Table 1. Status of California programs.

Funding Statute	Projects Funded			Projects Evaluated	
	Funded	Completed	Dropped	2/20/81	7/1/81
Section 5	33	22	3	18	27
Section 6	17	16	0	13	16
Section 9	11	7	1	3	3
Total	61	45	4	34	46

program was in trying to implement it without funding being provided for its administration. It took more than a year to correct this oversight, and that meant that the implementation moved very slowly since the resources that could be diverted to this new activity for almost one-half the legislatively established life were severely limited. This problem was compounded by the requirements of the other sections of the legislation, as the relatively small number of staff available and competent to carry out the combined responsibilities, even with funding available, was limited.

This very real problem is largely ignored in the paper, although it does address the lack of resources constraints from a different view. In my opinion, to ensure a reasonable chance of success, planners of such programs, and especially those responsible for legislation, need to be cognizant of the abilities of the responsible organizations to carry out the program. If that is in doubt, provisions for alternatives (i.e., contracting the work) need to be in the legislation.

Authors' Closure

Information provided by George Gray contributes to our thesis that professionals must assist legislators in thinking through the entire discretionary grant process before the legislation is passed. Legislation usually results from a crisis situation. Insufficient consideration is given to either program objectives or the staff required to disburse funds and monitor results. Our purpose was not to single out California and Minnesota, but to use examples to help other state agencies improve discretionary grant programs. Adequate staffing is essential and George Gray has helped by emphasizing an element that we had overlooked.

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Use of Productivity Measures in Projecting Bus and Rail Transit Operating Expenditures

JAMES M. HOLEC, JR., AND ROBERT L. PESKIN

This paper presents a model for projecting bus and rail operating costs that incorporates measures of productivity and performance typically used in the transit industry. The model was based on the recent experience of large, North American bus and modern rail transit operations as well as on data from vehicle manufacturers. A set of equations is presented that describes costs in specific aspects of operations and maintenance functions as a function of the quantity of service provided (e.g., vehicle miles and platform hours). Examples of the application of the model for the Houston Transitway Alternatives Analysis are presented. Areas for further model development and research are discussed briefly.

This paper presents a model for projecting bus and rail transit operating costs that incorporates measures of productivity and performance typically used in the transit industry. The model was based on the recent experience of large North American bus and modern rail transit operators as well as on data from vehicle manufacturers. This model, intended for use in the evaluation of regional transportation plans, was applied in the Houston Transitway Alternatives Analysis (HTAA). The project was performed by a team of consultants for the Metropolitan Transit Authority (MTA) of Harris County, Texas. Although some aspects of the model are specific to Houston, many aspects are applicable to the evaluation of alternative transit plans in other urban areas.

The remainder of this paper discusses the general approach and the structure of the model. The reasoning behind the selection of various model coefficient values is discussed in detail, particularly in those areas where the current Houston bus operating experience is deficient. The paper concludes with a brief discussion of the application of the model in the HTAA and the applicability of the overall approach for other planning and financial analysis studies for other transit properties.

APPROACH

Transportation planners have long struggled with the problem of estimating future operating expenditures for transit systems that are undergoing alternatives analysis. Typically, two general approaches have been used: engineered costs and historical unit costs. Engineered costs are estimates based on a complete inventory of staffing and material requirements for specific activities (i.e., estimates that relate the cost of vehicle operations to its component costs). Historical costs deal with aggregate costs. They are estimates that relate the cost of vehicle operations to unit costs for similar vehicles and operating conditions in the past.

The advantage of disaggregating the costs, as in engineered costs, is that components are identified and causes of change in cost might be easily discerned. An engineered cost approach also enables the analyst to take into account unique characteristics of the activity that is being examined and to identify the effects of changes in items such as labor contracts or material arrangements.

The advantage of aggregate costs, as in historical costs, is that no component, however minute, would be overlooked. Historical costs take into account items that may be overlooked when the engineered cost approach is used, such as slack time, overhead, and waste.

The distinctive advantages of both of these methods were obtained in preparing estimates of bus and rail operating expenditures for HTAA. The HTAA operating cost estimating approach is based on historical unit costs decomposed to reflect productivity measures and specific-resource cost components. It therefore approaches the advantages of engineered costs; that is, it makes changes in cost more transparent and permits the analyst to more explicitly take into account unique characteristics in the operating systems considered in the alternatives analysis process. At the same time, it avoids the shortcomings of the engineered cost approach, by reflecting the uncertainty of operations and maintenance activity because the experiences of actual operating systems are used.

The basis for this cost estimating approach is derived from recent work (1-3) in the area of transit performance evaluation. Outside the context of the alternatives analysis process, it offers transit management an easily adaptable technique for service planning and, with refinement, could be extended for use by smalland medium-sized systems as a budgeting aid.

GENERAL STRUCTURE OF MODEL

The model is comprised of a set of equations intended to compute all costs specifically attributable to various important aspects of bus or rail operation. They are, therefore, both mutually exclusive and complete. Costs are expressed in terms of values that describe, in general, the quantity of service provided, computed in the course of the planning process (e.g., annual vehicle miles). Four types of equations are presented:

1. Formulations of labor cost for major cost components,
2. Formulations of materials and supplies costs for major cost components,
3. Formulations of combined labor plus materials and supplies costs for minor cost components, and
4. Formulations of general and administrative costs.

The labor cost formulations are of the form:

$$\begin{aligned}\text{Labor cost} = {} & \text{unit of service} \times \text{labor productivity factor} \\ & \times \text{cost per unit of labor} \times \text{staff burden} \\ & \times \text{fringe multiplier} \times \text{direct expenses multiplier} \qquad (1)\end{aligned}$$

The subcomponent terms used in this form are defined as follows:

1. Unit of service = number of vehicle miles, vehicle (or train) hours, station hours, or number of vehicles based on the estimate used in defining the alternative. The cost models are intended to model costs per unit of service provided rather than per unit of service used (e.g., per passenger or per passenger mile) because most costs are incurred by supplying the service rather than by how many passengers use it.
2. Labor productivity factor = number of nonsupervisory personnel or personnel hours required to adequately staff each unit of service provided. This factor implicitly considers the impacts of worker efficiency, need for training, and scheduled and unscheduled absenteeism.
3. Cost per unit = wage per hour (or per year) for the nonsupervisory employees who provide the basic service. This is usually the wage for vehicle operators and mechanics and includes average wages (straight wages plus overtime, vacation, and sick pay). It does not include expenses for fringe benefits (such as pension funds, social security, or insurance).
4. Staff burden = ratio by which operator or mechanic wages are multiplied to compute total wages and salaries for total staff including supervisors and administrative and support staff.
5. Fringe multiplier = ratio by which total wages and salaries are multiplied to account for fringe benefits.
6. Direct cost multiplier = ratio by which wages, salaries, and fringe benefits are multiplied to account for direct expenses for office supplies and related items.

OPERATING COST COMPONENTS

The computations of operating cost for bus and rail transit are specified in such a way that data obtained from various sources could be used to evaluate the coefficients and specific values for Houston (such as wages and fringe benefits) may be included. The data sources include the following:

1. Transit property annual reports;
2. Transit property budgets;
3. Reports that fulfill requirements of Section 15 of the Urban Mass Transportation Act of 1964, as amended;
4. Other correspondence and reports supplied by transit properties contacted; and
5. Data supplied by transit vehicle manufacturers.

The data used to create the operating cost models are based on the experience of North American transit operators that are representative of the type of operation anticipated in Houston. Bus operating data came primarily from the operators of large bus fleets:

1. Washington Metropolitan Area Transit Authority (WMATA),
2. Southern California Rapid Transit District (SCRTD),
3. Alameda-Contra Costa Transit (AC Transit),
4. Southeastern Pennsylvania Transit Authority (SEPTA),
5. Chicago Transit Authority (CTA),
6. Greater Cleveland Regional Transit Authority,
7. Metropolitan Atlanta Rapid Transit Authority (MARTA),
8. Milwaukee County Transit System,
9. Southeastern Michigan Transit Authority (SEMTA),
10. Baltimore Mass Transit Administration (MTA), and
11. Seattle Metro.

Rail transit operating cost components are based on the operating experience of the following newer rail systems:

1. WMATA,
2. Bay Area Rapid Transit District (BART),
3. Port Authority Transit Corporation (PATCO-Lindenwold Line),
4. Toronto Transit Commission, and
5. Edmonton Transit.

The rail operating experience of older systems, such as CTA, SEPTA, Port Authority Trans Hudson Corporation (PATH), New York City Transit Authority (NYCTA), and Massachusetts Bay Transit Authority (MBTA) are not considered to be representative of the newer technology to be employed in Houston. The limited operating experience of MARTA is considered to be insufficient and possibly misleading.

Much of the operating cost model structure and values of the components are based on the experience of WMATA because WMATA was able to supply detailed budget data on manpower and materials and supplies expenses; further, WMATA provides the type of guideway plus feeder bus service similar to most of the guideway alternatives under consideration in Houston.

Bus Operating Costs Components

Details of the major cost components computed for the bus systems in each of the alternatives are presented in Figure 1. Notice that the first term in each formulation is the unit of service provided, as defined in the planning process. This is multiplied by other factors of productivity and cost. The coefficient values for each of these factors is presented directly below each factor. The coefficients represent, in general, the cost for operating a mixed fleet of new-look buses of various ages and advance design buses. Specific values for articulated buses are also noted in Figure 1. Bus operating cost components include the following:

1. Bus operating labor--Wages, salaries, and fringe benefits for bus operators, bus supervisors, and support staff and related direct expenses;
2. Terminal operating labor--Wages, salaries, and fringe benefits for information kiosk agents at large activity center bus terminals, supervisors, and support staff and related direct expenses (we assumed that one agent will staff each large terminal kiosk);
3. Vehicle maintenance labor--Wages, salaries, and fringe benefits for vehicle mechanics, supervisors, and support personnel;
4. Vehicle maintenance materials and supplies--Direct costs for parts, tires and tubes, lubricants, garage maintenance, and related expenses;
5. Right-of-way (ROW) maintenance labor and materials and supplies--Wages, salaries, and fringe benefits of maintenance personnel and direct expenses for roadway, structure, and lighting repair, and maintenance on the exclusive busways;
6. Station maintenance labor and materials and supplies--Wages, salaries, and fringe benefits for maintenance personnel and direct expenses for building repair, cleaning, and utilities or large activity center terminals and suburban guideway stations;
7. Parking lot maintenance labor and materials and supplies--Wages, salaries, and fringe benefits for maintenance personnel and direct expenses for surface lots at suburban transitway stations (we assumed that no fee is charged for the use of parking lots; therefore, no costs for parking meters or cashiers are included);
8. Fuel--Cost for diesel fuel consumed by vehicles;
9. Claims--Cost for workers' compensation and third-party casualty and liability claims and the costs to administer those claims; and
10. General and administrative--A percentage of the sum of the above costs to cover costs that cannot be allocated to any other cost components directly.

Rail Operating Cost Components

The major cost components computed for the rail rapid transit and light rail transit systems are described in detail in Figures 2 and 3. The coefficients represent operating costs for the new, highly automated heavy and light rail transit systems that are currently planned or operating in San Francisco, Washington, Atlanta, Miami, Toronto, Edmonton, Baltimore, and Lindenwold (Philadelphia). Rail operating cost components include the following:

1. Rail operating labor--Wages, salaries, and fringe benefits for train operators (revenue service and yards and interlockings), supervisors, and support staff (we assumed that only one operator per train is required, i.e., no conductor or ticket collector);
2. Station operating labor--Wages, salaries, and fringe benefits for station agents, supervisors, and support staff and related direct costs (we assumed that each station mezzanine will have a full-time agent);
3. Vehicle maintenance labor--Wages, salaries, and fringe benefits for vehicle mechanics, helpers and cleaners, supervisors, and support staff for vehicle inspection repair and maintenance;
4. ROW systems maintenance labor--Wages, salaries, and fringe benefits for mechanics, helpers, supervisors, and support staff for maintenance to track and structure and rail systems [automatic train control (ATC), power, communications, and computer];
5. Station maintenance labor--Wages, salaries, and fringe benefits for mechanics, janitors, supervisors, and support staff for station cleaning, repair, and maintenance;
6. Vehicle maintenance materials and supplies--Direct costs for lubricants, contract maintenance, and maintenance and repair parts;
7. ROW and systems maintenance materials and supplies--Direct costs for track and structure, ATC, communications, power, and computer repair and maintenance;
8. Station maintenance materials and supplies--Direct costs for station cleaning materials, escalator and elevator maintenance, and lighting and ventilation parts;
9. Parking lot maintenance labor and materials supplies--Same as for bus;
10. Propulsion energy--Electrical power consumed by rail vehicles including traction motors, lighting, and air conditioning;
11. Station energy--Electrical power consumed by stations for lighting, air conditioning, escalators, and other uses;
12. Claims--Same as for bus;
13. Revenue collection labor and materials and supplies--Wages, salaries, and fringe benefits for revenue collection teams and accompanying security teams and for supervisors, support staff, and related direct costs; labor and direct costs for farecards and maintenance of automatic fare collection equipment are also included [revenue collection costs for bus operations are included in bus maintenance (farebox pullers) and bus general and administrative (counting)];
14. Security labor and materials and supplies--Wages, salaries, and fringe benefits for station and train surveillance by officers and for supervisors, support staff, and related direct

Figure 1. Bus operating cost model factors (coefficient values are in 1979 dollars).

Vehicle Operating Labor	Platform Hours	x Payroll Hours / Platform Hour	x Operator Wage / Payroll Hour	x Staff Burden	x Fringe Multiplier	x Direct Expenses Multiplier	
		From: 1.33 in 1980 (MTA) To: 1.36 in 1984 (WMATA)	$7.15 MTA Add $0.50 for articulated buses	From: 1.17 (MTA) in 1980 To: 1.07 (WMATA) in 1988	1.20 in 1980 From: 1.24 in 1981 To: 1.30 in 1987	1.005 WMATA	
Terminal Operating Labor	Busway Terminals	x Total Agent-Years / Terminal	x Agent Wage / Person-Year	x Staff Burden	x Fringe Multiplier	x Direct Expenses Multiplier	
		4.76 (WMATA experience @ 20 hr/day)	$14,861 MTA (=bus operators)	1.062 WMATA	1.20 in 1980 From: 1.24 in 1981 To: 1.30 in 1987	1.003 WMATA	
Vehicle Maintenance Labor	Total Vehicle Miles	x Mechanic-Years / Million Veh-miles	x Mechanic Wage / Person-Year	x Staff Burden	x Fringe Multiplier		
		Nominal From: 20.6 in 1980, 1981 To: 12.4 in 1988 (Indust. Avg) High From: 20.6 in 1980, 1981 To: 16.8 in 1988 (CTA)	$17,360 in 1980 (MTA) $17,860 in 1981, 1982 $18,860 in 1983, 1984 $19,860 in 1985, 1986 $20,818 in 1987 (WMATA)	From: 1.41 in 1980, 1981 (MTA) To: 1.07 in 1988 (WMATA)	1.20 in 1980 From: 1.24 in 1981 To: 1.30 in 1987		
Vehicle Maintenance Materials & Supplies	Total Vehicle Miles	x $ / Vehicle-Mile					
		From: $0.260 (MTA) in 1980 To: Nominal = Standard = 0.095-Indust. Avg.........Articulated = 0.124 (Standard x 1.3)...in 1988 High = Standard = 0.120-WMATA.................Articulated = 0.155 (Standard x 1.3)...in 1988					
ROW Maintenance Labor and Materials & Supplies	Route Miles	x $ / Route-Mile					
		$8,000 TSDMPT Estimate					
Terminal Maintenance Labor and Materials & Supplies	Busway Terminals	x $ / Terminal					
		Nominal = $21,223 High = $24,464 (Assumes 1 mechanic plus 21% materials & suppplies cost)					
Suburban Station Maintenance Labor and Materials & Supplies	Suburban Stations	x $ / Station					
		Nominal = $10,611 High = $12,232 (Assumes 0.5 mechanic plus 21% materials & supplies cost)					
Parking Lot Maintenance Labor and Materials & Supplies	Parking Spaces	x $ / Space					
		Nominal = $89 (Avg. Miami and Montgomery Co., MD) High = $102-Montgomery Co., MD.					
Fuel	Total Vehicle Miles	x Gallons / Vehicle-mile					x $ / gallon
		Standard Articulated	Surface 0.25 (Avg) 0.36 (CTA)	Guideway 0.125 (CUTS Manual @ 40 mph) 0.137 (Standard plus 10%)			$.76 MTA
Workers Compensation Claims	Total Vehicle Miles	x #Claims Paid / Million Veh-mi	x Avg Award / Claim Paid	x Avg Labor & Exp / Claim Paid			
		Surface: Nominal = 34-MTA High = 37-WMATA Guideway: Nominal = 8 High = 10 (Assumes guideway accident rate = arterial/freeway rate = 1/4 surface rate - CUTS Manual)	$1,001 MTA	$124 MTA			
Third Party Casualty and Liability Claims	Revenue Vehicle Miles	x #Claims Paid / Million Rev-mi	x Avg Award / Claim Paid	x Avg Labor & Exp / Claim Paid			
		Surface = 61-WMATA Guideway = 15 (Assumes guideway accident rate = arterial/freeway rate = 1/4 surface rate - CUTS Manual)	Nominal = $673 (Avg of MTA and WMATA) High = $977-WMATA	$124 MTA			
Security Labor and Materials and Supplies	Suburban Stations, Park-n-Ride Lots, Mall Terminals	x Officers / Station	Shifts Required	Officer Wage / Person-Year	Staff Burden	Fringe Multiplier	Direct Expense Multiplier
		0.333 WMATA	5.2 WMATA: 24-hr. coverage plus absentees - Rail System	$10,459 WMATA	1.506 WMATA	1.20 in 1980 From: 1.24 in 1981 To: 1.30 in 1987	1.03 WMATA
General and Administrative	Total of Above	x G&A Multiplier					
		From: 0.328 (MTA) in 1980 To: 0.152 (WMATA) in 1988					

Figure 2. Rail rapid transit cost model factors (coefficient values are in 1979 dollars).

Vehicle Operating Labor	Platform Hours	× Payroll Hours / Platform Hour	× Operator Wage / Payroll Hour	× Staff Burden	× Fringe Multiplier	× Direct Expenses Multiplier	
		1.33 WMATA	$7.15 MTA	2.49 WMATA	1.20 in 1980 From: 1.24 in 1981 To: 1.30 in 1987	1.009 WMATA	
Station Operating Labor	Mezzanines	× Total Agent-Years / Mezzanine	× Agent Wage / Person-Year	× Staff Burden	× Fringe Multiplier	× Direct Expenses Multiplier	
		4.76 (WMATA experience with 20 hr/day)	$14,861 MTA (=bus operator)	1.062 WMATA	1.20 in 1980 From: 1.24 in 1981 To: 1.30 in 1987	1.003 WMATA	
Vehicle Maintenance Labor - Inspection	Active Vehicles (Including Spares)	× Mechanics / Vehicle	× Mechanic Wage / Person-Year	× Staff Burden	× Fringe Multiplier		
		0.627 WMATA	$18,323 WMATA	1.128 WMATA	1.20 in 1980 From: 1.24 in 1981 To: 1.30 in 1987		
Vehicle Maintenance Labor - Repair & Maintenance	Total Vehicle Miles	× Mechanics / Million Veh-mi	× Mechanic Wage / Person-Year	× Staff Burden	× Fringe Multiplier		
		6.65 WMATA	$18,323 WMATA	1.128 MATA	1.20 in 1980 From: 1.24 in 1981 To: 1.30 in 1987		
ROW and Systems Maintenance Labor	Single Track Miles	× Mechanic / Track-mile	× Mechanic Wage / Person-Year	× Staff Burden	× Fringe Multiplier		
		5.164 WMATA	$17,510 WMATA	1.251 WMATA	1.20 in 1980 From: 1.24 in 1981 To: 1.30 in 1987		
Station Maintenance Labor	Mezzanines	× Non-Superv. Pers / Mezzanines	× Avg Wage / Person-Year	× Staff Burden	× Fringe Multiplier		
		2.71 WMATA	$13,751 WMATA	1.191 WMATA	1.20 in 1980 From: 1.24 in 1981 To: 1.30 in 1987		
Vehicle Maintenance Materials & Supplies	Total Vehicle Miles	× $ / Vehicle-mile					
		Nominal = $0.163 (Avg BART and WMATA) High = $0.220-WMATA					
ROW and Systems Maintenance Materials & Supplies	Single Track Miles	× $ / Track-mile					
		Nominal = $22,290 (Avg BART and WMATA) High = $31,098-WMATA					
Station Maintenance Materials & Supplies	Stations	× $ / Station					
		$64,269 WMATA					
Parking Lot Maintenance Labor and Materials & Supplies	Parking Spaces	× $ / Space					
		Nominal = $89 (Avg of Miami and Montgomery Co. MD) High = $102-Montgomery Co., MD					
Revenue Collection Team Labor	Stations	× Collection Pers / Station	× Avg Wage / Person-Year	× Staff Burden	× Fringe Multiplier	×	
		0.8 WMATA	$14,861 MTA (=bus operators)	1.122 WMATA	1.20 in 1980 From: 1.24 in 1981 To: 1.30 in 1987		
AFC Maintenance Labor and Materials & Supplies	Mezzanine	× Mechanics / Mezzanine	× Mechanic Wage / Person-Year	× Staff Burden	× Fringe Multiplier	× Direct Expenses Multiplier	×
		0.68 WMATA	$18,240 WMATA	1.226 WMATA	1.20 in 1980 From: 1.24 in 1981 To: 1.30 in 1987	1.9 WMATA	
Revenue Protection Labor	Stations	× Police Officers / Station	× Officer Wage / Person-Year	× Staff Burden	× Fringe Multiplier	× Direct Expenses Multiplier	×
		1.37 WMATA	$10,459 WMATA	1.244 WMATA	1.20 in 1980 From: 1.24 in 1981 To: 1.30 in 1987	1.03 WMATA	
Security Labor	Stations	× Police Officers / Station	× Shifts Required	× Office Wage / Person Year	× Staff Burden	× Fringe Multiplier	× Direct Expenses Multiplier
		0.333 WMATA	5.2 WMATA: 24-Hour Coverage and absentees	$10,459 WMATA	1.506 WMATA	1.20 in 1980 From: 1.24 in 1981 To: 1.30 in 1987	1.03 WMATA
General and Administrative	Total of above costs	× G&A Multiplier					
		0.170					

Propulsion Energy	Total Vehicle Miles	× Kilowatt-Hours / Vehicle-mile	× $ / Kilowatt-Hour	
		Low = 8.29-BART High = 9.8-WMATA	$0.031 HL&P	
Station Energy-Subway	Subway Stations	× Operating Hours / Year	× Kilowatt-Hours / Station-Hour	× $ / Kilowatt Hour
		7300 20 hrs/day 365 days/year	614 WMATA experience plus DMJM A/C estimate	$0.031 HL&P
Station Energy-At grade & Elevated	Surface Stations	× Operating Hours / Year	× Kilowatt Hours / Station-Hour	× $ / Kilowatt-Hour
		7300 20 hrs/day 365 days/year	66 WMATA (Fall '79 Avg)	$0.031 HL&P
Workers Compensations Claims	Total Vehicle Miles	× #Claims Paid / Million Veh-mi	× Avg Award / Claim Paid	+ Avg Labor & Exp / Claim Paid
		37 WMATA	$1,001 MTA	$124 MTA
Third party Casualty and Liability Claims	Revenue Vehicle Miles	× #Claims Paid / Million Rev-mi	× Avg Award / Claim Paid	+ Avg Labor & Exp / Claim Paid
		6.12 WMATA	Nominal = $796 (Avg MTA and WMATA) High = $1,184 WMATA	$124 MTA

Figure 3. Light rail transit operating cost model factors that are different from those for rail rapid transit (coefficient values are in 1979 dollars).

Vehicle Maintenance Labor (Combined Inspection and Repair & Maintenance)	Total Vehicle Miles	× Mechanics / Million Veh-mi	× Mechanic Wage / Person-Year	× Staff Burden	× Fringe Multiplier
		20 Toronto	$18,323 WMATA	1.128 WMATA	1.20 in 1980 From: 1.24 in 1981 To: 1.30 in 1987
Vehicle Maintenance Materials & Supplies	Total Vehicle Miles	× $ / Vehicle-mile			
		Nominal = $0.080 (Avg of Toronto and Edmonton High = $0.114-Edmonton			
Station Maintenance Materials & Supplier	Mall Stations	$ / Station			
		$18,304 WMATA experience (no escalation maintenance, etc.)			
Propulsion Energy	Total Vehicle Miles	× Kilowatt-Hours / Vehicle-mile	× $ / Kilowatt-Hour		
		10.0 Siemens, Boeing Vertol	$0.031 HL&P		
Stations Energy (Mall Stations)	Mall Stations	× Operating-Hours / Year	× Kilowatt-Hours / Station-Hour	× $ / Kilowatt-Hour	
		7,300 20 Hrs/Day 365 Days/Year	15 Estimate based on WMATA experience	$0.031 HL&P	

expenses (security costs for bus operations are included in bus general and administrative); and

15. General and administrative--A percentage of the sum of the above costs to cover costs that cannot be allocated to any other cost component directly.

SELECTION OF NOMINAL COEFFICIENT VALUES

Figures 1-3 present the computations for two estimates of operating cost. The nominal, or expected, value is based on assumptions regarding improved worker productivity and reduced unit direct costs anticipated to occur, particularly as the bus fleet grows. For some components, a high value represents the case where less optimistic improvements over the current MTA operation occur. When no change from the nominal cost is expected, the nominal and high values are the same. In the analysis of alternatives, the difference between the nominal and high values is treated as a cost contingency. In the discussion below, arguments are presented regarding the selection of nominal and high values for the cost model coefficients and the reasoning behind assumptions concerning anticipated improvements from the current operation.

Selection of Productivity Values

Improvements in worker productivity are expected to have the greatest impact on operating costs. These productivity factors are as follows.

Bus Payroll Hours per Platform Hour

The current MTA value of 1.33 is expected to decrease slightly as relatively more peak-period, express service is introduced. The type of service envisioned is representative of current WMATA operations (1.36).

Bus Vehicle Operating Labor Staff Burden

The current MTA value of 1.17 is expected to decrease as the bus fleet expands and the overhead burden of supervisors and clerical and administrative staff is spread thinner. The large bus operations of WMATA have a power value of 1.07, and we assume that the MTA will achieve this value.

Bus Mechanics per Million Vehicle Miles

The current MTA value of 20.6 is high and is apparently due, in part, to inadequate bus maintenance facilities. The nominal value of 12.4 is the average for the following operators of relatively large bus fleets:

System	Bus Mechanics per Million Vehicle Miles
WMATA	13.3
AC Transit	7.8
CTA	16.8
SCRTD	11.3
Seattle Metro	13.4
MARTA	11.9

CTA, which has the highest value, represents one of the best-administered maintenance programs, although its buses serve primarily slower urban routes.

Bus Vehicle Maintenance Labor Staff Burden

As the bus fleet expands, the administrative staff will be spread thinner. Thus, the current MTA value of 1.41 will be reduced. The WMATA value of 1.07 is considered representative.

In general, productivity improvements for bus operations are expected to occur gradually. No improvement is expected until after 1982, when the Kashmere heavy maintenance facility opens. The transition is assumed to be completed by 1988 when the first busways begin operation.

Selection of Representative Wage Values

Certain job classifications are expected to experience increases in real dollar wages due to the need for the MTA to compete with the private sector for highly trained technical staff. The wages selected for the most important labor cost components are discussed below.

Rail and Bus Vehicle Operators and Station Agents

The current MTA real dollar wages for bus drivers are expected to remain constant. The top hourly wage is currently among the highest in the state. As with WMATA, rail car operators' and station agents' wages are approximately the same as those of bus drivers.

Bus Mechanic Wages

MTA is currently experiencing some difficulty in hiring sufficiently trained diesel mechanics due to the relatively low wages offered compared with those in the private sector. In order to attract the large number of mechanics necessary to serve the expanding bus fleet, it is assumed the annual wage will increase with each contract negotiation as follows:

Year	Annual Wage (1979 dollars)
1980	17 360--MTA wage
1981-1982	17 860
1983-1984	18 860
1985-1986	19 860
1987-1995	20 818--WMATA wage

Rail Mechanic Wages

All rail maintenance nonsupervisory employee wages are assumed to be equal to the WMATA value. These positions (in vehicle, station, right-of-way, and ATC maintenance) require highly skilled mechanics and technicians who command a fairly high wage in the private sector. We assumed that current MTA wages for bus mechanics would not attract these personnel.

Selection of Fringe Multiplier Value

The 1980 MTA multiplier value of 1.20 will increase to 1.24 in 1981 due to a doubling of MTA's contribution to the pension fund. We anticipate that this value will increase further, as it has with other transit properties. A value of 1.30 in 1987 (slightly higher than the WMATA current value) is assumed.

Selection of Other Direct Cost Values

Nominal and high values were selected for the following cost components.

Bus Vehicle Maintenance Materials and Supplies Cost per Vehicle Mile

The current MTA value of 0.26 is relatively high and is expected to fall as improved maintenance practices are implemented for the larger fleet and new maintenance facilities. A nominal value of 0.095, achieved by 1988, is representative of the industry. A high value of 0.120 is also achieved by 1988, the value for WMATA.

Heavy Rail Vehicle Maintenance Materials and Supplies Cost per Vehicle Mile

The nominal value of 0.163 is the average for BART and WMATA. The high value of 0.220 is the WMATA value.

Heavy Rail Right-of-Way and Systems Maintenance Materials and Supplies Cost per Vehicle Mile

The nominal value of 22 290 is the average for BART and WMATA. The high value of 31 098 is the WMATA value.

Light Rail Vehicle Maintenance Materials and Supplies Cost per Vehicle Mile

The nominal value of 0.080 is the average for Edmonton and Toronto. The high value of 0.114 is the Edmonton value.

Parking Lot Maintenance Materials and Supplies Cost per Parking Space

The nominal value of 89 is the average for Miami, Florida, and Montgomery County, Maryland. The high value of 102 is the Montgomery County value.

Selection of General and Administrative Factor

The current MTA value of 0.328 is extraordinarily high for a medium-sized bus-only transit operation. This can be explained by the large administrative staff that performs many of the functions found in larger, multimodal properties. These additional functions include the following:

1. Contraflow operation,
2. Metro lift (elderly and handicapped service),
3. Customer service (ticket sales and telephone information), and
4. Program development (particularly of long-range regional transportation planning).

We anticipate that, as the bus fleet expands, the absolute value of these administrative costs will not increase and will reduce in relative terms over time. For bus operations this value is assumed to approach the lower WMATA value of 0.152 by 1988, when bus guiding operations begin. The value for rail operations (0.170) is the WMATA rail value.

APPLICATION OF COST MODEL

The bus and rail transit cost models described above were applied to the priority corridor alternatives in the phase 2 HTAA. The following alternatives were considered (4):

1. Base--Extensive improvements in the level of service provided by surface bus operations with express service provided on two currently programmed busways and on freeway contraflow lanes.
2. Low capital--Express bus service on narrow, one-way busways built primarily in conjunction with state-funded freeway reconstruction projects supplemented by extensive feeder bus service.
3. Busway--Express bus service on wide, two-way busways in all major transportation corridors supplemented by extensive feeder bus service.
4. Heavy rail--Conventional heavy rail (rail rapid transit) service from a tunnel in the central business district (CBD) to two major activity centers via aerial structure in the travel corridor of greatest demand. Express bus service similar to the busway alternative in all other corridors. Both heavy rail and busways supplemented by extensive feeder bus service.
5. Light rail with CBD tunnel--Light rail transit service from a tunnel in the CBD to two major activity centers, with a spur that penetrates the larger activity center, via aerial structure in the travel corridor of greatest demand. Express bus service similar to the busway alternative in all other corridors. Both light rail and busways supplemented by extensive feeder bus service.
6. Light rail with CBD mall--Light rail transit service from a contraflow, one-way pair surface street operation in the CBD to two major activity centers via aerial structure in the travel corridor of greatest demand; express bus service similar to the busway alternative in all other corridors. Both light rail and busways are supplemented by extensive feeder bus service.

All alternatives included two CBD bus transit malls and an extensive park-and-ride program. Further, all alternatives are designed to provide similar levels of service in terms of residential feeder bus route spacing and headways and in terms of connectivity to major activity centers.

Detailed results of the operating cost analysis for the bus and rail (if any) components for each alternative in 1995 (the design year) are shown in Tables 1-4. A summary of the combined 1995 nominal operating costs is given in the table below. These costs include differential inflation effects for each cost component (5). [Note: Costs are given in 1979 dollars.]

	Operating Cost ($000 000s)		
Alternative	Bus	Rail	Total
Base	181.53		181.53
Low capital	209.86		209.86
Busway	210.30		210.30

Table 1. Bus physical and operating characteristics for Houston Transitway alternatives in 1995.

System Characteristic	Base	Low Capital	Busway	Heavy Rail	Light Rail CBD	
					Tunnel	Mall
Active vehicles	2 004.0	2 174.0	2 171.0	1 857.0	1 828.0	1 820.0
Standard	2 004.0	2 174.0	2 171.0	1 857.0	1 828.0	1 820.0
Articulated	0.0	0.0	0.0	0.0	0.0	0.0
Platform hours (000 000s)	5.572	6.177	5.987	5.318	5.206	5.193
Standard	5.572	6.177	5.987	5.318	5.206	5.193
Articulated	0.0	0.0	0.0	0.0	0.0	0.0
Total vehicle miles (000 000s)	73.855	89.317	103.901	88.915	85.773	86.408
Standard surface	73.855	85.119	59.618	58.643	56.830	57.317
Standard guideway	0.0	4.198	44.283	30.272	28.943	29.091
Articulated surface	0.0	0.0	0.0	0.0	0.0	0.0
Articulated guideway	0.0	0.0	0.0	0.0	0.0	0.0
Revenue vehicle miles (000 000s)	65.810	79.726	92.849	79.362	76.535	77.106
Route miles guideway	21.0	87.6	102.6	91.3	89.4	91.3
Activity center terminals	7.0	6.0	6.0	5.0	4.0	5.0
Suburban stations	23.0	46.0	48.0	39.0	39.0	39.0
Parking spaces	21 000.0	21 000.0	21 000.0	15 500.0	15 500.0	15 500.0

Table 2. Bus operating costs for Houston Transitway alternatives in 1995.

Cost Component	Base ($000 000s)		Low Capital ($000 000s)		Busway ($000 000s)		Heavy Rail ($000 000s)		Light Rail CBD ($000 000s)			
									Tunnel		Mall	
	Nominal	High	Nominal	High	Nominal	High	Nominal	High	Nominal	High	Nominal	High
Vehicle operating labor	75.74	82.82	83.97	91.82	81.39	88.99	72.29	79.05	70.77	77.38	70.59	77.19
Terminal operating labor	0.69	0.69	0.59	0.59	0.59	0.59	0.49	0.49	0.40	0.40	0.49	0.49
Vehicle maintenance labor	29.80	40.38	36.04	48.83	41.92	56.80	35.88	48.61	34.61	46.89	34.87	47.24
Vehicle maintenance materials and supplies	7.02	8.86	8.49	10.72	9.87	12.47	8.45	10.67	8.15	10.29	8.21	10.37
ROW maintenance labor and materials and supplies	0.17	0.17	0.70	0.70	0.82	0.82	0.73	0.73	0.72	0.72	0.73	0.73
Station maintenance labor and materials and supplies	0.39	0.45	0.62	0.71	0.64	0.73	0.52	0.60	0.50	0.57	0.52	0.60
Parking lot maintenance labor and materials and supplies	1.87	2.14	1.87	2.14	1.87	2.14	1.38	1.58	1.38	1.58	1.38	1.58
Fuel	35.43	47.28	41.84	55.84	39.22	52.34	35.39	47.23	34.20	45.65	34.47	46.01
Claims	8.77	10.77	10.24	12.58	8.36	10.36	7.84	9.69	7.58	9.37	7.65	9.45
Security labor and materials and supplies	0.84	0.84	1.46	1.46	1.52	1.52	1.24	1.24	1.21	1.21	1.24	1.24
Subtotal	160.72	194.41	185.81	225.38	186.20	226.77	164.21	199.89	159.51	194.06	160.14	194.89
General and administrative	20.80	25.16	24.05	29.17	24.10	29.35	21.25	25.87	20.64	25.12	20.73	25.22
Total	181.53	219.57	209.86	254.55	210.30	256.12	185.46	225.76	180.15	219.18	180.87	220.12

Note: Costs are given in 1979 dollars.

Alternative	Operating Cost ($000 000s)		
	Bus	Rail	Total
Heavy rail	185.46	23.99	209.45
Light rail CBD			
Tunnel	180.15	32.16	212.31
Mall	180.87	27.75	208.62

Table 3. Rail physical and operating characteristics for Houston Transitway alternatives in 1995.

System Characteristic	Heavy Rail	Light Rail CBD	
		Tunnel	Mall
Platform hours (000 000s)	0.058	0.118	0.110
Total vehicle miles (000 000s)	5.736	6.253	5.035
Revenue vehicle miles (000 000s)	5.700	6.170	4.976
Active vehicles	90.0	118.0	102.0
Track miles	33.1	42.9	37.9
Total stations	13.0	18.0	16.0
Subway	2.0	2.0	0.0
Surface	11.0	16.0	12.0
Mall	0.0	0.0	4.0
Mezzanines	15.0	20.0	20.0
Parking spaces	5500.0	5500.0	5500.0

Several brief observations can be made regarding the performance of the model in this application. The base alternative has lower costs than the other alternatives due to relatively lower quantity of service provided (measured in terms of both vehicle miles and hours) compared with the other alternatives. The low-capital alternative, although it provides a similar level of service as the busway and rail alternatives, does so with substantially less service on bus guideways. The resulting lower speeds result in more platform hours (and thus greater vehicle operating costs) and fuel consumption (and thus greater fuel costs).

The costs for the rail alternatives demonstrate the trade-offs involved in replacing bus service in the priority corridor with rail service. For example, the heavy rail alternative, which uses trains of high capacity and only one operator, reduces the

Table 4. Rail operating costs for Houston Transitway alternatives in 1995.

			Light Rail CBD ($000 000s)			
	Heavy Rail ($000 000s)		Tunnel		Mall	
Cost Component	Nominal	High	Nominal	High	Nominal	High
Vehicle operating labor	1.80	1.80	3.66	3.66	3.42	3.42
Station operating labor	1.47	1.47	1.96	1.96	1.96	1.96
Vehicle maintenance labor	2.81	2.81	4.24	4.24	3.42	3.42
ROW and systems maintenance labor	5.63	5.63	7.30	7.30	6.45	6.45
Station maintenance labor	0.87	0.87	1.15	1.15	1.15	1.15
Vehicle maintenance materials and supplies	0.93	1.26	0.50	0.71	0.40	0.57
ROW and systems maintenance materials and supplies	0.74	1.03	0.96	1.33	0.84	1.18
Station maintenance materials and supplies	0.84	0.84	1.16	1.16	0.84	0.84
Parking lot maintenance labor and materials and supplies	0.49	0.56	0.49	0.56	0.49	0.56
Propulsion energy	2.66	2.89	3.21	3.21	2.59	2.59
Station energy	0.73	0.73	0.86	0.86	0.32	0.32
Claims	0.39	0.41	0.42	0.44	0.34	0.36
Revenue collection labor and materials and supplies	1.12	1.12	1.52	1.52	1.43	1.43
Security labor and materials and supplies	0.47	0.47	0.66	0.66	0.58	0.58
Subtotal	20.95	21.89	28.09	28.78	24.24	24.84
General and administrative	3.03	3.17	4.07	4.17	3.51	3.60
Total	23.99	25.06	32.16	32.94	27.75	28.43

Note: Costs are given in 1979 dollars.

total expense for vehicle operator labor (i.e., bus and rail operators combined) compared with the busway alternative. However, the rail technology adds maintenance costs not experienced in a bus-only system. Another example can be seen in the light rail CBD mall alternative that provides service similar to that of the heavy rail alternative but requires greater vehicle operator costs. This is due to the need for more platform hours as a result of scheduling shorter trains, a requirement imposed by the short block length in downtown Houston and the resulting use of shorter trains.

CONCLUSION

The model presented in this paper has two distinguishing features. First, it is based on formulations of expense categories that use standard transit industry measures of productivity and performance on service delivery. These formulations permit the analyst to test the sensitivity of cost projections to underlying assumptions and to display the results of these tests in a clear and understandable manner. They also permit the analyst to vary the values of these productivity parameters over time to allow for anticipated improvements or deterioration in performance at the outset.

Second, the model is based on formulations of expense categories that can easily be adapted to and calibrated by using data from the Section 15 chart of accounts. This feature of the model suggests the potential for more general applications in midrange financial planning for transit systems.

Many opportunities remain in the development of this type of cost-projection tool. Of particular interest, when comparing larger and smaller transit properties, is the need to identify those components of cost that are fixed. The model presented in this paper is completely variable-cost based. We recognize that some areas of transit operations are relatively independent of the quantity of service provided and should not be treated as a variable cost.

The model is currently being applied for WMATA in projecting operating costs for FY 1981-1990. Further investigation is being conducted regarding the structure of the cost formulations and the values of the model coefficients. Among the many anticipated model improvements are the following:

1. Detailed estimation of the costs of rail electrical power that explicitly consider demand charges, which result in greater costs per kilowatt hour during periods of peak use;
2. Identification of rail right-of-way costs specifically attributable to incremental track miles, passenger stations (and mezzanines), or power substations; and
3. Fixed administrative costs, both in specific operations and maintenance costs components and in the general and administrative overhead cost component.

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Abridgment

Constrained Matching Procedure for Allocating Public Transportation Assistance in Minnesota

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As public transportation subsidy costs increase, federal, state, and local decision makers become more concerned about the effectiveness, fairness, and efficiency of subsidy-allocation procedures. This paper describes a new allocation approach, developed for the Minnesota Department of Transportation, that matches each local subsidy dollar with two state dollars, up to a policy maximum percentage of the total operating costs. Based on a review of the experience in several states and recent proposals for the federal program, we discuss four general subsidy-allocation criteria—equity, efficiency incentives, administrative practicality, and managerial dynamics. Advantages and disadvantages of the constrained matching approach and four other methods are then presented. We also describe the application of the new approach.

Until the early 1970s, user fares covered almost all of the operating costs of public transportation services, and few states or communities provided public subsidies for these services. Currently, however, fares rarely cover the full costs of the services desired by citizens, and increasing amounts of federal, state, and local funds are being committed to subsidizing public transportation systems. Rapidly escalating public transportation costs alarm state and local decision makers and, as competition for public funds has increased, they have sought ways of limiting the growth in subsidy payments to public transportation.

This paper describes a new subsidy-allocation procedure that was developed for the Minnesota Department of Transportation (MnDOT). Based on experience in other states and at the federal level and on four criteria for assessing subsidy-allocation procedures, we present the advantages and disadvantages of five alternative approaches. We present proposals for a new allocation method based on matching local funds to a policy maximum percentage of total operating costs. A complete documentation of these proposals is available (1).

REVIEW OF ALTERNATIVE ALLOCATION APPROACHES

A comprehensive survey in 1978 found 22 states that have 50 programs that provide operating assistance for public transportation services (2). Almost half (23 programs) based the subsidy on deficits in one way or another. Usually, the amount of subsidy was a portion of the net deficit after receipt of federal funds. The next most common procedure (10 programs) was to base subsidies on the amount of funds received from provisions of Section 5 of the Urban Mass Transportation Act of 1964, as amended. Other methods reported included formulas based on patronage, vehicle miles, population or population density, and operating expenses. More recently, California, New York, and the U.S. Department of Transportation have made or proposed various modifications to these procedures (3-5). Pennsylvania has begun to apply performance measures to funding programs.

Criteria for Assessing Allocation Procedures

Four criteria are helpful for assessing allocation schemes: equity, efficiency incentives, administrative practicality, and managerial dynamics (6). One could also assess different allocation approaches based on their effectiveness in meeting the objectives of the subsidy program, but two major limitations make this assessment criterion infeasible:

1. Political and technical problems of determining for any subsidy program specific, quantifiable objectives and their trade-offs and
2. Difficulty of estimating accurately what impacts different subsidy approaches will have on service levels and the resultant ridership or other objectives.

Equity is an important allocation consideration. Subsidy recipients in similar situations should be treated alike. The problem is how to determine what are similar situations and how to deal with very different ones. Establishment of what is equitable can be very difficult; for example, Is a fair process that may lead to unequal outcomes equitable? Should funding be equalized based on population, state taxes contributed, system ridership, or some measure of service such as vehicle hours? There is also a generally held concern that public subsidy programs should use general tax revenues to help lower-income groups rather than the more affluent. However, given the multiple objectives of public transportation programs, the subsidies often benefit different population groups unequally. Legislatures must consider various aspects of fairness and, through discussion and negotiation, establish an equitable procedure. Any procedure can, of course, be challenged in court by affected parties who claim unequal treatment.

The efficiency incentives are significant, both for the recipients and the administering agency. A basic problem is to guarantee whatever support is necessary to ensure a minimum level of performance in meeting program objectives while motivating recipients to improve their performance. Allocation schemes that are independent of system performance,