OPERATING COST MODELS FOR URBAN PUBLIC TRANSPORTATION SYSTEMS AND THEIR USE IN ANALYSIS

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Data concerning operating cost of bus and rail systems were collected from operating agencies and the American Transit Association. Operating cost models were prepared for individual rail rapid transit systems and bus systems. The use of these models in economic comparisons with highway and other transit alternatives is discussed and illustrated. Data deficiencies are discussed, and recommendations concerning accounting formats are made.

• AFTER FAILING to produce a compromise bill in 1972, Congress passed a bill in 1973 that permitted some diversion of Highway Trust Fund moneys to construction of mass transit facilities. At the same time the Environmental Protection Agency authorized the enforcement of strict antiautomobile regulation in major urban areas as a means for cities to meet federal clean-air standards by 1976.

Since 1956, when the Federal-Aid Highway Act of that year created the Highway Trust Fund and authorized the construction of the 41,000-mile Interstate System, the focal point of transportation planning in the United States has been the movement of people and goods via automobile. Even in urban communities of considerable density, the automobile has played an ever more important role in urban travel. Transit ridership declined from its peak of 23.2 billion in 1954 to 10.9 billion in 1956 and, by 1971, had fallen to 6.8 billion.

However, the increasing congestion in most major cities and the general realization that the automobile cannot efficiently meet the travel demands of dense urban corridors have sparked a renewal of interest in new transit facilities and the revitalization of existing properties. Thus, the early 1970s have seen the construction of the first new rapid transit systems in the United States for more than 2 decades in south Jersey (Lindenwold-Philadelphia), San Francisco (BART) and Washington, D.C. With these already operating or under construction, other new systems are planned for Baltimore and Atlanta, and extensions for New York. Many cities have taken new approaches to bus service with startling success: express bus services (N.Y.C.), bus rapid transit (Shirley Highway), and minibus service (Washington, D.C.). The federal government has fueled this interest by providing $10 billion in federal funds for up to two-thirds subsidy of capital expenses for new or improved transit facilities over a 12-year period ending in 1982. A 1973 act increased the subsidy limit to 80 percent. Other federal programs have provided money for demonstration projects involving new transit technology or novel applications of existing technology.

The transportation planner can no longer be merely a highway planner. However, whereas vast amounts of data documenting pertinent aspects of highway operation, construction, and maintenance exist, there is a distinct lack of such data for other transportation modes. This is especially true where economic data are concerned. Automobile operating costs have been well documented by the American Association of State Highway Officials (1) and others (2, 3). These sources provide the planner with the data and procedures for estimating all quantifiable aspects of highway cost and methodologies for comparing alternative highway plans on an economic basis. Similar data for public transportation are needed to enable the planner to evaluate alternative public transport plans and to compare transit and highway plans on an economic basis.

The major objective of this study, and the prime result of this report, is a series of unit cost models that make possible the estimation of costs for public transit systems for rail rapid transit and bus transit. The models deal primarily with operating cost, and other aspects are added as separate items.

DATA ACQUISITION

Two main sources of data were tapped for this study: the American Transit Association (ATA), to whom most operators send yearly budget figures (4), and the operators of the transit properties themselves.

For data concerning rail rapid transit facilities, the transit operators provided copies of their 1971 budget reports. Although such data were available from ATA in summary form, the breakdown and categorization of cost items appeared to be inconsistent from system to system and, in several cases, only partial data were available. Another complication was that many operators of rail rapid transit facilities also operate bus systems. In such cases, many cost items, e.g., administrative costs, are given only for the total system and are not allocated separately to the rail and bus systems. In most cases, it was also not possible to separate labor and nonlabor costs, an unfortunate situation that prohibited close examination of each of these items separately.

Along with the operating budgets of rail rapid transit systems, each operator was asked to provide certain system characteristics to permit the computation of unit costs. These data include the total number of revenue track-miles in the system, number of revenue route-miles, number of annual car-miles and car-hours of operation, number of stations, and so forth.

Data for bus systems were obtained directly from ATA summaries, which exist for several hundred public and private operations in various parts of the country. These summaries, unlike those for rail rapid transit systems, are relatively uniform in their breakdown of cost categories. This is due to two prime factors: Bus costs are not so complex nor do they involve so many categories as rail rapid transit; and the ATA summaries are in general similar to forms that interstate operators regularly file with the ICC, and the format is fairly standard for all companies.

A representative sample of data from 20 bus companies was selected for detailed analysis and unit cost treatment. At a later date, it is hoped that these data can be examined closely for all systems reporting to ATA. In this regard, all of the ATA data for years up to 1970 are on computer file at the Institute for Defense Analysis, which uses the data for other types of economic analyses than those presented here (5). It is hoped that these computer files may be used by others to further the type of research described here.

URBAN PUBLIC TRANSPORTATION COST ELEMENTS

In classical economic analysis of highway systems, several cost items must be considered to make up the total cost of the highway transportation network. The cost to build the highway is a capital expense, borne directly by the government (state, federal, municipal) and indirectly by road users and others through taxes. Highway maintenance is an annual cost item, also borne by governmental units and indirectly by taxpayers. The highway transportation cost, however, must also include those items borne directly by the road user: vehicle operating cost (gas, oil, tire wear, maintenance), vehicle depreciation, and travel time. These road user costs may be computed on an annual basis by using AASHO data tabulations (1) or those of Winfrey (3). The total cost of a highway transportation system is the sum of capital, maintenance, and road user costs. Of course, capital expenses must be "written off" or represented as an equivalent annual cost to conform to the same units as other items. This is done by applying the cost over the entire service life of the physical facility with consideration of interest. Mechanically the capital cost or capital investment is multiplied by an appropriate capital recovery factor, which depends on the service life of the facility in years and the market rate of interest.

For public transportation systems, the situation is slightly different in that the transit property owner directly bears capital costs, maintenance costs, and operating costs. The only costs borne directly by the user are travel time and fare. Of these, the fare is not considered inasmuch as it is used (together with various subsidies) to pay for operating and maintenance costs. To include it, then, would be a "double-counting" of certain costs. This is entirely analogous to Winfrey's strong argument for the exclusion of gasoline and other road user taxes from road user cost (these moneys are used by the government to build and maintain highways).

For public transportation systems, therefore, three cost elements must be considered: capital expenses (construction of trackbed, other physical plant, purchase of equipment), operating and maintenance expenses, and user costs (travel time).

Capital and Construction Costs

Capital and construction costs include the construction of rights-of-way, stations, maintenance facilities, and control systems and purchase of rolling stock for rail rapid transit systems. For bus systems, the purchase of buses and the construction of maintenance and terminal and station facilities constitute most capital cost. For rapid transit systems, the major cost elements involve the construction of physical facilities over which vehicles travel. For bus systems, which use public rights-of-way in practically all cases, the major cost element is the purchase of buses. In some cases, buses will operate on private rights-of-way providing a service called bus rapid transit. In such cases, the cost of the right-of-way and structure must, of course, be included.

The size and extent of physical facilities required by rail rapid transit cause the initial costs for such systems to be extremely high. For example, the BART system in San Francisco, which opened its first section for service in September 1972, will have cost $1.4 billion by its completion, and the completion cost for the 95-mile Washington, D.C., system is estimated at $3 billion. Costs for the provision of bus services are of a different order of magnitude, involving the purchase of vehicles ranging from $30,000 to $40,000.

Also to be considered is the fact that a rail rapid transit system may require a decade or more to construct, whereas bus services, particularly where there are existing bus companies, may be provided in a period of weeks with little or no disruption of surroundings during the preparation period.

The great advantage of the rail rapid transit system, and the one that will most often justify the large initial cost of such services, is capacity. A single train with a single motorman can carry more than 2,000 persons; a bus carries up to 80 persons with one driver. Rapid transit systems can carry over 60,000 persons per hour on a single track; bus routes rarely carry more than 10,000 persons per hour, which requires 125 buses per hour, quite a traffic problem in most areas.

Operating Expenses

Despite the high initial cost of rapid transit systems, the critical financial plight faced by rail and bus operators alike is operating costs. Because of the nature of the services, public transportation is extremely labor-intensive. Labor costs in the strongly unionized transportation industry have skyrocketed in recent years and, with them, the operating costs of transit services. In the case of rail rapid transit 80 percent to 90 percent of all operating expenses are directly attributable to labor as direct salaries and wages and various employee benefits.

It is unfortunate, but data and procedures for estimating transit operating costs are neither so plentiful nor so formalized as corresponding procedures for private vehicle operating costs. There is a degree of variability introduced because of the great importance of labor expenses to the total operating cost outlook. Labor expenses may vary widely from city to city, depending on area of the country, unions, and other unpredictable factors. This makes it difficult to generalize costs from system to system. The estimate of public transit operating costs often involves case-specific techniques and data.

Despite the difficulties involved, several general approaches to the estimation of transit operating costs exist. The two most popular methods are the unit cost method and the regression method. Both methods make use of the same basic predictive formula.

$$OC = A(VM) + B(VH) + C(PV) + D(RP)$$

where

OC = annual operating cost,
VM = annual vehicle-miles of operation,
VH = annual vehicle-hours of operation,
PV = number of vehicles in use during peak periods,
RP = annual (or daily) revenue passengers, and
A,B,C,D = constants of calibration.

The difference between the unit cost and regression methods is the way the constants of calibration are determined. In the regression method, standard multiple regression techniques are used with a set of existing cost data.

The unit cost technique is used here and has produced results that are in general as good as or better than the regression technique. Although less analytic, the unit cost approach is more rational and more closely matches actual operating characteristics. The method entails separation of operating costs into subcategories such as vehicle maintenance, track maintenance (rail only), fuel or power, and transportation expenses. A determination of which of these costs relates best to which parameter must then be made. Table 1 gives a breakdown of cost elements by their respective base parameters as recommended in a study conducted for the Washington Metropolitan Area Transit Authority (6).

The model is simply calibrated by using an existing set of data. Costs are stratified into those relating to vehicle-hours, vehicle-miles, peak-period vehicles, and revenue passengers. Dividing the totals by the number of vehicle-hours, vehicle-miles, or so on gives the desired constants of calibration.

The unit cost model has been applied with great success to specific transit companies. Calibrated with past data, the model has been used to predict future costs for service alterations for the company in question. No universally applicable calibration has been accomplished because of the wide variation in unit costs among various systems.

One essential requirement for calibration of a unit cost model is a set of data that can be categorized as shown in Table 1. Unfortunately, even with the variability in operating costs among different systems, there is more variability in the way these are reported. The accounting systems used by public transit operators vary widely, and a breakdown as indicated in Table 1 may not be possible. In such cases, judgment must be used to effect the best possible separation of costs according to their principal underlying variable. In some accounting systems, considerable detail is lacking, and two- or three-variable unit cost models may be necessary. Where this is so, the loss of variables will negatively affect the accuracy of the model's predictions.

User Costs

The third category of costs to consider in public transportation is user costs. The user of a public transportation facility experiences two direct costs: travel time and fare.

Travel time is handled the same as vehicular traffic; a unit cost per person-hour must be assumed. For vehicular analysis, AASHO (1) assumed a cost of \$0.86/person-hour or \$1.55/vehicle-hour. This value is quite conservative, and higher values could be justifiably used. Various studies have resulted in travel time values of \$1.40 to \$3.40 per person-hour. Whichever value is used must be used for all alternatives being compared. If a transit line is being compared to a highway system and the AASHO road user cost tables have been used without modification to estimate

Table 1. Allocation of transit cost elements for unit cost model.

Item	Vehicle-Hours	Vehicle-Miles	Peak-Hour Vehicles	Revenue Passengers
Equipment maintenance and garage expenses				
Supervision		X		
Maintenance of service equipment			X	
Maintenance of buildings and grounds			X	
Maintenance of revenue equipment		X		
Tires and tubes (buses only)		X		
Other		X		
Transportation expenses				
Supervision	X			
Operators' wages	X			
Fuel and oil or power		X		
Station expenses			X	
Other	X			
Traffic and advertising		X		
Insurance and safety				X
Administrative and general				
Officers' salaries			X	
Employee wages			X	
Legal expenses			X	
Welfare expenses	X			
Other			X	

Source: (6).

Table 2. Total operating costs (in dollars) for selected rapid transit systems, 1971.

Coat Category	NYCTA	TTC (Toronto)	MUCTC (Montreal)	SEPTA (Philadelphia)	CTA	CTS (Cleveland)	PATCO (Lindenwold)
Maintenance of way and structure	77,701,000	2,919,720	2,522,708	1,897,709	15,278,035	459,355	672,273
Maintenance of equipment	83,711,000	3,244,494	2,503,693	2,680,480	9,770,516	804,914	831,235
Power	49,632,000	2,134,227	3,435,689	2,110,509	5,816,565	557,939	595,934
Conducting transportation	141,458,600	3,515,213	3,869,086	7,562,681	31,134,198	1,473,567	1,455,469
Administration	9,008,075[a]	652,000[a]	1,651,423	431,355[a]	3,030,858[a]	378,377[a]	205,572
Miscellaneous	142,436,700[b]	868,511[b]	775,030	4,996,916[b]	2,252,455	1,011,686[b]	529,734
Total	503,947,375	13,339,165	14,757,629	19,679,630	67,282,627	4,685,838	4,287,255
Annual car-mile	359.8×10^6	22.74×10^6	18.37×10^6	13.39×10^6	51.48×10^6	4.27×10^6	2.92×10^6
Annual car-hour	19.51×10^6	1.194×10^6	1.102×10^6	—	—	0.134×10^6	0.122×10^6
Peak-hour vehicle	6,127	—	261	—	995	117	70
Annual rev. pass.	$1,258 \times 10^6$	98.49×10^6	65.86×10^6	50.34×10^6	105.6×10^6	15.29×10^6	8.66×10^6

[a]Estimated from totals for bus and rail. [b]Includes employee benefits.

Table 3. Unit costs for use in models of rail rapid transit costs.

System	Maintenance of Way[a]	Maintenance of Equipment[a]	Power[a]	Conducting Transportation[b]	Administration[c]	Miscellaneous[d]
NYCTA	0.216	0.232	0.138	7.250	1,470.23	0.113
CTA	0.297	0.190	0.113	—	3,046.09	0.021
SEPTA	0.142	0.200	0.158	—	—	0.099
CTS	0.107	0.189	0.131	10.998	3,233.90	0.066
PATCO	0.199	0.246	0.176	11.930	2,936.74	0.061
TTC	0.128	0.142	0.094	2.944	—	0.009
MUCTC	0.138	0.136	0.187	3.511	6,327.29	0.012
Avg U.S.	0.192	0.211	0.143	10.059	2,669.22	0.072
Avg Canada	0.133	0.139	0.140	3.228	6,327.29	0.011

[a]In dollars per car-mile. [b]In dollars per car-hour. [c]In dollars per peak-hour vehicle. [d]In dollars per revenue passenger.

highway costs, then the AASHO value of \$1.86/person-hour must be used to evaluate travel time for the transit system. If the Winfrey tables (3) are used to estimate highway costs and a travel time value of \$2.00/person-hour has been assumed, it must be used as well for the transit cost estimates.

There is much debate among economic analysts on the treatment of travel time. All agree that it most often is the single most heavily weighted factor in an economic comparison. The use of a flat rate for the travel time value is justifiably challenged. To equate the value of 100 persons saving 1 minute of travel time to 1 person saving 100 minutes is not reasonable, even though the total in both cases is 100 person-minutes. These issues, however, are not the subject of this paper.

OPERATING COST MODELS

Rail Rapid Transit

The principal difficulty faced in predicting transit operation costs is the wide variability in unit costs from system to system. This will be illustrated in the sections that follow. However, it will also be seen that capital costs for these systems also vary widely from place to place. This variability is particularly true of rail rapid transit. Construction costs are dependent on a wide variety of surface and subsurface conditions, particularly where tunneling is concerned. Equipment cost varies with the type of equipment purchased—air-conditioned or not air-conditioned, automated or not automated, sound-insulated or not, and so on. Operating costs, as discussed, vary with labor rates but also with age of equipment, condition of track bed, operating speed, and so forth.

It is not the purpose of this paper to treat construction or equipment costs in detail. Rapid transit construction costs range from \$10 to 20 million/mile for tunnels, \$2 to 5 million/mile for elevated structures, and \$1 to 2 million/mile for surface rights-of-way, exclusive of land purchase. Stations cost an additional \$2 to 3 million if underground and \$½ million if elevated or at grade. Detailed reports on construction costs, including tunneling (10), are available in the literature.

Rolling stock costs vary with the size of the car, the type of unit (single cars, married pairs, four-car units), performance criteria, and passenger amenities. The new New York City Transit Authority R-44 car costs approximate \$¼ million per car. Costs for other rapid transit cars are detailed in the literature (11-15).

ATA, to which most transit operators belong, publishes an annual summary of costs, revenues, and operating statistics for rail and bus systems. Although highly useful for bus systems, the ATA summaries on rail transit are of limited utility. For rail systems, data are missing for several whole systems and for certain cost categories in other systems. Further, the breakdown of cost elements appears to be inconsistent among systems in the ATA summaries. For this reason, data presented here were extracted from the annual budget summaries of the various transit operators directly.

This is a difficult analysis task. No two operators employ the same bookkeeping systems, nor are cost accounts readily comparable. Many large municipal systems that operate both bus and rail transit have overlapping and combined accounts, particularly for administrative aspects. One such system, the Massachusetts Bay Transportation Administration, kept only combined accounts, making it impossible to extract rail or bus unit costs for that system. Estimates had to be used to divide administrative costs into rail and bus for the Chicago Transit Authority (CTA).

Most operating budgets, however, make it possible to stratify data into six major categories:

1. Maintenance of way and structures—maintenance of stations, including labor and material costs;
2. Maintenance of equipment—maintenance of rolling stock, maintenance garages, fare collection equipment, and so forth;
3. Power—costs for purchase and generation of power;
4. Conducting transportation—motormen, conductors, station agents, traffic managers, dispatchers;

5. Administration—office and executive staffs, personnel, public relations; and
6. Miscellaneous—insurance and taxes.

Total operating costs for each of these categories, as well as other statistics of interest, are given in Table 2. The data in this table were extracted from operating budgets of seven U.S. and Canadian transit systems for the year 1971 (16-21).

To apply these data to an appropriate unit cost model requires that the various cost categories be assigned to the proper unit of determination. If Table 1 is used as a guide, the following assignment should be made:

Cost	Category
Maintenance of equipment, maintenance of way and structures, power	Vehicle-miles
Conducting transportation	Vehicle-hours
Administration	Peak-period vehicles
Miscellaneous	Revenue passenger

Some general comments can be made. Canadian and U.S. systems should not be directly compared. Price structures, particularly for labor, are drastically different in the two countries and preclude meaningful comparison. Where inconsistencies within categories are observed, these may generally be traced to characteristics of the rapid transit systems.

An examination of unit costs versus all possible units confirms the recommendations of Table 1, and the cost assignments recommended were used. Table 3 gives the data used in the formulation of unit cost models for rail rapid transit.

Unit cost models may now be developed for each system and for U.S. and Canadian averages. Where individual unit values are missing because of lack of data, the appropriate average will be used as a reasonable approximation. When these models are used for predictions of operation costs on new systems or proposed extensions to existing systems, care must be taken in the choice of models. If the characteristics of the proposed system are similar to one of the existing systems, the model for that system might be adopted. For example, a proposal for a new high-speed automated line might appropriately make use of the PATCO model for the Lindenwold line. If the characteristics of the proposed line are not well defined, average models should provide useful estimates within a reasonable range of error. Operating costs for extensions to existing systems should be estimated by using the model for the system in question. Unit cost models are given in Table 4.

The estimates that can be made by using these unit cost models are based on 1971 price levels. Such estimates should be adjusted to reflect inflation. Costs can be updated by using the national average inflation rate, which has been about 7 percent over the decade of the 1960s and early 1970s. For the approach, resultant cost estimates would be multiplied by 1.07^x, where x is the number of years between the time of the estimate and 1971.

Ideally, trend data for the various rapid transit operators should be investigated. Unfortunately, such data are not readily available. A previous work by Lang and Soberman (22), however, does contain data on unit rail costs for 1960. Four systems can be compared: New York, Cleveland, Chicago, and Philadelphia. Table 5 gives the comparison of unit costs on a per car-mile basis.

In 11 years, rail transit costs have more than doubled! This is due mainly to rising labor rates and particularly to a great rise in employee benefit costs. Approximately 85 to 95 percent of all operating costs are directly and indirectly labor-related. Based on the average total operating cost per car-mile, a compound inflation rate of 7 percent is indicated. Inasmuch as this agrees with national average inflation rates, a factor of 1.07^x might be used. This factor should be adjusted if government controls initiated in 1972 succeed in reducing the inflation rate. In general, the factor would be $(1 + i)^x$, where i is the average inflation rate over x years.

It should be noted that, for use in economy studies, inflation rates are ignored. However, capital costs for all alternatives must be based on price levels for the same year.

Table 4. Unit cost models for prediction of rail rapid transit operating costs.

System	Model
NYCTA	OC = (0.216 + 0.232 + 0.138)CM + 7.250CH + 1,470.23PC + 0.113RP = 0.586CM + 7.250CH + 1,470.230PC + 0.113RP
CTA	OC = (0.297 + 0.190 + 0.113)CM + 3,046.09PC + 0.021RP = 0.600CM + 10.059CH + 3,046.090PC + 0.021RP
SEPTA	OC = (0.142 + 0.200 + 0.58)CM + 10.059CH + 2,669.22PC + 0.099RP = 0.500CM + 10.059CH + 2,669.220PC + 0.099RP
CTS	OC = (0.107 + 0.189 + 0.131)CM + 10.998CH + 3,233.90PC + 0.066RP = 0.427CM + 10.998CH + 3,233.900PC + 0.66RP
PATCO	OC = (0.199 + 0.246 + 0.176)CM + 11.930CH + 2,936.74PC + 0.061RP = 0.621CM + 11.930CH + 2,936.740PC + 0.061RP
TTC	OC = (0.128 + 0.142 + 0.094)CM + 2.944CH + 6,327.29PC + 0.009RP = 0.364CM + 2.944CH + 6,327.290PC + 0.009RP
MUCTC	OC = (0.138 + 0.136 + 0.187)CM + 3.511CH + 6,327.29PC + 0.012RP = 0.461CM + 3.511CH + 6,327.29PC + 0.012RP
Avg U.S.	OC = (0.192 + 0.211 + 0.143)CM + 10.059CH + 2,669.22PC + 0.072RP = 0.546CM + 10.059CH + 2,669.220PC + 0.072RP
Avg Canada	OC = (0.133 + 0.139 + 0.140)CM + 3.228CH + 6,327.29PC + 0.011RP = 0.412CM + 3.228CH + 6,327.290PC + 0.011RP

Note: OC = annual operating costs, CM = annual car-miles, CH = annual car-hours, PC = no. of peak-period vehicles, and RP = annual revenue passenger.

Table 5. Unit rapid transit costs (in dollars per car-mile) for 1960 and 1971.

Category	Year	NYCTA	CTA	SEPTA	CTS	Average
Maintenance of way and structures	1960 1971	0.132 0.216	0.082 0.297	0.108 0.142	0.057 0.107	0.095 0.191
Maintenance of equipment	1960 1971	0.098 0.232	0.099 0.190	0.069 0.200	0.041 0.189	0.077 0.203
Power	1960 1971	0.113 0.138	0.098 0.113	0.091 0.158	0.044 0.131	0.087 0.135
Conducting transportation	1960 1971	0.265 0.393	0.298 0.605	0.309 0.565	0.251 0.345	0.281 0.477
Other	1960 1971	0.090 0.421	0.090 0.496	0.088 0.405	0.063 0.326	0.083 0.412
Total	1960 1971	0.698 1.401	0.667 1.307	0.665 1.469	0.456 1.097	0.622 1.319

Table 6. Unit operating costs for publicly owned bus systems, 1970.

City	Annual Bus-Miles	Annual Bus-Hours	Peak-Hour Buses	Annual Revenue Passengers	Maintenance (dollars per bus-mile)	Conducting Transportation (dollars per bus-hour)	Fuel (dollars per bus-mile)	Admin. (dollars per peak-hour bus)	Misc. (dollars per revenue passenger)	Total (dollars per bus-mile)
Chicago	89,326,082	10,006,568	2,224		0.228	6.387	0.034	10,607.47	—	1.277
New York	67,958,432	8,854,103	2,187	409,000,904	0.419	7.818	0.034	11,383.34	0.017	1.939
Los Angeles	57,478,555	4,438,067	1,325	142,059,393	0.157	6.283	0.029	4,485.50	0.057	0.915
Philadelphia	37,248,271		1,256	140,902,696	0.202	—	0.033			
Detroit	37,029,607	2,919,662	930	108,296,614	0.131	6.939	0.028	15,202.05	0.012	1.123
Cleveland	23,222,679		652		0.125	—	0.028		—	0.737
Atlanta	19,425,505	1,500,337	462	48,345,963	0.103	5.448	0.024	4,128.97	0.032	0.725
Kansas City	10,179,235	901,169	270	16,870,798	0.145	5.405	0.024	2,590.09	0.055	0.806
South Jersey	1,109,459	156,580	45	7,187,798	0.378	4.120	0.040	2,315.07	0.013	1.177
Wichita	1,417,458	134,069	52	2,063,270	0.081	3.200	0.027	1,507.41	0.078	0.525
Average					0.197	5.700	0.020	6,527.48	0.038	1.025

Table 7. Unit costs for privately owned bus systems, 1970.

City	Annual Bus-Miles	Annual Bus-Hours	Peak-Hour Buses	Annual Revenue Passengers	Maintenance (dollars per bus-mile)	Conducting Transportation (dollars per bus-hour)	Fuel (dollars per bus-mile)	Admin. (dollars per peak-hour bus)	Misc. (dollars per revenue passenger)	Total (dollars per bus-mile)
New Jersey (Newark area)	82,933,427	6,379,079	1,871	165,544,793	0.150	6.030	0.024	5,243.73	0.075	0.9065
Oakland-San Francisco	23,987,889	1,683,595	638	48,064,026	0.109	7.238	0.022	3,842.57	0.046	0.8329
Buffalo	13,347,376	1,228,522	420	46,469,696	0.219	5.261	0.028	3,823.07	0.049	1.020
New York	3,779,291		137	26,369,925	0.240	—	0.037	5,561.35	0.040	1.519
Jacksonville	5,314,077	501,616	131	12,398,820	0.126	3.361	0.027	2,831.47	0.044	0.644
Long Beach	5,041,010	418,471	98	11,180,240	0.080	4.243	0.017	4,794.10	0.034	0.568
Charlotte City	3,149,090	383,112	116	9,081,782	0.122	2.967	0.036	1,533.82	0.051	0.722
Hempstead	1,527,272		44	4,127,384	0.236	—	0.037	5,050.41	0.055	1.044
Twin Cities	2,186,613	178,960	68	4,442,892	0.115	3.513	0.024	1,331.26	0.034	0.587
Utica	1,222,397	112,655	43	3,539,382	0.192	4.667	0.028	2,373.72	0.033	0.829
Average					0.159	4.659	0.028	3,639.05	0.046	0.862

Local Buses

The bus is the "underrated star" of urban public transportation. Although much attention, including research, planning, and publicity, has been given to the development and operation of rail transit systems, the urban bus has been quietly carrying the overwhelming majority of public transit users. Corridor demands sufficient to justify the construction of rail rapid transit facilities exist in only a few of the nation's largest urban centers. Whereas rail systems exist in only six U.S. cities, bus services are provided in virtually every municipality of 50,000 population or more and in many smaller urban and suburban areas.

The provision of bus services is many times less expensive than comparable first costs for rail systems. This is understandable, considering that buses may make use of public rights-of-way, whereas rail services require the construction of extensive right-of-way facilities. Also, whereas each purchase of rapid transit rolling stock requires a special vehicle design and incurs the plant set-up costs to manufacture that design, a bus is a "shelf" item that can be ordered from a number of manufacturers, principally General Motors and Flxible.

Similar to the treatment of rail, costs of providing and operating a bus system are divided into the three major categories of capital costs, operating costs, and user costs.

Capital expenditures for bus systems are primarily limited to the purchase of equipment and the construction of garage and maintenance facilities. Occasionally, the construction of busways is undertaken to provide a special service called "bus rapid transit."

The price of a standard bus depends on the size of the vehicle and the options desired. General Motors, the major manufacturer of transit buses (89.3 percent of all buses in the N.Y.C. metropolitan region are GM manufactured), has a wide range of standard models. The largest of these, a 53-seat coach with an 8-cylinder diesel engine and air conditioning, costs from $40,000 to $45,000, depending on other options. The smallest, a 33-seat coach with a 6-cylinder diesel engine and air conditioning, costs approximately $30,000. Air conditioning is an option but is almost standard on buses manufactured since 1970. Air conditioning costs from $4,000 to $4,400 per bus. An antipollution system developed in 1971 may be added for less than $500 on a new bus, although it costs many times more to add the device to an older vehicle. The device substantially reduces overall pollutants emitted and virtually eliminates visible pollutants. (Prices quoted are for 1972.)

The service life of a bus ranges from 15 to 25 years depending on the quality of maintenance and intensity of use. It should be noted that careful servicing and maintenance of buses greatly increase useful service life. Bus engines (diesel) must be overhauled every 200,000 to 300,000 miles.

Operating costs for bus systems are generally divided into five major categories: maintenance, conducting transportation, fuel, administration, and miscellaneous. These costs are readily isolated from ATA annual statements (26). Unit costs may be assigned according to Table 1, which was specifically prepared for bus systems.

Maintenance expenses for buses include normal vehicle servicing and engine repairs plus major engine overhauls at intervals of several hundred thousand miles. Diesel engines entail lower maintenance costs than gasoline engines and go longer intervals between overhauls. Garage and maintenance facilities must also be maintained, but this represents only a small fragment of the total maintenance cost.

Expenses under conducting transportation include bus drivers, dispatchers, and operating supervisors. Costs in this category are almost 100 percent for labor and make up approximately 50 percent of total operating costs.

Fuel and oil consumption varies with a number of factors, including speed of operation, acceleration rate, number of stop and go cycles, loaded weight of vehicle, and size and type of engine. Fuel costs for diesel engines are lower than those for gasoline engines in buses of similar size. This is primarily due to the lower cost of diesel fuel, not to great differences in consumption rates, which are higher in diesel engines.

Administrative costs include all normal costs for system supervisors and supporting staffs, accounting, personnel, training, public relations, and other administrative departments.

Miscellaneous costs cover items such as insurance, operating taxes (for private operators), and advertising. Both administrative and miscellaneous costs vary widely depending on the extent of auxiliary services offered by the various systems and the efficiency of administrative operations.

Tables 6 and 7 give unit costs for public and privately owned bus services. Data are for 1970 and were extracted from the 1970 ATA operating report (26).

Most of the unit costs in Tables 6 and 7 show greater variability than would be desirable for the development of reliable unit cost models. In general, there is a tendency for smaller operators to have lower unit costs. Though this trend is not distinct enough to base a relationship on, a definite diseconomy of scale is indicated. It appears that privately owned services run more economically than publicly owned systems, but this appearance is partly because the private operations given in Table 7 are in general smaller than the public services in Table 6. Because of this, no strong conclusion may be reached on this point. Services in southern areas have lower costs because of lower labor wage rates in these areas.

To use the data in Tables 6 and 7 for the formulation of unit cost models and operating cost predictions requires careful judgment. Where no definitive information on characteristics of proposed bus services is available, average unit costs might be used to obtain gross cost estimates. However, where the service characteristics are better defined, unit costs for a particular operator of similar size in a similar area would undoubtedly produce more reliable predictions. Of course, where additional bus services are planned for an existing system, unit costs for that system should be investigated and used. Example unit cost models based on the average unit costs in Tables 6 and 7 are as follows: for public operations

$$\begin{aligned} OC &= (0.197 + 0.030)VM + 5.700VH + 6{,}527.48PV + 0.038RP \\ &= 0.227VM + 5.700VH + 6{,}527.48PV + 0.038RP \end{aligned}$$

and for private operations

$$\begin{aligned} OC &= (0.159 + 0.028)VM + 4.659VH + 3{,}639.05PV + 0.046RP \\ &= 0.187VM + 4.659VH + 3{,}639.05PV + 0.046RP \end{aligned}$$

where

- OC = annual operating costs,
- VM = annual vehicle-miles,
- VH = annual vehicle-hours,
- PV = number of vehicles in peak-hour service, and
- RP = annual revenue passengers.

These costs may be increased by 1.07^x to account for inflation. This, however, is not done for economy studies in which inflation is most often ignored, being constant among all alternatives.

As with rail rapid transit costs, the only user cost element included in economy studies is travel time. The unit travel time value used must be the same for all alternatives in comparative analysis.

USE OF OPERATING COST MODELS IN ECONOMIC ANALYSIS

For the purposes of discussion, it is assumed that the reader has a working knowledge of the basic methods and theory of engineering economy, particularly as it is applied to highways. The reader is referred to basic textbooks on the subject if background is needed (3, 27).

The concern here is not for the precise estimation of cost items for a given year, but for the use of these data in comparative analysis in the planning sense. Alternatives for transportation improvements should be compared from the economic standpoint as one input into the ultimate decision-making process. Although alternative highway plans have always been examined in this manner, the results of this research now make it possible to compare transit alternatives to each other in the same way and, more importantly, transit versus highway alternatives.

For the planner, three elements of cost take on importance and must be considered: capital costs, operating and maintenance costs, and direct user costs including travel time. To combine all three, they must be converted to similar bases. Either the annual cost method of analysis, in which all costs are converted to equivalent annual cost, or the present worth method, in which all costs are converted into a single sum representing a given number of years of service, may be used.

Because the bus data presented here are for 1970 and the rail data for 1971, bus costs should be multiplied by 1.07 when the two are compared to adjust them to the same base year. When transit costs are compared to automobile costs, the case is not so clear. Most highway cost analyses will be generated by using AASHO tables, which are for a base year of 1959. However, it would be improper to inflate these to a base year of 1971 (multiply by 1.07^{12}), inasmuch as improvements in automobile efficiency have greatly offset inflation. In fact, studies conducted by Claffey (2) and others show that automobile operating costs have decreased and are lower than those predicted by AASHO in many cases. Therefore, lacking any better basis for modifying AASHO data, they should be used directly without adjustment. Further, in using AASHO tables, an implicit travel time value of $0.86/person-hour is assumed, and this must then be used to evaluate transit alternates as well. Because this value is considered low by most transportation economists, the AASHO travel time component may be omitted and another value used for both highway and transit alternates.

FUTURE RESEARCH AND DATA NEEDS

Because of certain data deficiencies, this project was able to produce specific cost models for specific transit systems. A generalization of these would be most useful but can be obtained only if systematic relationships between unit cost coefficients and underlying transit system characteristics can be isolated. All attempts at such investigations produced little of interest. However, a great deal of the problem relates to the lack of uniformity in data from different systems and the lack of data describing characteristics of great interest, e.g., train speed and average station spacing for rail systems.

As a result of the investigations reported on, recommendations concerning uniform formatting of data for rail and bus systems are made. It is intended that attempts be made to obtain data from the sources participating in this study in this format, so that further investigation into general cost models may be made.

From the research point of view, the need for uniform reporting of data is great. It is recognized, however, that situations existing in each transit system may be quite unique and that budgeting formats are suited to the convenience of the operator. It is hoped that the operators who cooperated with this effort will find the results useful to them and that they will make an effort to supply the information needed to generalize the results obtained herein.

A brief outline of the desired format for budget data follows this discussion (Appendix). Note that, within each budget category, there is a breakdown of costs into nonlabor, direct labor (salaries and wages), and indirect labor (benefits: pension, vacation, workmen's compensation, medical plans). This is viewed as a critical point in that each component of cost may depend on variables not common to all components. Also, cost items to be included in each account are defined in some detail so as to avoid confusion. It is hoped that the detail of these definitions will result in the acquisition of a more uniform data base.

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APPENDIX

SUGGESTED DATA FORMAT FOR RAPID TRANSIT SYSTEMS

The following system characteristics should be obtained for use as independent variables in cost analysis. They should all be for a particular year of operation.

1. Annual car-miles;
2. Annual train-miles (1 train traveling 1 mile is 1 train-mile regardless of train length;
3. Annual car-hours;
4. Annual train-hours (1 train traveling for 1 hour is 1 train-hour, regardless of train length);
5. Miles of revenue track in system;
6. Total route-miles in system;
7. Total number of stations in system;
8. Total number of cars owned;
9. Maximum speed of operation in system;
10. Average station spacing;
11. Number of cars owned of the following ages: <5, 5 to 10, 10 to 15, 15 to 20, 20 to 25, 25 to 30, 30 to 35, 35 to 40, 40 to 45, 45 to 50, and >50 years; and
12. Annual revenue passengers.

The tabular arrangement shown in Figure 1 is recommended for reporting of annual costs categorized as shown.

Maintenance of way and structures includes all equipment, labor, and labor benefit costs associated with the maintenance of trackage, switches, power supply, signals, ventilation, and all station facilities.

Maintenance of equipment includes all parts, equipment, labor, and labor benefit costs involved in maintaining revenue rolling stock, maintenance equipment, and the upkeep and operating cost of maintenance facilities (shops, cleaning facilities, yard and garage facilities, etc.).

Power includes all costs, including labor and labor benefits, incurred in the purchase and/or generation of power.

Conducting transportation includes the cost of train crews (motormen and conductors), station attendants, guards, porters, traffic managers, switchmen, towermen, and the like.

Administrative expenses include the operating costs of system executives and their supporting staffs, bookkeeping and accounting costs, personnel services, public relations departments, consumer information services, lost and found, and purchase and stores departments.

Miscellaneous expenses include insurance against public liability, taxes, and other miscellaneous items not covered under other categories.

In addition, information concerning labor aspects as shown in Figure 2 should be obtained.

SUGGESTED DATA FORMAT FOR BUS TRANSIT SYSTEMS

The following system characterics should be obtained:

1. Total number of routes operated;
2. Total number of route-miles operated;
3. Annual bus-miles operated;
4. Annual bus-hours operated;
5. Total number of bus stops in system;
6. Average speed of buses in service;
7. Average bus stop spacing;
8. Number of buses owned of the following ages: <5, 5 to 10, 10 to 15, 15 to 20, 20 to 25, 25 to 30, 30 to 35, and >35 years and how many are gasoline-powered and diesel-powered;

Figure 1. Annual cost categorization for rapid transit systems.

Category of Expense	Type of Expense		
	Nonlabor	Direct Labor	Indirect Labor
Maintenance of Way and Structures Track and Switches Power and Signals Stations			
Maintenance of Equipment Rolling Stock Plant and Other Equipment			
Power Purchase or Generation			
Conducting Transportation			
Administrative Expenses			
Miscellaneous Expenses			

Figure 2. Labor data for rapid transit systems.

Labor Category	No. of Employees	Average Hourly Wage	Average Hourly Benefits
Motormen			
Conductors			
Station Attendants (includes ticket or token agents)			
Station Porters			
Switchmen/Signalmen			
Traffic Managers			
Operating Supervisors			
Track Maintainers			
Car Maintainers			
Maintenance Supervisors			
Yardmen			
Guards/Police			
Administrative Secretaries/Clerks			
Executives			
Other Administrative Personnel			

Figure 3. Breakdown of operating expenses for bus transit systems.

Category of Expense	Type of Expense		
	Nonlabor	Direct Labor	Indirect Labor
Maintenance			
Fuel			
Conducting Transportation			
Administrative Expenses			
Miscellaneous Expenses			

9. Annual revenue passengers; and
10. Mileage of express bus routes operated.

Operating expenses should be broken down as shown in Figure 3. Maintenance includes the cost of servicing, cleaning, overhauling, and repairing buses, garage expenses, direct labor involved in such maintenance, and the corresponding labor benefits.

Fuel includes the cost of purchasing deisel or gasoline to power buses and all labor costs involved in operating filling stations.

Conducting transportation includes the cost of all drivers, traffic and schedule supervisors, dispatchers, and the like.

Administrative expenses include the total cost of executive offices and support personnel, bookkeeping and accounting, and personnel and public relations services.

Miscellaneous expenses include public liability insurance, taxes, terminal expenses (if any), advertising, and other costs not included elsewhere.

A labor data summary, shown in Figure 4, should be obtained.

Figure 4. Labor data summary for bus transit systems.

Labor Category	No. of Employees	Average Hourly Wage	Average Hourly Benefits
Drivers			
Dispatchers/Traffic Managers			
Maintenance Personnel			
Maintenance Supervisors			
Administrative Secretaries/Clerks			
Executives			
Other Administrative and Office Employees			