

Allocation of Operating and Maintenance Expenses

Operating and maintenance expenses for bus, subway, and commuter rail systems nationwide were allocated to peak and offpeak periods on the basis of actual data from UMTA (*5*), using the methods described previously. The resulting peak and offpeak annual expenses by mode are summarized in Table 1. Overall, the results tend to reflect the relative differences in the peaking characteristics of each mode; commuter rail, for example, had the highest percentage of operating and maintenance costs occurring in the peak.

Allocation of Annualized Capital Expenses

According to UMTA (*5*), $2,787 million was expended in 1983 for capital projects by nearly all transit systems in the United States from all sources of public capital assistance. In addition, in FY 1983, about $3.2 billion in UMTA capital grants were obligated, but not necessarily expended (*29*). The actual amounts expended are difficult to determine from this figure, because other sources are used to match UMTA grants, which would tend to result in a larger number. This factor is offset, however, by the fact that obligations are expended over more than 1 year.

Neither UMTA report (*5*,*29*) disaggregates capital expenses by the three major transit modes included here. However, APTA (*28*) presents information on federal capital grant approvals by transit mode. Averaged over the period 1965 to 1983, federal capital grants for bus, subway, and commuter rail systems were 32.2, 54.2, and 13.6 percent, respectively. Thus, these averages over a relatively long period (which smooth out year-to-year variations) can be used to allocate by mode the total capital expenditures that were made in 1983, assuming that the modal distribution for federal allocations reasonably reflect that for total allocations. The resultant capital expenditures by mode and time period are presented in Table 2.

Allocation of Passenger Revenues

Following the allocation methods described in preceding sections and using data sources consistent with the estimation of operating and maintenance expenses by time of day, Table 3 presents the ridership and passenger revenue statistics by time period for each transit mode. As expected, those transit systems with a higher concentration of riders in the peak (e.g., commuter rail) have a correspondingly higher percentage of passenger revenue occurring in the peak.

Net Cost of Peak and Offpeak Transit Service

The net cost of peak and offpeak trips taken on transit systems nationwide can be calculated as the sum of annual operating and maintenance expenses (Table 1) plus annualized capital costs (Table 2) minus passenger revenues (Table 3). A summary of these calculations is presented in Table 4.

TABLE 1 NATIONAL OPERATING AND MAINTENANCE EXPENSES FOR PEAK AND OFFPEAK PERIODS BY TRANSIT MODE FOR 1983 (MILLIONS)

Mode	Peak	Off-Peak	Total
Bus	$ 2,337	$ 2,898	$ 5,235
Subway	1,258	984	2,242
Commuter Rail	907	271	1,178
Total	$ 4,502	$ 4,153	$ 8,655

SOURCE: 1983 Section 15 Report microcomputer diskette and calculations by Charles River Associates.

TABLE 2 NATIONAL CAPITAL EXPENSES FOR PEAK AND OFFPEAK PERIODS BY TRANSIT MODE FOR 1983

Mode	Percent of Capital Funds	Percent Allocated To Peak	Capital Expenses (millions) Peak	Off-Peak	Total
Bus	32.2%	80%	$ 718	$ 179	$ 897
Subway	54.2	85	1,284	227	1,511
Commuter Rail	13.6	85	322	57	379
	100.0%		$2,324	$ 463	$2,787

SOURCE: American Public Transit Association, *1988 Transit Fact Book*, Washington, D.C., 1988; Urban Mass Transportation Administration, *National Urban Mass Transportation Statistics, 1983, Section 15 Annual Report*, December, 1984; and calculations by Charles River Associates.

TABLE 3 NATIONAL RIDERSHIP AND PASSENGER REVENUE FOR PEAK AND OFFPEAK PERIODS BY TRANSIT MODE FOR 1983

	Linked Trips (millions)			Passenger-Miles (millions)			Passenger Revenue ($ millions)		
Mode	Peak	Offpeak	Total	Peak	Offpeak	Total	Peak	Offpeak	Total
Bus	1,587	1,871	3,458	10,093	10,822	20,915	951	1,121	2,072
Subway	925	520	1,445	11,267	5,606	16,873	712	400	1,112
Commuter rail	194	68	262	4,130	1,227	5,357	467	139	606
Total	2,706	2,459	5,165	25,490	17,655	43,145	2,130	1,660	3,790

Source: Tabulations from the 1983–1984 Nationwide Personal Transportation Study; *1985 Transit Fact Book*, American Public Transit Association, 1985; 1983 telephone survey of New York City transit riders, *Transit Pass Marketing Study*, Charles River Associates, Sept. 1983; and *Allocation of Federal Transit Operating Subsidies to Riders by Income Group*, Charles River Associates, Draft Final Report prepared for UMTA, March 1986.

As presented in Table 4, the peak period has the highest net costs for each of the three transit modes. On a per-trip basis, however, the net cost nationwide for a peak trip averaged over all three transit modes in 1983 was $1.74, compared to an estimate of $1.20 for an offpeak trip. On a relative basis, the largest difference in net costs between a peak trip and an offpeak trip occurs in the case of commuter rail. In this instance, the net cost per trip was $3.93 in the peak versus $2.78 in the offpeak.

When expressed on a per-passenger-mile basis, the differences in net costs between the peak and offpeak periods are not as large, although deficits for a peak trip are still greater than those in the offpeak. Again, this is truer for commuter rail than for either bus or subway systems.

CONCLUSIONS

Estimates of the net costs of trips taken on bus, subway, and commuter rail systems in the United States during peak and offpeak periods are provided. Net costs are defined to include capital costs as well as more traditional estimates of operating and maintenance expenses minus passenger revenues. A variety of allocation factors have been used in conjunction with actual transit expenditures to derive the estimates presented.

On the basis of the data and assumptions used, the net costs of transit trips taken in the peak are higher than for trips taken in the offpeak, although the differences are not as large when net costs are expressed on a per-passenger-mile basis. These results suggest that further consideration be given to the adoption of peak-period surcharges, or the use of distance-based fares, because average trip lengths are typically longer in the peak.

As indicated earlier, the numerical results may change if alternative assumptions on certain of the allocation factors are adopted. In addition, while useful on a nationwide analysis, site-specific conditions, or the use of a marginal cost analysis, may lead to different conclusions for any particular transit property.

TABLE 4 NET COSTS OF PEAK AND OFFPEAK TRANSIT TRIPS IN THE UNITED STATES BY TRANSIT MODE FOR 1983

	Bus			Subway			Commuter Rail			Total		
Item	Peak	Off-Peak	Total	Peak	Off-Peak	Total	Peak	Off-Peak	Total	Peak	Off-Peak	Total
Operating and												
Maintenance Cost (millions)	$2,337	$2,898	$5,235	$1,258	$984	$2,242	$907	$271	$1,178	$4,502	$4,153	$8,655
Capital Cost (millions)	718	179	897	1,284	277	1,511	322	57	379	2,324	463	2,787
Passenger Revenue (millions)	(951)	(1,121)	(2,072)	(712)	(400)	(1,112)	(467)	(139)	(606)	(2,130)	(1,660)	(3,790)
Net Costs:												
Total (millions)	$2,104	$1,956	$4,060	$1,830	$811	$2,641	$762	$189	$951	$4,696	$2,956	$7,652
Per Trip	$1.33	$1.05	$1.17	$1.98	$1.56	$1.83	$3.93	$2.78	$3.63	$1.74	$1.20	$1.48
Per Passenger Mile	$0.208	$0.181	$0.194	$0.162	$0.145	$0.157	$0.185	$0.154	$0.178	$0.184	$0.167	$0.177

SOURCE: Tables 1, 2, 3.

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