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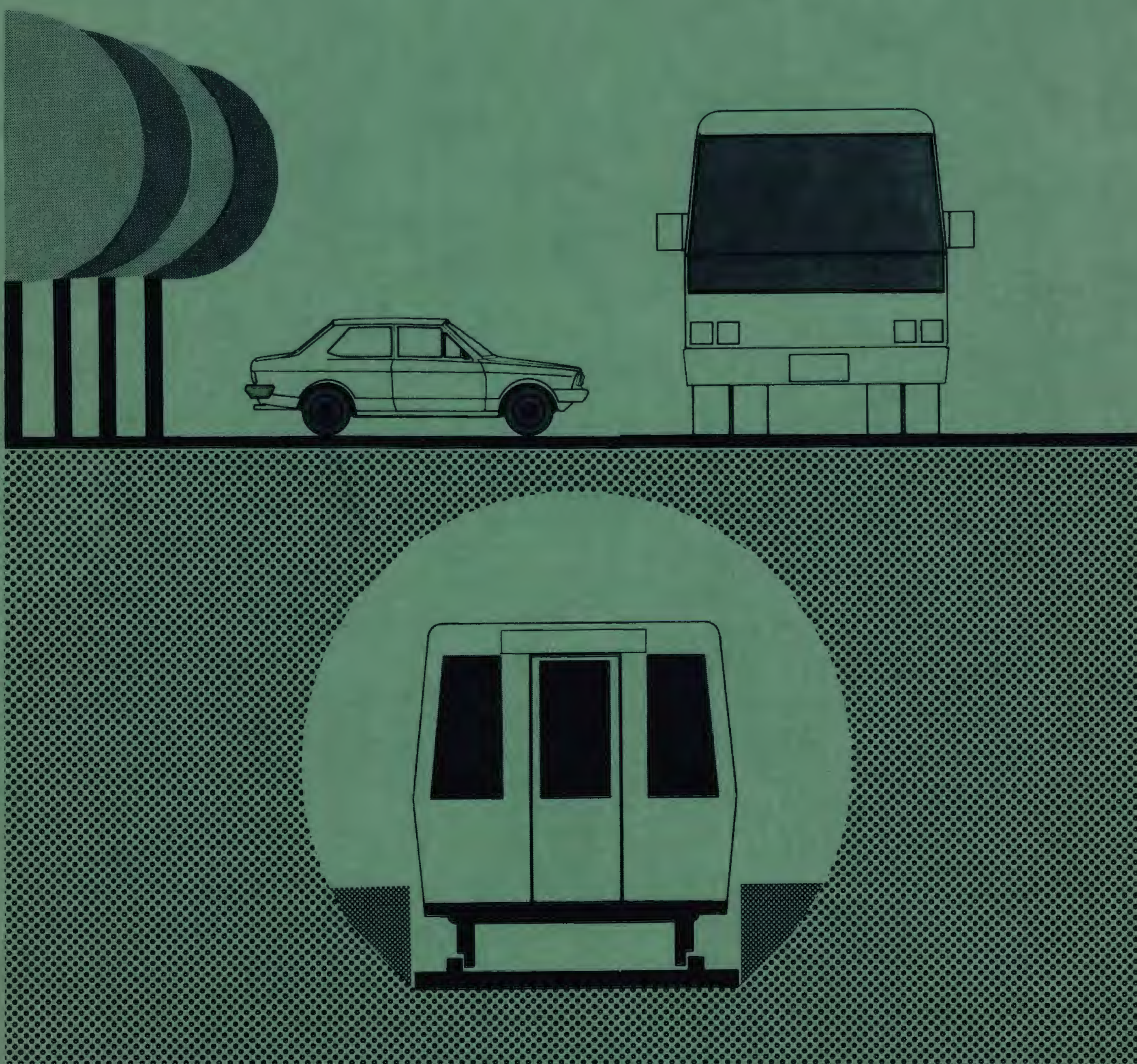

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16. Abstract
This report is a handbook to be used by transportation planners for estimating the performance characteristics of urban transportation modes. The modes covered are rail rapid transit, light rail, bus, auto, automated guideway, and pedestrian assistance systems. The performance characteristics described here all relate to eight supply parameters: speed, capacity, operating costs, labor inputs, energy consumption, pollution, capital costs, and accident frequency. (All characteristics of systems related to demand are covered in a separate volume, Characteristics of Urban Transportation Demand.)

This report is a sixth and major revision to this handbook, and most tables are new or contain more detailed information than appeared in previous editions.

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CHARACTERISTICS OF URBAN TRANSPORTATION SYSTEMS

Final Report
October 1985

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Characteristics of Urban Transportation Systems, also known as "CUTS," originated in the consolidation by DeLeuw, Cather and Company of two studies, one performed by DeLeuw, Cather for the Urban Mass Transportation Administration (UMTA) and the other titled "A Comparative Analysis of Transportation Costs," by the Urban Institute under contract to the Federal Highway Administration (FHWA). The authors of the first edition were D. Sanders and T. Reynen. It was incorporated into the Urban Transportation Planning System (UTPS) documentation and was published as a hard-copy report in May 1974.

A subsequent revision performed by J. Hinkle of DCCO in May 1975, included a major expansion of the topics and systems covered. The next revision, which was primarily an updating, was performed by Rock Creek Associates under the direction of R. Watkins in October 1977. A fourth revision, primarily incorporating energy and air pollution data was performed internally by UMTA and was also made available in hard copy. The fifth revision, performed by COMSIS Corporation under the direction of R. Watkins, updated the capital and operating costs, the bus and auto performance data, and all safety data.

This sixth and major revision was performed under the direction of A. Reno of System Design Concepts, Inc., (Sydec) under subcontract to Cambridge Systematics, Inc. The major changes in this revision were the addition of information on labor inputs and vehicle capacities, the addition of more detailed data on capital and operating costs, and the addition of guidance for those desiring up-to-date information from currently available data series which are summarized in this document. In addition, the data has been updated to 1982 or 1983.

The authors would like to thank S. Zimmerman (UMTA), J. Ossi (UMTA), T. Dooley (Transportation Systems Center), J. Mora (UMTA), W. Kulyk (UMTA), R. Hoyler (UMTA), L. Platte (U.S. Environmental Protection Agency) and G. Fielding (University of California at Irvine) for providing source data and advice on the contents of this document. The authors would like to provide a special thanks to S. Thomas of Sydec, who prepared the tables in the CUTS.

The authors wish to state that the contents of this document reflect their own views, and that they alone are responsible for the accuracy of the material presented.

FOREWORD

Information on the observed characteristics of existing urban transportation systems is used in all stages of planning and project development so that reasonable and desireable alternatives can be developed, refined, and evaluated. The "Characteristics of Urban Transportation Systems," also commonly referred to as "CUTS," is intended to provide empirical evidence of alternative system costs, physical, operating, and performance characteristics, and impacts. The modes covered are rail rapid transit, light rail transit, bus, auto, automated guideway, and pedestrian assistance systems. The contents of this report do not reflect the official views or policy of the United States Department of Transportation, nor does this report constitute a standard, specification, or regulation.

If you have any general comments on CUTS, please contact me at the address below. If you have specific comments on one of the tables herein, a suggested format for your comments is found on the "Comment Form" on page 190. We would appreciate any help you can provide us in maintaining CUTS as an up-to-date transportation planning and analysis data resource.

Additional copies of CUTS are available at cost from the National Technical Information Service (NTIS), in Springfield, Virginia, 22161.

Samuel Zimmerman
Director, Office of Methods and Support, URT-40
Urban Mass Transportation Administration
Washington, DC 20590

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CHAPTER I

INTRODUCTION

In an analysis of transportation systems, whether for short or long range planning, the planner must be able to describe and succinctly evaluate a proposed system. The literature offers many tools for estimating operating, environmental, demand, construction, and other characteristics of transport technologies. Often, however, the data presented are out-of-date, inconclusive, unspecified or merely local in nature. The very number of sources confuses rather than helps in the search for pertinent information, and the great variety of sources can produce statistics often unreliably or misleadingly compared or grouped because of initial measurement differences.

The objective of this document is to provide a single source of sketch planning data on the most important performance characteristcs of five contemporary urban transportation systems (rail, bus, highway-automobile, automated guideway, and pedestrian assistance systems) in a format that lends itself to easy reference. This handbook does not deal explicitly with passenger demand, but assesses only the supply or performance characteristics of urban transportation systems. The eight supply parameters chosen for this report are:

- Speed
- Capacity (service volume)
- Labor Inputs
- Operating Costs
- Energy Consumption
- Pollution (including emissions and noise)
- Capital Cost (including land, construction, structures, and vehicles)
- Accident Frequency

The level of detail at which these data are treated is one suitable for use in sketch planning -- that is, the preliminary screening of possible transportation configurations or concepts in outline and with detail sufficient only to support broad policy decisions. An instance might be the evaluation of a large number of concepts as a first phase of alternatives analysis. Planners will normally continue sketch planning until they complete their comparison of possibilities or find a strategic plan worth analyzing in greater detail. To complete this analysis, they will then require data of a specificity and timeliness impossible in a ready reference. More refined estimates must be obtained by reviewing current bids and in discussions with vendors.

Organization of Handbook

The material in this handbook comes from many sources, as the references indicate. It is a series of independent, self-descriptive tables for the following conventional transport modes.

Rail Transit (commuter, rapid, and light)
Local Bus and Bus Rapid Transit
Automobile-Highway System (automobiles and other vehicles)
Automated Guideway Transit Systems
Pedestrian Assistance Systems

Each of the above transport modes is treated in its own chapter according to eight supply parameters. Furthermore, parameters are discussed at several levels of detail to assist the urban planner in characterizing a particular transport mode. These levels are:

Actual Values (site specific)
Average or Median Value
Range of Values
Theoretical Value

Actual values for particular cities or sites are presented where appropriate for particular parameters such as transit operating costs, capital costs, and labor inputs.

The average or median is a design value typical of the conditions being described. It usually reflects substantial empirical observations. It can be used by planners where site-specific details are not avaiable. However, because site specific conditions are so important, they should always be considered whenever possible.

The range of values shows the high and low values of a parameter allowing sensitivity analyses to be performed in the evaluation phase. Often it is indicated which particular systems exhibit certain values, and planners can use this information to choose more accurate values. In cases in which ranges of values and average values are presented, the user should check the range before using an average value to decide if the variation demands more site-specific details.

If neither the average value nor the range of values is adequate, then the theoretical value can be used. Only a few tables present theoretical values, which are convenient mathematical formulae which the planner can apply to obtain a theoretical parameter such as capacity.

Necessary qualifications are given with each table in an attempt to make this handbook nearly self-contained, and source information is given to simplify the problems of the user who requires further information. Each section dealing with conventional transport has its own appendix containing important site-specific information.

Use of the Handbook

As in the use of other handbooks or manuals of this type, care must be exercised. Since this handbook is specifically for use by transportation planners in the preliminary evaluation of alternative systems, the values and relationships presented are purposely simplified. In most cases, therefore, they are not sufficiently refined for use in such studies as transit operations analysis, traffic engineering, or detailed design. The handbook cannot be used without comprehensive understanding of the transport system being analyzed. Nothing in this handbook should be used to supersede or confute competently developed site-specific estimates.

Obviously, values will need adjustment as time passes, since they are stated in terms of 1982 and 1983. Knowledge of local factors, such as wage rates, energy type and availability, and geography, is important for accurate analysis. Some transportation, labor, and construction cost indices are presented in Appendix A.

All tables in the chapters are updated to 1982 or 1983 (unless otherwise indicated). Costs in Appendix tables are usually actual.

How to Acquire Additional or Updated Information

Although this handbook has been regularly updated by UMTA, many parameters such as prices and costs change regularly. A list of sources and how to acquire them is included here, so that those interested in particular information may acquire it directly from the available sources. It should be noted that some individual projects and proposals may differ substantially in costs or in other important parameters from even the most up to date information.

The most comprehensive source of price and income data is the Survey of Current Business, published monthly by the Bureau of Economic Analysis of the U.S. Department of Commerce. It contains virtually all cost indices as well as other information on economic activity. It is available for an annual subscription price of $30.00. Orders should be sent to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Make checks payable to the Superintendent of Documents.

The U.S. Department of Labor, Bureau of Labor Statistics, Washington, D.C. 20212 News contains up-to-date Consumer Price Index (CPI) information. For current and historical information call (202) 523-1222 or (202) 523-1208.

The Joint Economic Committee of the U.S. Congress publishes a monthly Economic Indicators which summarizes the most general price and other economic indicators. The subscription price is $21.00 per year and it can be ordered through the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402. Make checks payable to Superintendent of Documents.

McGraw Hill, Inc. publishes the weekly Engineering News-Record, which contains information and data about construction and construction prices. Subscription rates are $33.00 per year, but are solicited only from persons with identifiable commercial or professional interests in construction or building. Subscription orders should be sent to Fulfillment Manager, Engineering News-Record, P.O. Box 430, Hightstown, N.J. 08520.

The Urban Mass Transportation Administration, U.S. DOT, publishes a yearly National Urban Mass Transportation Statistics, which contains information about each transit operation in the U.S. which receives UMTA support. It includes data on transit revenues, expenses, services, safety, energy consumption, maintenance performance, mileage, employee counts, fleet size, and fleet age. The yearly document is available from the Office of Technical Assistance, Urban Mass Transportation Administration, URT-7, 400 7th Street, S.W., Washington, D.C. 20590. Phone: (202) 426-9157.

The Motor Vehicle Manufacturers Association of the United States, Inc. publishes a yearly Motor Vehicle Facts and Figures which gives price, production, operating cost, fleet composition, accidents, and fuel economy data assembled from various primary sources. Single copies are

$7.50 and may be ordered from the Communications Department, Motor Vehicle Manufacturers Association, 300 New Center Building, Detroit, Michigan 48202.

The U.S. Bureau of the Census, Department of Commerce, publishes a Statistical Abstract of the United States, which contains a wealth of price, income, production, and other data of interest in transportation. The Statistical Abstract may be ordered from the Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402. Phone: (202) 783-3238, or from any U.S. Department of Commerce district office.

The Federal Highway Administration, U.S. DOT, publishes an annual Highway Statistics, which contains data on motor fuel consumption, motor vehicle registrations, drivers licenses, highway finance, highway expenditures, and roadway extent and characteristics, vehicle miles of travel, fuel economy, and highway performance. Highway Statistics is available through the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

The Monthly Data Report prepared by Philip Patterson of the U.S. Department of Energy and the Motor Vehicle MPG and Market Shares Report prepared by Oak Ridge National Laboratory provide up-to-date information and analyses of motor vehicle fuel economy, sales, and prices. These reports may be ordered through Philip D. Patterson, CE-13, Office of Vehicle and Engine Research and Development, Department of Energy, 1000 Independence Avenue, S.W., Room GA-098, Washington, D.C. 20585. Phone: (202) 252-9118.

CHAPTER II

RAPID RAIL, COMMUTER RAIL, AND LIGHT RAIL TRANSIT

This chapter contains a set of updated quantitative values for the eight supply parameters selected to characterize fixed rail transit systems: speed, capacity, operating cost, labor inputs, energy consumption, pollution (emissions and noise), capital costs, and accident frequency. Every effort was made to provide different values or tables for rapid rail, commuter rail, and light rail transit systems, although this could not be completed for all the parameters. Appendix B should be consulted for more detailed information.

TABLE 2-1

TYPICAL RAIL RAPID TRANSIT SPEEDS

Average Station Spacing (miles)	Range of Average Speeds[1/] (mph)
0-1	20-25
1-2	35-40
2-3	45-50
Over 3	50-55

[1/] These speeds reflect current or expected rail rapid transit technology; they include estimates of typical dwell times.

Sources: Metropolitan Atlanta Rapid Transit Authority, unpublished data, Atlanta, Georgia, 1973.

Port Authority Transit Corporation, unpublished data, Philadelphia, Pennsylvania, 1973.

Washington Metropolitan Area Transit Authority, unpublished data, Washington, D.C., 1973.

Bay Area Rapid Transit District, unpublished data, San Francisco, California, 1973.

Notes: See Table B-2 in the Appendix for rail rapid transit speeds versus station spacing.

Existing U.S. rail transit systems average 22.0 revenue car miles per revenue car hour. Revenue car hours include layover and turn around times. The range of revenue car miles per revenue car hour is from 15 to 29 for U.S. systems.

TABLE 2-2

TYPICAL COMMUTER RAIL SPEEDS

Average Station Spacing (miles)	Range of Average Speeds[1] (mph)
0-2	20-30
2-3	27-35
3-5	29-31
5-6	24-45

[1] These speeds reflect recent commuter rail speeds and includes typical dwell times.

Note: Above data based on analyses of the Penn Central, Pennsylvania-Reading Seashore lines, Southern Pacific, Chessie System, several lines of the Southeastern Pennsylvania Transportation Authority, and the Long Island Railroad, Metro North, and N.J. Transit.

Sources: Planning Research Corporation Systems Science Company, "A Methodology for Conducting Economic and Demand Analyses of New Systems," March 1973.

Journal of Urban Transportation Corporation, Modes of Transportation: Sources of Information on Urban Transportation, New York, August 1965.

Stanford Research Institute, U.S. Passenger Transportation: an Inventory of Resources and an Analysis of Capabilities of Several Modes, Menlo Park, California, March 1967.

Timetables from Long Island Rail Road, Metro North Rail Road, and N.J. Transit for fall, 1983.

TABLE 2-3

TYPICAL LIGHT RAIL SPEEDS

United States

Range of Speeds (Mph)	Average Speed (Mph)
8.7-19.6	14.1

Source: Based on FY 1982 Section 15 data for Phildelphia, Newark, Boston, Cleveland, San Francisco, Pittsburgh, New Orleans, and San Diego. Speeds vary based on percent of operation on grade separated facilities vs. in mixed traffic.

Europe

Average Station Spacing (miles)	Range of Speeds[1] (mph)	Default Speed[1] (mph)
0-0.25	9.9-14.3	12.6
0.25-0.50	9.3-18.6	13.5
Default Value		13.0

1 Based on light rail speed data from Rotterdam, Dusseldorf, Frankfurt (30-40 percent grade separated), Stuttgart (40 percent grade separated), Hanover, Gothenburg (70 percent grade separated), Cologne (63 percent grade separated), and Bielefeld (40 percent grade separated).

Source: Vuchic, Vukan, Light Rail Transit Systems - A Definition and Evaluation, U.S. Department of Transportation, October 1972.

TABLE 2-4

RAIL RAPID OPERATING COSTS

System	Operating Cost	Cost Per Total Vehicle Hour	Cost Per Revenue Vehicle Hour	Cost Per Revenue Vehicle Mile
NYCTA	$1,308,343,991	$78.42	$94.08	$5.12
CTA	178,751,350	96.53	97.53	3.60
PATCO	14,468,179	95.80	97.84	3.37
SEPTA	77,802,476	90.31	90.39	5.91
BARTD	117,820,646	114.20	114.20	4.16
WMATA	107,250,244	106.05	110.07	6.16
MARTA	15,830,318	77.04	79.75	4.20
Average		$94.05	$97.69	$4.65
St Dev		13.58	11.65	1.10
Minimum		$77.04	$79.75	$3.37
Maximum		114.20	114.20	6.16

Source: National Urban Mass Transportation Statistics, U.S. DOT Urban Mass Transportation Administration, Fiscal Year 1982

Key:

NYCTA: New York City Transit Authority
CTA: Chicago Transit Authority
PATCO: Port Authority Transit Corporation (Lindenwold)
SEPTA: Southeastern Pennsylvania Transportation Authority (Phildelphia)
BARTD: Bay Area Rapid Transit District, San Francisco-Oakland, Calif.
WMATA: Washington Metropolitan Area Transit Authority
MARTA: Metropolitan Atlanta Rapid Transit Authority

TABLE 2-4 (continued)

RAIL RAPID TRANSIT OPERATING COSTS FOR U.S. SYSTEMS
(FY 1982)

System		Cost Per Employee	Cost Per Peak Vehicle
NYCTA		$42,324.79	$269,817.28
CTA		44,256.34	201,296.57
PATCO		$44,793.12	150,710.20
SEPTA		41,472.54	298,093.78
BARTD		61,015.35	378,844.52
WMATA		40,426.02	429,000.98
MARTA		30,979.10	293,154.04
	Average	$43,609.61	$288,702.48
	St Dev	$8,950.44	$95,704.04
	Minimum	$30,979.10	$150,710.20
	Maximum	$61,015.35	$429,000.98

Key to system names: see preceding page.

TABLE 2-5

RAIL RAPID LABOR INPUTS PER UNIT OF SERVICE

System	Personnel Per 1,000 Vehicle Revenue Hours	Personnel Per 1,000 Vehicle Total Hours	Personnel Per Peak Vehicle	Personnel Per 10,000 Vehicle Revenue Miles
NYCTA	2.223	1.853	6.374	1.210
CTA	2.204	2.181	4.548	0.813
PATCO	2.184	2.139	3.365	0.753
SEPTA	2.180	2.177	7.188	1.426
BARTD	1.872	1.872	6.209	0.681
WMATA	2.723	2.623	10.612	1.524
MARTA	2.574	2.487	9.463	1.355
Average	2.280	2.190	6.823	1.109
St Dev	0.028	0.029	2.555	0.351
Minimum	1.872	1.853	3.365	0.681
Maximum	2.723	2.623	10.612	1.524

Source: National Urban Mass Transportation Statistics, U.S. DOT Urban Mass Transportation Administration, Fiscal Year 1982

Key to system names: See Table 2-4.

TABLE 2-6

RAIL RAPID LABOR INPUTS PER UNIT OF SERVICE BY TYPE OF EMPLOYEE

System	Vehicle Operators Per 1,000 Total Vehicle Hours	Vehicle Mechanics Per 10,000 Total Vehicle Miles	Vehicle Mechanics and Vehicle Servicers Per 10,000 Total Vehicle Miles	Other Personnel Per 1,000 Total Vehicle Hours
NYCTA	0.358	0.116	0.147	1.269
CTA	1.008	0.063	0.083	0.947
PATCO	0.318	0.123	0.158	1.364
SEPTA	0.261	0.203	0.241	1.547
BARTD	0.208	0.080	0.090	1.417
WMATA	0.524	0.450	0.571	1.079
MARTA	0.268	0.143	0.143	1.952
Average	0.421	0.168	0.205	1.368
St Dev	0.028	0.013	0.017	0.328
Minimum	0.208	0.063	0.083	0.947
Maximum	1.008	0.450	0.571	1.952

Source: National Urban Mass Transportation Statistics, U.S. DOT Urban Mass Transportation Administration, Fiscal Year 1982

Key: See Table 2-4.

TABLE 2-7

RAIL RAPID TRANSIT COSTS AND EMPLOYEES PER UNIT OF CAPACITY

System	Cost Per Thousand Place Miles	Cost Per Thousand Place Hours	Employees Per Million Place Miles	Employees Per Million Place Hours
NYCTA	$50.60	$929.63	1.196	21.96
CTA	$43.29	$1,173.67	0.978	26.52
PATCO	$26.89	$779.58	0.600	17.40
SEPTA	$54.31	$830.05	1.310	20.01
BARTD	$29.61	$813.42	0.485	13.33
WMATA	$43.38	$775.11	1.073	19.17
MARTA	$28.74	546.22	0.928	17.63
Average	$39.55	$835.38	0.939	19.43
St. Dev.	$11.14	$188.94	0.030	4.12
Minimum	$26.89	$546.22	0.485	13.33
Maximum	$54.31	$1,173.67	1.310	26.52

Note: One "place" equals 5.38 square feet, as defined by Pushkarev, Boris, et. al., Urban Rail in America: An Exploration of Criteria for Fixed Guideway Transit, Indiana University Press, 1982. A place is used as a common measure of passenger capacity.

TABLE 2-8

RAIL TRANSIT OPERATORS
NUMBER OF TOP HOURLY WAGE RATES REPORTED TO APTA BY TOP WAGE RATE AND SIZE OF URBAN AREA (FEBRUARY 1, 1984)

Size Class of Urban Area (Population)	$14.00 Per Hour or More	$13.00 to $13.99 Per Hour	$12.00 to $12.99 Per Hour	$11.00 to $11.99 Per Hour	$10.00 to $10.99 Per Hour	$9.00 to $9.99 Per Hour	$8.00 to $8.99 Per Hour	$7.00 to $7.99 Per Hour	$6.00 to $6.99 Per Hour	$5.00 to $5.99 Per Hour	Less than $5.00 Per Hour	Totals
1,000,000 or more	5	2	14	8	5	4	2	0	0	0	0	40
500,000 to 1,000,000	0	0	0	0	0	0	0	0	0	0	0	0
200,000 to 500,000	0	0	0	0	0	1	0	0	0	0	0	1
100,000 to 200,0000	0	0	0	0	0	0	0	0	0	0	0	0
Under 100,000	0	0	0	0	0	0	0	0	0	0	0	0
Totals	5	2	14	8	5	5	2	0	0	0	0	41

Source: American Public Transit Association, Labor Information Service, "Top Hourly Wage Rate Summary -- Part 3: Rail Transit Operators," February 1, 1984.

Notes: Two or more top wage rates may be reported for the same operator due to different labor categories (e.g., engineer, conductor, etc.).

TABLE 2-8 (continued)

RAIL TRANSIT OPERATORS
PERCENTAGE OF TOP HOURLY OPERATORS IN EACH WAGE CATEGORY (FEBRUARY 1984)

Percentage in Each Wage Category by Mode	$14.00 Per Hour or More	$13.00 to $13.99 Per Hour	$12.00 to $12.99 Per Hour	$11.00 to $11.99 Per Hour	$10.00 to $10.99 Per Hour	$9.00 to $9.99 Per Hour	$8.00 to $8.99 Per Hour	$7.00 to $7.99 Per Hour	$6.00 to $6.99 Per Hour	$5.00 to $5.99 Per Hour	Less than $5.00 Per Hour	Totals
Heavy Rail	0%	5%	37%	26%	26%	5%	0%	0%	0%	0%	0%	100%
Light Rail	0%	0%	38%	31%*	0%	23%	8%	0%	0%	0%	0%	100%
Commuter Rail	50%*	10%*	20%	0%	0%	10%	10%	0%	0%	0%	0%	100%
Incline	0%	0%	0%	50%	0%*	50%	0%	0%	0%	0%	0%	100%
Totals	12%	5%	34%*	20%	12%	12%	5%	0%	0%	0%	0%	100%

Source: American Public Transit Association, Labor Information Service, "Top Hourly Wage Rate Summary -- Part 3: Rail Transit Operators," February 1, 1984.

Notes: Two or more top wage rates may be reported for the same operator due to different labor categories (e.g., engineer, conductor, etc.).

* Denotes median.

TABLE 2-9

LIGHT RAIL OPERATING COSTS

System	Operating Cost	Cost Per Total Vehicle Hour	Cost Per Revenue Vehicle Hour	Cost Per Revenue Vehicle Mile
SEPTA	$25,035,635	$40.12	$40.24	$4.35
NJT	2,037,553	70.18	70.18	3.58
MBTA	15,128,556	224.45	224.45	14.82
GCRTA	10,927,741	137.08	137.08	8.47
SF MUNI	21,063,152	61.22	61.22	5.36
PAT	13,510,327	118.04	118.04	7.91
NOPSI	3,520,066	43.34	43.34	5.00
SDTI	3,320,816	55.82	56.16	3.13
Average		$93.78	$93.84	$6.58
St Dev		63.27	63.22	3.84
Minimum		$40.12	$40.24	$3.13
Maximum		224.45	224.45	14.82

Key:
Philadelphia: SEPTA
Newark: NJT
Boston: MBTA
Cleveland: GCRTA
San Francisco: MUNI
Pittsburgh: PAT
New Orleans: NOPSI
San Diego: SDTI

Source: National Urban Mass Transportation Statistics, U.S. DOT, Urban Mass Transportation Administration, Office of Technical Assistance, (Fiscal Year 1982).

TABLE 2-9

LIGHT RAIL OPERATING COSTS (continued)

System	Cost Per Employee	Cost Per Peak Vehicle[1]	Cost Per Thousand Place Miles[2]	Cost Per Thousand Place Hours[2]
SEPTA	$27,523.13	$210,843.82	$84.88	$785.91
NJT	48,513.17	127,347.06	48.67	954.84
MBTA	54,224.22	222,478.76	130.95	1,982.80
GCRTA	34,770.09	257,136.93	104.55	1,691.46
SF MUNI	30,853.04	318,313.06	58.68	670.16
PAT	51,298.90	282,143.96	135.95	2,029.15
NOPSI	27,287.33	176,003.30	73.68	639.29
SDTC	51,887.75	276,734.67		
Average	$40,794.70	$233,875.20	$91.05	$1,250.52
St. Dev.	$11,753.64	$62,330.22	$34.09	$625.92
Minimum	$27,287.33	$127,347.06	$48.67	$639.29
Maximum	$54,224.22	$318,313.06	$135.94	$2,029.15

1/"Peak vehicles" are the maximum number of vehicles in service (either revenue or deadhead) at any point in time.

2/"Places" are a measure of passenger capacity (5.38 square feet).

TABLE 2-10

LIGHT RAIL LABOR INPUTS PER UNIT OF SERVICE

System	Personnel Per 1,000 Revenue Vehicle Hours	Personnel Per 1,000 Total Vehicle Hours	Personnel Per Peak Vehicle	Personnel Per 10,000 Revenue Vehicle Miles
SEPTA	2.032	2.026	7.661	2.194
NJT	1.447	1.447	2.625	0.737
MBTA	4.139	4.139	4.103	2.734
GCRTA	3.989	3.989	7.395	2.466
SF MUNI	2.459	2.459	10.317	2.153
PAT	2.595	2.595	5.500	1.738
NOPSI	1.588	1.588	6.450	1.831
SDTI	1.082	1.076	5.333	0.603
Average	2.416	2.415	6.173	1.807
St Dev	1.136	1.137	2.360	0.771
Minimum	1.082	1.076	2.625	0.603
Maximum	4.139	4.139	10.317	2.734

Source: National Urban Mass Transportation Statistics, U.S. DOT, Urban Mass Transportation Administration, Office of Technical Assistance, (Fiscal Year 1982).

Key: See Table 2-9.

TABLE 2-11

LIGHT RAIL LABOR INPUTS PER UNIT OF SERVICE BY TYPE OF EMPLOYEE

	Vehicle Operators Per 1,000 Total Vehicle Hours	Vehicle Mechanics Per 10,000 Total Vehicle Miles	Vehicle Mechanics and Vehicle Servicers Per 10,000 Total Vehicle Miles	Other Personnel Per 1,000 Total Vehicle Hours
SEPTA	0.790	0.302	0.359	0.904
NJT	0.586	0.246	0.316	0.241
MBTA	1.632	0.382	0.500	1.751
GCRTA	1.192	0.333	0.388	2.170
SF MUNI	0.857	0.517	0.606	0.910
PAT	0.935	0.252	0.375	1.101
NOPSI	0.640	0.426	0.553	0.468
SDTI	0.353	0.056	0.075	0.588
Average	0.873	0.314	0.396	1.017
St Dev	0.396	0.014	0.017	0.653
Minimum	0.353	0.056	0.075	0.241
Maximum	1.632	0.517	0.606	2.170

Source: National Urban Mass Transportation Statistics, U.S. DOT, Urban Mass Transportation Administration, Office of Technical Assistance, (Fiscal Year 1982).

Key: See Table 2-9.

TABLE 2-12

LIGHT RAIL EMPLOYEES PER UNIT OF CAPACITY

System	Employees Per Million Place Miles[1]	Employees Per Million Place Hours[1]
SEPTA	3.084	28.555
NJT	1.003	19.682
MBTA	2.415	36.567
GCRTA	3.007	48.647
SF MUNI	1.902	21.721
PAT	2.650	39.555
NOPSI	2.700	23.428
Average	2.394	31.165
St. Dev.	0.729	10.746
Minimum	1.003	19.682
Maximum	3.084	48.647

[1]A place is a measure of capacity (5.38 square feet).

TABLE 2-13

ELECTRIC RAIL RAPID TRANSIT ENERGY CONSUMPTION

Electrical[1/] Energy Source	Average Value Energy Consumption (per car-mile)	Range of Values Energy Consumption[2/] (per car-mile
Coal	5.10 pounds	4.55-10.20 pounds
No. 6 fuel oil	0.44 gallons	0.41-0.46 gallons
Diesel fuel	0.46 gallons	0.44-0.49 gallons
Gasoline	0.51 gallons	0.49-0.55 gallons
Furnace oil	0.47 gallons	0.45-0.50 gallons
Kerosene	0.50 gallons	0.46-0.55 gallons
Natural gas	60.00 cubic feet	52.00-66.00 cubic feet
Manufactured gas	120.00 cubic feet	100.00-164.00 cubic feet

1/Average consumption for rail transit systems is about 6.6 kilowatt-hours per car-mile.

2/Based on 1979 data from the following rail transit systems: Cleveland, Philadelphia, Washington, Chicago, and New York.

Sources: Fink, D.G., and Carroll, J.M., Standard Handbook for Electrical Engineers, McGraw-Hill, New York, 1963.

Wells, J.D., Asher, N.J., Flowers, M.R., et al., Economic Characteristics of the Urban Public Transportation Industry, Institute for Defense Analyses, Washington, D.C., February 1972.

Lang, A.S., and Soberman, R.M., Urban Rail Transit: Its Economics and Technology, MIT Press, Cambridge, Massachusetts, 1964.

U.S. Department of Transportation, National Urban Mass Transportation Statistics (UMTA-MA-60-0107-81-1), Washington, D.C., May 1981.

TABLE 2-14

DIESEL COMMUTER RAIL TRANSIT ENERGY CONSUMPTION

Value	Diesel Consumption (per car-mile)
Average	1.9 gallons
Range	1.4 - 2.4 gallons

Source: DeLeuw, Cather and Company, Energy Analysis of Urban Passenger Travel Alternatives, Washington, D.C., April 1974.

TABLE 2-15

ELECTRIC LIGHT RAIL TRANSIT ENERGY CONSUMPTION

Current data (1981 Section 15 Reports) do not support a significant difference between light rail and rail rapid energy consumption per car-mile. Older data suggest that light rail consumes about 75 percent as much energy per car-mile as rail rapid. Values from Table 2-13 should be used as they stand, or adjusted or reflect an assumed efficiency factor for light rail.

TABLE 2-16

MAGNITUDE OF POLLUTANTS GENERATED BY RAIL RAPID TRANSIT POWERED BY ELECTRICAL ENERGY1/

	Electrical Energy Source		
Pollutant	Coal (grams/car-mile)	Natural Gas (grams/car-mile)	Residual2/ Oil (grams/car-mile)
Carbon monoxide	0.4536	negl.	0.0068
Hydrocarbons	0.1860	negl.	0.5443
Oxides of nitrogen	18.5976	9.5256	17.6904
Oxides of sulfur	69.8544	0.0095	13.6080
Aldehydes	0.0045	0.0240	0.1043
Particulates	146.5128	0.3629	1.7237
Totals	235.6089	9.9220	33.6775

1/Assumes 5.3 kwhr/car-mile, .5% sulfur content for oil, and 10% ash content for coal.

2/Residual oil includes fuel oil and furnace oil.

Note: The type, age, control devices, and location of the power generating plant can make a large difference in the quantities of pollutants emitted. These rates assume no stack (scrubber) controls for the generating plant. If stack controls were placed on the plant to reduce oxides of sulphur and particulates by a certain percentage, the rates for oxides of sulphur and particulates should be reduced by that percentage - e.g., a 50 percent capture of oxides of sulphur and particulates would reduce the oxides of sulphur and particulate emission rates 50 percent. Stack controls would cause a negligible reduction in the oxides of nitrogen rates and no reduction in the carbon monoxide, hydrocarbon, and aldehyde pollution rates.

Source: Wells, J.D., Asher, N.J., Flowers, M.R., et al., Economic Characteristics of The Urban Public Transportation Industry, Institute for Defense Analyses, Washington, D.C., February 1972.

TABLE 2-17

MAGNITUDE OF POLLUTANTS GENERATED BY LIGHT RAIL TRANSIT
POWERED BY ELECTRICAL ENERGY[1]

Pollutant [3]	Electrical Energy Source Coal (grams/car-mile)	Natural Gas (grams/car-mile)	Residual[2] Oil (grams/car-mile)
Carbon monoxide	0.3515	negl.	0.0053
Hydrocarbons	0.1442	negl.	0.4218
Oxides of nitrogen	14.4131	7.3823	13.7101
Oxides of sulfur	54.0383	0.0074	10.5462
Aldehydes	0.0035	0.0186	0.0808
Particulates	113.3401	0.2812	1.3359
Totals	182.2907	7.6895	26.1001

[1]Assumes 5.3 kwhr/car-mile, .5% sulfur content for oil, and 10% ash content for coal.

[2]Residual oil includes fuel oil and furnace oil.

[3]Default value and range of values are based on the efficiency factor from Table 2-15.

Note: The type, age, control devices, and location of the power generating plant can make a large difference in the quantities of pollutants emitted. These rates assume no stack (scrubber) controls for the generating plant. If stack controls were placed on the plant to reduce oxides of sulphur and particulates by a certain percentage, the rates for oxides of sulphur and particulates should be reduced by that percentage - e.g., a 50 percent capture of oxides of sulphur and particulates would reduce the oxides of sulphur and particulate emission rates 50 percent. Stack controls would cause a negligible reduction in the oxides of nitrogen rates and no reduction in the carbon monoxide, hydrocarbon, and aldehyde pollution rates.

TABLE 2-18

NATIONAL DISTRIBUTION OF FUEL SOURCES FOR ELECTRIC POWER GENERATON[1] (1950-1980)

Fuel Source	1950	1955	1960	1965	1970	1975	1980
Coal	47.1	55.1	53.5	54.1	46.2	44.7	51.1
Hydro	29.2	20.7	19.3	18.4	16.2	15.6	12.1
Natural gas	13.5	17.4	21.0	21.0	24.3	15.6	15.1
Residual oil[2]	10.3	6.8	6.1	6.1	11.9	15.1	10.7
Nuclear	-	-	.1	.4	1.4	9.0	11.0

[1]Fossil fuel provides over 80 percent of power needed for rail transit systems. Each location, however, shows its own characteristics, and thus there is a large variance in this figure.

[2]Residual oil includes fuel oil and furnace oil.

Source: U.S. Statistical Abstract, 1982-83.

TABLE 2-19

NATIONAL COMPOSITE OF POLLUTANTS GENERATED BY FUEL SOURCES FOR RAIL RAPID TRANSIT[1]
(1980)

	FUEL			Average Pollutants Generated
	Coal	Natural Gas	Residual Oil[2]	
Pollutant	(Grams/ Car-mile)	(Grams/ Car-mile)	(Grams/ Car-mile)	Grams/ Car-mile)
Carbon monoxide	0.2318	0.0000	0.0007	0.2325
Hydrocarbons	0.0225	0.0000	0.0582	0.1533
Oxides of nitrogen	9.5034	1.4384	1.8929	12.8346
Oxides of sulfur	35.6956	0.0014	1.4560	37.1530
Aldehydes	0.0023	0.0036	0.0112	0.0171
Particulates	74.8680	0.0548	0.1844	75.1072

1 This table was calculated by multiplying the number of grams of pollutants per car-mile for each energy source (1972) given in Table 2-16 by the percent of electricity generated by that energy source (1980) as given in Table 2-18. It was assumed that no pollutant emissions resulted from generating electricity by water, and that nuclear energy air pollution was minimal. The type of pollution control devices now in place may vary from these estimates.

2 Residual oil includes fuel oil and furnace oil.

Sample Calculation

Average carbon monoxide/ car mile (.5110)(.4536) + (.1510)(negl.) + (.1070)(.0068) = 0.2325 grams/car-mile

TABLE 2-20

NATIONAL COMPOSITE OF POLLUTANTS GENERATED BY FUEL SOURCES FOR LIGHT RAIL TRANSIT[1] (1980)

	FUEL			Average Pollutants Generated
	Coal	Natural Gas	Residual Oil[2]	
Pollutant	(Grams/ Car-mile)	(Grams/ Car-mile)	(Grams/ Car-mile)	Grams/ Car-mile)
Carbon monoxide	0.1796	0.0000	0.0006	0.1802
Hydrocarbons	0.0737	0.0000	0.0451	0.1188
Oxides of nitrogen	7.3651	1.1147	1.4670	9.9468
Oxides of sulfur	27.6136	0.0011	1.1284	28.7431
Aldehydes	0.0018	0.0028	0.0086	0.0132
Particulates	57.9168	0.0425	0.1429	58.1022

1 This table was calculated by multiplying the number of grams of pollutants per car-mile for each energy source (1972) given in Table 2-17 by the percent of electricity generated by that energy source (1980) as given in Table 2-18. It was assumed that no pollutant emissions resulted from generating electricity by water, and that nuclear energy air pollution was minimal. The type of pollution control devices now in place may vary when compared to these estimates.

2 Residual oil includes fuel oil and furnace oil.

Sample Calculation

Average carbon monoxide/ car mile (.5110)(.3515) + (.1510)(negl.) + (.1070)(.0053) = 0.1802 grams/car-mile

TABLE 2-21

MAGNITUDE OF POLLUTANTS GENERATED BY COMMUTER RAIL
DIESEL LOCOMOTIVE
(1970)

Pollutant	Magnitude (grams/mile)
Carbon monoxide	30.8
Hydrocarbons	22.0
Oxides of nitrogen	33.0
Oxides of sulfur	28.6
Aldehydes	1.8
Particulates	11.0
Organic acids	3.1

Note: Data are based on weighting factors applied to actual tests conducted at various load and idle conditions with an average gross vehicle weight of 30 tons and fuel consumption of about 5.0 miles per gallons.

Source: Unpublished test data on locomotive engines. General Motors Corporation, Warren, Michigan, July 1970.

TABLE 2-22

RAPID RAIL NOISE EXPOSURE

	MBTA (Boston)	SEPTA (Philadelphia)	PATCO (New Jersey)	RTA (Cleveland)	BART (San Francisco)	CTA (Chicago)	NYCTA-2 LINES (New York)
IN-CAR NOISE							
Average Inter-Station L_A (Max)-dBA	82	85	76	83	80	85	90
(Standard Deviation)-dBA	(6.1)	(5.9)	(3.2)	(1.5)	(3.3)	(3.7)	(4.2)
L_{eq}(R)-dBA*	79	84	73	81	78	84	89
IN-STATION NOISE							
Average Station L_A (Max)-dBA	87	92	80	82	80	85	100
(Range)-dBA	(80-93)	(80-98)	(70-89)	(77-88)	(76-85)	(75-103)	(83-112)
Average Station L_{eq}-dBA	76	80	72	73	69	75	87
WAYSIDE NOISE							
Average L_A (Max) in Residential Areas at 50 Feet-dBA	87	86	84	95	89	92	87
(Range)-dBA	(83-92)	(76-89)	(76-94)	(84-99)	(86-91)	(74-101)	(76-102)

*Average in-car L_{eq} level for entire system.

Source: Gregory Chisholm, Herbert Bogen, Michael Dinning, Michael Primeggia, National Assessment of Urban Rail Noise, Report Number UMTA-MA-06-0099-79-2, U.S. Department of Transportation Research and Special Programs Administration, Transportation Systems Center, March 1979.

Note:

L_A Max is the maximum sound level experienced by a person during the period of exposure.

L_{eq}, the Equivalent Sound Level, represents the equivalent steady noise level which in a given period of time would contain the same noise energy as the time varying noise during the same period.

TABLE 2-23

AVERAGE COST PER MILE FOR LAND-RAIL RAPID AND LIGHT RAIL

City	Average 1980 Dollar Land Cost (Millions Per Mile)1/	Average 1983 Dollar Land Cost (Millions Per Mile2/
Rail Rapid		
San Francisco	$5.1	$6.2
Atlanta	8.9	10.8
Boston	2.4	2.9
Baltimore	2.8	3.4
Washington	3.7	4.5
Chicago	0.6	0.7
Philadelphia	1.8	2.2
Average of Averages	3.6	$4.4
Light Rail		
Edmonton	$1.3	$1.6
Calgary	2.2	2.7
San Diego	1.5	1.8
Average of Averages	1.7	$2.0

1/Source: Thomas Dooley, Transportation Systems Center, U.S. DOT.

2/Previous column multiplied by change in the Consumer Price Index. Land values and indexes of land values are highly volatile and year by year land values in a particular city may show substantial changes. Values above depend on percentage in subways or in highway medians.

TABLE 2-23 (continued)

RAPID AND LIGHT RAIL TRANSIT LAND COSTS

City and Line	1980 Cost Per Mile ($ Millions)	Percent Along Existing Railroad Corridor	Percent in Highway Median
Rail Rapid			
San Francisco (BART)			
Alameda (Freemont-Fruitvale)	5.1	80%	0%
Contra Costa (Concord-Richmond)	2.2	0%	20%
Richmond (Richmond-Ashby)	8.3	0%	0%
Central Oakland (Mac-OakW)	9.4	0%	0%
Mission (16th-Daly)	7.0	0%	0%
S. F. Line (E-C)	2.1	0%	0%
Transbay	NA	NA	NA
TOTAL	5.1	5%	1%
Atlanta (MARTA)			
Phase A	8.9	50%	0%
Boston (MBTA)			
Red Line South	2.3	80%	0%
Red Line North	4.2	20%	0%
Orange Line North	2.1	100%	0%
Baltimore (MTA)			
Section I	2.8	56%	0%
Washington (WMATA)			
101 Mile System	3.7	20%	0%
Chicago (CTA)			
Englewood	4.7	0%	0%
Philadelphia (PATCO)			
Lindenwold	1.8	75%	0%
Light Rail			
San Diego	1.5	90%	0%

Source: Thomas Dooley, Transportation Systems Center, U.S. DOT.

TABLE 2-24

1983 DOLLAR COSTS OF RECENTLY CONSTRUCTED
RAPID RAIL INFRASTRUCTURE

Location	Miles	Percent Underground	Stations	1983 Cost Per Two Track Mile ($Millions)
Atlanta	16.3	42%	17	$81.7
Baltimore	8.0	56%	9	97.7
Boston (2 Projects)	12.7	25%	9	74.3
Chicago (3 Projects)	22.9	8%	19	19.9
Cleveland	19.0	2%	18	15.0
Miami	21.0	0%	20	34.9
Philadelphia	14.5	0%	13	21.0
San Francisco	71.0	28%	34	60.9
Washington	70.0	57%	60	113.6

Source: Thomas Dooley, Transportation Systems Center, U.S. DOT.

Notes: These are summary costs, and it must be noted that the per-mile costs vary considerably for underground, at-grade, or elevated construction. For more detailed information, see tables B-13, B-14, and B-15.

Costs are subject to change for projects still under construction, such as Miami, Washington, and Atlanta.

Infrastructure includes land, guideway, stations, power, track, signal, yards and shops, and project design and management unless otherwise noted. Costs were converted to 1983 dollars using ENR cost indexes for each city, except Miami and Washington, for which the U.S. index was used, with the conversion based on the mid-point of construction. This introduces some error for systems whose construction spanned several years..

TABLE 2-25

EXPECTED COST AND RANGE OF COSTS - RAPID RAIL SYSTEMS

Percent Underground	Expected Cost Per Mile ($M)	95 % Probability* Range ($M)	80% Probability Range ($M)
8.4	$33	$23-43	$28-39
24.2	60	51-67	55-64
40	86	76-94	80-91
60	118	104-131	109-126
80	151	131-170	139-162
100	184	159-208	169-199

Source: Dooley, Thomas, Transportation Systems Center, developed using data from nine systems, converted to 1983 dollars using the ENR construction index.

*For example, if 60 percent of the system is underground, there is a 95 percent probability that the cost in 1983 dollars will fall in the range of $104 to $131 million per mile. There is a 5 percent probability (one chance in twenty) that the cost in 1983 dollars will be less than $104 million or exceed $131 million.

TABLE 2-26

DISTRIBUTION OF RAPID RAIL SUBSYSTEM COSTS BY MAJOR SUBSYSTEM

	Percent of Costs, by City and Project					
	San Francisco	Atlanta	Baltimore	Chicago	Boston MBTA	
Subsystem	BART (All)	MARTA Phase A	MTA Phase I	CTA O'Hare	Red Line South	Red Line Northwest 1/
Land	7%	9%	2%	0%	11%	2%
Guideway	37	33	25	20	15	32
Stations	20	20	30	28	34	39
Trackwork	3	2	2	7	7	3
Power	3	1	2	5	6	4
Control	4	2	4	8	7	4
Facilities	2	2	2	4	0	0 1/
Eng./Mgt./Test	14	23	24	8	6	16
Vehicles	12	7	9	20	15	0 1/

Source: Thomas Dooley, Transportation Systems Center, U.S. DOT.

1/The lack of either vehicle purchases or facilities associated with the Red Line Northwest project renders it non-comparable with the other systems.

TABLE 2-27

1983 DOLLAR COSTS OF RECENTLY CONSTRUCTED LIGHT RAIL INFRASTRUCTURE

Location	Miles	Percent Underground	Stations	1983 Cost Per Two Track Mile ($Millions)
San Diego	16	0%	18	$6.3
Calgary	8.2	7	12	20.3
Edmonton	4.5	22	5	22.2
Buffalo	6.4	81	14	88.4

Source: Thomas Dooley, Transportation Systems Center, U.S. DOT. The figures compiled by Thomas Dooley and shown in the appendix were converted to 1983 dollars from 1980 dollars using the average U.S. ENR Construction Cost Index for years 1980 and 1983.

Note: Costs vary substantially based on whether underground, elevated, or at-grade construction was required in the particular context. For more detail, see tables B-16, B-17, B-18, and B-19.

TABLE 2-28

COSTS OF RAIL RAPID TRANSIT ROLLING STOCK

Year Ordered	City	Quantity Ordered	Price Per Car	Price Per Foot	Price Per Place
1983	Cleveland	60	$872,770	$11,637	$6,010
1982	New York	225	915,000	12,200	6,564
1982	New York	825	798,770	15,561	10,688
1982	New York	325	844,500	16,452	11,299
1982	Atlanta	30	1,109,900	14,798	7,583
1982	San Francisco	150	1,002,883	13,372	6,851
1980	Philadelphia	125	570,840	8,457	4,550
1979	Washington	94	749,991	10,000	5,292
1979	Baltimore/Miami	208	616,238	8,217	4,313
1978	Chicago	300	444,295	9,208	5,308

Source: N.D. Lea and Associates, Inc., "U.S. Transit Railcar Market Survey," prepared for Urban Mass Transportation Administration Office of Technical Assistance, September 1983.

Notes: Costs are in actual dollars as of order date. Unit costs depend on number of cars ordered, passenger amenities, size, electronic equipment, etc.

A "place" is equal to 5.38 square feet.

TABLE 2-29

COSTS OF LIGHT RAIL TRANSIT ROLLING STOCK

Year Ordered	City	Quantity Ordered	Price Per Car	Price Per Foot	Price Per Place
1983	San Jose	30	$860,000	9,946	$6,108
1982	Pittsburgh	55	896,200	10,584	6,464
1981	San Francisco	30	776,895	10,642	6,484
1981	Portland	26	775,521	8,914	5,456
1981	Buffalo	26	645,000	9,948	6,052
1979	San Diego	14	630,000	8,430	5,231

Source: N.D. Lea and Associates, Inc., "U.S. Transit Railcar Market Survey," prepared for Urban Mass Transportation Administration Office of Technical Assistance, September 1983.

Notes: Costs are in actual dollars as of order date. Unit costs depend on number of cars ordered, passenger amenities, size, electronic equipment, etc.

A "place" is equal to 5.38 square feet.

TABLE 2-30

RAIL RAPID TRANSIT INJURIES AND FATALITIES
PER CAR-MILE AND PER PASSENGER (1983)

TYPE OF PERSON	NON-FATAL INJURIES Per Million Passengers	NON-FATAL INJURIES Per Million Car-Miles	FATALITIES Per Million Passengers	FATALITIES Per Million Car-Miles
Passenger in Vehicle, Boarding, or Alighting	0.36	1.36	.003	.012
Authorized Person in Station or Other Authorized Location	0.75	2.79	.002	.007
Non-Authorized Person in Non-Authorized Location	0.01	0.02	.004	.014
Emergency Force (Fire, Police, Medical)	0	0	0	0
Contractor, Other Official Duty Person	*	0.01	.001	.005
Passenger in Unauthorized Area	0.14	0.53	.022	.081
TOTAL	1.26	4.72	.032	.119

*Figure is less than 0.01.

Source: David M. Daley, U.S. Department of Transportation, Heavy Rail Transit Safety 1983 Report, Report Number UMTA-MA-06-0152-84-1, July 1984.

TABLE 2-31

COMMUTER RAIL ACCIDENTS
(PER MILLION PASSENGER MILES)
(1977-1980)

Type of Accidents	Rate	Range
Injuries	2.253	.82 - 7.30
Fatalities	0.127	.041 - 0.195

Based on four years of data from all U.S. commuter railroads.

Note: Does not include injuries and fatalities to employees or other persons involved who are not passengers.

Fatal accidents are not included in injury rate calculations.

Injury rate for passengers may be lower for new systems since many of the above accidents were caused by defects in equipment/ maintenance of rolling stock and structures. Above accidents caused by negligence of track defects (42 percent), equipment failures (19 percent), human factors (26 percent), other (13 percent).

Source: Table B-27.

TABLE 2-32

LIGHT RAIL TRANSIT ACCIDENTS
INJURIES AND FATALITIES
(1982)

Type of Accidents	RATES Per Million Car-Miles	Per Million Passengers
Accidents	176.11	21.34
Injuries	89.52	10.85
Fatalities	0.31	0.04

Source: U.S. Department of Transportation, National Urban Mass Transportation Statistics, 1982 Section 15 Report, Washington, D.C., November 1983.

TABLE 2-33
DETAILED BREAKDOWN OF ENERGY REQUIREMENTS FOR RAIL RAPID TRANSIT
(Btu's per place-mile[1/])

Mode	Speed MPH[2/]	Vehicle Operation[3/]	Maintenance[4/]	Wayside and Station[5/]	Vehicle Manufacture[6/]	Guideway Construction[7/]	Total[8/]
Rapid Transit at Grade	10	670 [9/]	34	149	13	819	1,685
	20	670 [9/]	34	75	13	410	1,202
	50	670 [9/]	34	30	13	164	911
Rapid Transit Underground	20	670 [9/]	34	516	13	867	2,100
	30	670 [9/]	34	344	13	578	1,639
	50	670 [9/]	34	206	13	347	1,270

Source: Pushkarev, Boris S., with Jeffrey M. Zupan and Robert S. Cumella, Urban Rail In America, A Regional Plan Association Book, Indiana University Press 1982, pp. 85-98.

1/ Energy use is given per place-mile to take account of different vehicle sizes. One place = 5.38 sq. ft. or $0.5 m^2$ of vehicle area.

2/ Miles per hour.

3/ Vehicle operation is nearly independent of speed: the energy needed for frequent acceleration on the slower systems roughly balances that needed to attain high speed on the faster systems.

4/ Energy used for vehicle maintenance depends on fleet size.

5/ Wayside and station energy is mostly a fixed value that declines per place-mile as traffic density per line-mile increases. It varies with the spacing of stations, the type of construction (aboveground or underground), and the type of ventilation (with or without air conditioning).

6/ The energy needed to manufacture vehicles varies among modes according to the longevity of the different equipment.

7/ Based on the construction cost per mile of line of 1977 dollars, the average energy content of a fixed guideway construction dollar (30,000 Btu) in 1977 prices, and the useful life of the various types of guideways.

8/ The total energy requirement of a mode is not a fixed number but a variable, strongly dependent on traffic volume and additional factors such as regenerative braking on rapid transit cars and air-conditioning of stations.

9/ Subtract 130 if regenerative braking is available.

TABLE 2-34

DETAILED BREAKDOWN OF ENERGY REQUIREMENTS FOR LIGHT RAIL
(Btu's per place-mile[1/])

Mode	Speed MPH[2/]	Vehicle Operation[3/]	Maintenance[4/]	Wayside and Station[5/]	Vehicle Manufacture[6/]	Guideway Construction[7/]	Total[8/]
Light Rail At Grade	10	370	34	149	24	600	1,177
	20	370	34	75	24	300	803
	50	370	34	30	24	120	578
Light Rail Underground	10	370	34	1,032	24	1,667	3,127
	20	370	34	516	24	833	1,777
	50	370	34	206	24	333	967

Source: Pushkarev, Boris S., with Jeffrey M. Zupan and Robert S. Cumella, Urban Rail In America, A Regional Plan Association Book, Indiana University Press 1982, pp. 85-98.

1/Energy use is given per place-mile to take account of different vehicle sizes. One place = 5.38 sq. ft. or $0.5m^2$ of vehicle area.

2/Miles per hour.

3/Vehicle operation is nearly independent of speed: the energy needed for frequent acceleration on the slower systems roughly balances that needed to attain high speed on the faster systems.

4/Energy used for vehicle maintenance depends on fleet size.

5/Wayside and station energy is mostly a fixed value that declines per place-mile as traffic density per line-mile increases. It varies with the spacing of stations, the type of construction (aboveground or underground), and the type of ventilation (with or without air conditioning).

6/The energy needed to manufacture vehicles varies among modes according to the longevity of the different equipment.

7/Based on the construction cost per mile of line of 1977 dollars, the average energy content of a fixed guideway construction dollar (30,000 Btu) in 1977 prices, and the useful life of the various types of guideways.

8/The total energy requirement of a mode is not a fixed number but a variable, strongly dependent on traffic volume and additional factors such as regenerative braking on rapid transit cars and air-conditioning of stations.

TABLE 2-35

SELECTED HEAVY RAIL VEHICLE CAPACITIES

Operator	Car Numbers	Gross Area Square Feet	Capacity in Places	Stated Capacity Seats (A:B)	Standees Design (A:B)	Standees Crush (A:B)
MARTA	101-200	788	146	68	72	182
	501-520	791	147	62	78	173
MTA	100-171	769	143	76	90	149
MBTA	1600-1651	698	130	64	NA	205
	1500-1523	698	130	60	NA	198
	0600-0669	452	84	42	NA	113
	1200-1319	604	112	58	NA	162
CTA	2201-2350	450	84	47:51	53:49	103:99
	2401-2600	450	84	45:49	55:51	105:101
	2601-2900	450	84	43:49	57:51	107:101
GCRTA	171-180	732	136	80	40	100
NYCTA	R-42	605	112	46	174	254
	R-44	750	139	72:76	200:204	278:274
	R-46	750	139	70:76	202:204	280:274
	R-44 SIRT	750	139	72:76	200:204	278:274
PATH	PA2/710-723	474	88	41	99	156
	PA2/152-181	474	88	42	98	156
	PA3/724-769	474	88	35	139	187
SEPTA	701-929	503	93	56	59	146
	601-646	503	93	54	61	146
PATCO	201-250	690	128	80	20	120
	101-125	690	128	72	18	118
	251-296	690	128	80	20	120
BART	501-774	750	139	72	48	144
	101-276	792	147	72	48	144
WMATA	1000-1299	762	142	80	95	140
	2000-2093	762	142	68	119	164

Source: Michael Jacobs, Robert E. Skinner, and Andrew T. Lemer, "Technical Guidance for Transit Project Planning: Estimation of Transit Suppy Parameters, September 1982; compiled from data supplied by the American Public Transit Association (APTA), 1980.

"Capacity in Places" is defined as 5.38 square feet, by B. Pushkarev, Urban Rail In America: An Exploration of Criteria for Fixed Guideway Transit," 1982, Indiana University Press.

NA = Not available.

TABLE 2-36

CAPACITIES OF SELECTED LIGHT RAIL TRANSIT VEHICLES
(INCLUDES BOTH NORTH AMERICAN AND EUROPEAN VEHICLES)

Vehicle	Gross Area Square Feet	Capacity in Places	Stated Capcity		
			Seated	Standees	
				Design	Crush
PCC Car (Non-Artic)	391.5	73	49	69	NA
UTDC Toronto (Non-Artic)	422.1	78	51	90	NA
BN Ghent (Non-Artic)	336.4	63	34	69	80
BN Marseille (Non-Artic)	308.8	57	16	71	81
MAN Nurnberg (Non Artic) (powered unit)	355.3	66	29	100	NA
Wegmen/Bremen (Artic)	413.6	77	48	101	118
Boeing US Std LRV (Artic)	629.1	117	SF 68	151	NA
			BOS 52	167	NA
Met-Cam Newcastle (Artic)	792.5	147	84	188	246
BN/Brussels (Artic)	495.1	92	43	115	138
DuWAG/Hanover (Artic)	524.6	98	44	134	160
MAN/Nurnberg (Artic)	506.5	94	41	145	227
MAN/Angsberg (Dual-Artic)	600.4	112	61	87	174
DuWAG/Hanover (Dual-Artic)	698.0	130	46	104	208
DuWAG/Frankfort (Dual-Artic)	693.9	129	62	108	216
BN/Brussels/(Dual-Artic)	653.7	122	48	110	128

Source: Jacobs, Michael, Robert E. Skinner, and Andrew T. Lemer, "Technical Guidance for Transit Project Planning: Estimation of Transit Supply Parameters" compiled from N.D. Lea Transportation Research Corporation data, September 1982. One "place" equals 5.38 square feet, based on Pushkarev, Boris, et. al. Urban Rail in America, Indiana University Press, 1982.

CHAPTER III

LOCAL BUS AND BUS RAPID TRANSIT

This chapter contains a set of quantitative values for the eight supply parameters selected to characterize motorized bus transport: speed, capacity, operating cost, labor inputs, energy consumption, pollutant emissions, capital cost, and accident frequency. In some cases, buses have been treated without regard to variations in size and function. This is not true in relation to speed, capacity, energy consumption, and pollutant emission, where some distinctions are made according to bus type and function. Appendix C should be consulted for more detailed and specific information.

TABLE 3-1

TYPICAL BUS SPEEDS

Type of Service	Speed (mph) Peak	Off-Peak
Local Bus (Small City) on Collector Street	10	12
Local Bus (Large City) on Collector Street	5	7
Local Bus in Bus Lane on Collector Street[1/]	8	10 [2/]
Local Bus on Arterial Street[3/]	10-11	13-15
Local Bus on Arterial Reserved Lane[4/]	15	17 [5/]
Express Bus on Freeway	30	45
Express Bus in Freeway Bus Lane	45	45 [6/]
Bus on CBD Bus Mall	5	5

[1/]Data reflect speeds in large cities; reserved curb, median, and contra-flow bus lanes as well as bus streets.

[2/]Not usually operated in off-peak hours; estimated at 10 mph.

[3/]Data reflects speeds in small and large cities.

[4/]Data reflects speeds in large cities: reserved curb, median, and contra-flow bus lanes.

[5/]Not usually operated in off-peak hours; estimated at 17 mph.

[6/]Not usually operated in off-peak hours; estimated at 45 mph.

Note: See Tables C-1, C-2, and C-3 for site-specific speeds on bus lanes.

Sources: Levinson, H., Hoey, W., Sanders, D., Wynn, H., Bus Use of Highways: State of the Art, National Cooperative Highway Research Report 143, Washington, D.C., 1973.

Levinson, H., and Sanders, D., Reserved Bus Lanes on Urban Freeways: A Macro Model, Highway Research Board, Washington, D.C., January 1974.

American Transit Association (now APTA), Transit Operating Reports, Washington, D.C., 1971-1972.

E. Edminister and D. Koffman, "Streets for Pedestrians and Transit - An Evaluation of Three Transit Malls in the United States, Final Report." February 1979, Report Number UMTA-MA-06-0048-79-1.

TABLE 3-2

OBSERVED PEAK HOUR BUS VOLUMES

Facility	Number of Buses per Hour	Headway (Seconds)	Passengers Per Hour	Average Bus Speed (MPH)
Freeways or Busways				
Lincoln Tunnel	735	4.9	32,560	30
I-495, New Jersey (Exclusive Bus Lane)	485	7.3	21,600	30-40
San Francisco-Oakland Bay Bridge	350	10.3	13,000	30-40
Shirley Highway Busway	200	18.0	10,000	35+
Bus Only Malls				
State Street (Chicago)	180	20.0	9,000	0-5
4th and 5th Streets (Portland, Oregon)	180	20.0	9,000	5-10
Arterial Streets				
Michigan Ave., Chicago	228	15.0	11,400	NA
Madison Avenue, NYC	220	18.0	10,000	NA
Hillside Avenue, NYC	170	17.0	8,500 1/	NA
14th Street (D.C.)	160	23.0	8,000	5-12
Market Street (Phila.)	150	24.0	6,100-9,900	5-10
K Street (D.C.)	130	28.0	6,500	5-8
Main Street (Rochester)	80	45.0	4,000	5
Various Other Downtown Streets	80-120	30-40	4,500-6,000 1/	5-10

Source: Levinson, Herbert S., "Chapter 12: Transit, of the New Highway Capacity Manual," September 29, 1984, p. 127. Data were compiled from various bus-use studies.

1/Passengers per hour estimated at 50 per bus.

NA = Not available.

TABLE 3-3

BUS AND PASSENGER SERVICE VOLUMES AT BUS BOARDING STOPS

Type of Fare Payment	Bus Loading Condition1/	Cumulative Total Passengers Per Hour — Number of Berths2/				Cumulative Total Buses Per Hour — Number of Berths3/			
		1	2	3	4	1	2	3	4
Pay Upon Boarding 1 door available	On-line	650	1140	1460	1620	13	23	30	33
	Off-line	650	1200	1750	2240	13	24	35	45
Prepayment 1 door available	On-line	950	1660	2140	2380	19	34	43	48
	Off-line	950	1760	2570	3280	19	36	52	66
Prepayment 2 doors available	On-line	1550	2710	3490	3830	31	54	70	77
	Off-line	1550	2870	4190	5350	31	58	84	107

1/On-line loading: passengers board buses while the buses are still in the main roadway; off-line loading: bus berths located off the main roadway where a bus, once loaded, can pull out and into the traffic stream.

2/Passenger rates account for expected internal impedances, peak 20-minute demand, and inefficiencies in berth loading capabilities.

3/Based on 50 passengers per bus.

Source: Wilbur Smith and Associates, Design and Analysis of Bus and Truck Roadway Systems in Urban Areas, Draft Report, New Haven, Connecticut, November 1973.

TABLE 3-4

BUS OPERATING COSTS FOR LARGE BUS SYSTEMS IN THE U.S.
(FY 1982)

System	Total Operating Cost	Cost Per Total Vehicle Hour	Cost Per Revenue Vehicle Hour	Cost Per Revenue Vehicle Mile
NYCTA/MaB (NY)	$633,370,618	$49.38	$53.78	$6.64
SCRTD (LA)	353,651,195	48.35	52.53	3.90
CTA (CHICAGO)	320,924,248	42.41	42.41	4.23
SEPTA (PHILA.)	171,908,984	48.14	51.76	5.14
SEMTA (DETROIT)	137,080,269	51.51	62.60	4.01
AC (SF/OAKLAND)	96,232,839	42.39	43.45	2.95
SF MUNI	74,499,490	44.22	47.76	5.00
WMATA (WASH DC)	190,347,331	46.13	64.20	3.62
DTS (DALLAS)	37,138,776	35.97	35.97	2.54
HOUSTON	88,038,437	49.83	57.94	3.98
BISTATE (ST. LOUIS)	81,762,989	43.09	51.35	4.01
PAT (PITTSBURGH)	105,240,408	41.16	42.40	3.20
BALTIMORE	86,774,032	41.68	46.45	3.99
SDTC (SAN DIEGO)	32,385,693	39.47	52.03	3.35
MARTA (ATLANTA)	78,763,721	35.90	39.61	2.95
DENVER	69,166,983	43.01	60.12	3.57
MILWAUKEE	59,051,218	35.38	35.77	2.88
KANSAS CITY	27,505,066	43.69	46.63	3.27
NEW ORLEANS	48,379,542	40.72	40.72	3.90
PORTLAND, OR	64,422,498	40.85	54.08	3.33
BUFFALO	31,598,144	33.26	33.32	3.05
ORANGE COUNTY, CA	60,663,082	47.67	52.60	3.66
Average		$42.92	$48.52	$3.78
St Dev		5.02	8.70	0.91
Minimum		$33.26	$33.32	$2.54
Maximum		51.51	64.20	6.64

TABLE 3-4 (continued)

BUS OPERATING COSTS FOR LARGE BUS SYSTEMS IN THE U.S.
(FY 1982)

System	Cost Per Employee	Cost Per Peak Vehicle
NYCTA/MaB	$41,431.98	$202,743.48
SCRTD (LA)	44,596.62	186,328.34
CTA (CHICAGO)	43,896.08	164,914.82
SEPTA (PHILA.)	49,713.41	156,994.51
SEMTA (DETROIT)	51,302.50	170,923.03
AC (SF/OAKLAND)	44,836.79	131,465.63
SF MUNI	44,424.26	188,130.03
WMATA (WASH DC)	43,162.66	125,310.95
DALLAS	34,709.14	84,024.38
HOUSTON	46,804.06	228,078.85
BISTATE (ST. LOUIS)	41,652.06	125,211.32
PAT (PITTSBURGH)	42,487.04	135,794.07
BALTIMORE	43,714.88	123,258.57
SDTC (SAN DIEGO)	39,255.39	165,233.13
MARTA (ATLANTA)	33,717.35	123,068.31
DENVER	42,459.78	131,496.17
MILWAUKEE	40,809.41	114,440.34
KANSAS CITY	42,315.49	111,809.21
NEW ORLEANS	37,503.52	127,314.58
PORTLAND, OR	39,816.13	136,199.78
BUFFALO	32,375.15	85,631.83
ORANGE COUNTY	46,307.70	167,577.57
Average	$42,150.84	$144,815.86
St Dev	$4,706.65	$36,375.72
Minimum	$32,375.15	$84,024.38
Maximum	$51,302.50	228,078.85

TABLE 3-5

BUS OPERATING COSTS FY 1981
BY SYSTEM SIZE AND OPERATING CHARACTERISTICS

SYSTEM SIZE AND OPERATING CHARACTERISTICS	N	MEAN SPEED MPH	Cost Per Revenue Vehicle Service Hour 1981 Dollars MEAN	MEDIAN	ST. DEV.
Small Systems (1-100 Peak Veh)					
Average Characteristics	41	12.6	23.22	22.72	5.74
High Peak-to-Base, Central City	11	10.2	24.32	21.74	8.44
Fast Suburban	10	16.8	30.58	31.25	10.23
Medium Systems (101-250 Peak Veh)					
Average Characteristics	71	12.9	26.91	27.78	5.34
High Peak-to-Base	31	13.0	31.39	32.26	7.10
Fast Suburban	4	14.4	25.35	27.78	3.67
Large Systems (251-600 Peak Veh)					
Average Characteristics	8	12.0	38.26	38.46	11.12
High Peak-to-Base	31	13.0	31.39	32.25	7.10
Fast Suburban	7	14.8	44.30	43.48	19.03
Very Large Systems (601 - 1600 Peak Vehicles Required	12	13.9	46.46	47.62	7.75
Largest Systems (over 1601 Peak Vehicles Required)	3	10.2	48.74	48.58	0.45

NOTES: Systems grouped primarily by number of vehicles required to meet peak demand. Subdivision based on average speed and peak-to-base service supplied. Operating cost defined as total major bus system operating expense: Form 301 Uniform System of Accounts and Records and Reporting System, Vol. II, 1977 (UMTA-IT-06-0094-77-1).

Source: U.S. Department of Transportation, Transportation Systems Center, National Urban Mass Transportation Statistics: Third Annual Report, Section 15 Reporting System: Magnetic Data Tape (Cambridge, MA: 1983)

Fielding, G.J. and K. Faust, Dimensions of Bus Performance for Peer Groups of Transit Agencies in FY 1980 and FY 1981 Using Section 15 Data, (Irvine: University of California, Institute of Transportation Studies, 1983, Appendix V).

TABLE 3-6

VARIATIONS IN BUS OPERATING COST PER HOUR
AS A FUNCTION OF AVERAGE SPEED OF ROUTE

Change in Speed Compared to Average System Wide Speed (in Miles Per Hour)	Percentage Difference in Costs	
	Costs Per Hour	Cost Per Mile
+10 mph	+19.6%	-30.1%
+9	+17.6%	-28.3%
+8	+15.7%	-26.3%
+7	+13.7%	-24.1%
+6	+11.8%	-21.7%
+5	+9.8%	-19.0%
+4	+7.8%	-16.1%
+3	+5.9%	-12.7%
+2	+3.9%	-9.0%
+1	+2.0%	-4.8%
0	0	0
-1	-2.0%	+5.5%
-2	-3.9%	+12.0%
-3	-5.9%	+19.7%
-4	-7.8%	+28.8%
-5	-9.8%	+40.0%
-6	-11.8%	+53.9%
-7	-13.7%	+71.9%
-8	-15.7%	+95.7%
-9	-17.6%	+128.9%
-10	-19.6%	+178.5%

Source: Based on a linear regression of operating cost per hour vs. speed in miles per hour for a major bus operator. The linear regression of operating cost per hour vs. speed yielded the following equation:

Operating Cost Per Hour ($) = 0.8595 (Miles Per Hour) + $31.81
Mean Speed = 14.06 mph; standard deviation (speed) = 5.29 mph
Mean Cost Per Hour = $43.89; standard deviation (cost per hour) = $7.53
Number of observations = 136 routes; R^2 = 0.37

Notes: Caution should be used in applying these results because of the nature of the input data. There is in fact no available measurement of the "actual" costs of various routes which operate at various average speeds. Some costs were allocated among routes on the basis of miles of travel on the routes. Thus, average speed will influence the relative amounts allocated to each route per hour of service. Approximately 16% of the costs were allocated to miles of operation in order to produce the input values. In addition, another 25% of administrative and overhead costs were not included in the regression. If they were included, the percentage differences would be lower by about one quarter. For more detail on variations in cost see Cohen, H.S., et. al., "Interim Report for NCTRP Project 40-2: Estimating Incremental Costs of Bus Route-Service Changes," 1984.

TABLE 3-7
BUS LABOR INPUTS PER UNIT OF SERVICE

System	Personnel Per 1,000 Revenue Hours	Personnel Per 1,000 Total Hours	Personnel Per Peak Bus	Personnel Per 10,000 Revenue Miles
NYCTA/MaB (NY)	1.298	1.192	4.893	1.603
SCRTD (LA)	1.178	1.084	4.178	0.875
CTA (CHICAGO)	0.966	0.966	3.757	0.963
SEPTA (PHILA.)	1.041	0.968	3.158	1.034
SEMTA (DETROIT)	1.220	1.004	3.332	0.782
AC (SF/OAKLAND)	0.968	0.945	2.930	0.658
SF MUNI	1.075	0.996	4.235	1.126
WMATA (WASH DC)	1.487	1.069	2.903	0.838
DTS (DALLAS)	1.036	1.036	2.421	0.733
HOUSTON	1.238	1.065	4.873	0.850
BISTATE (ST. LOUIS)	1.233	1.035	3.006	0.962
PAT (PITTSBURGH)	0.998	0.969	3.196	0.754
BALTIMORE	1.063	0.953	2.820	0.914
SDTC (SAN DIEGO)	1.325	1.005	4.209	0.852
MARTA (ATLANTA)	1.175	1.065	3.650	0.876
DENVER	1.416	1.013	3.097	0.842
MILWAUKEE	0.876	0.867	2.804	0.705
KANSAS CITY	1.102	1.032	2.642	0.772
NEW ORLEANS	1.086	1.086	3.395	1.041
PORTLAND, OR	1.358	1.026	3.421	0.836
BUFFALO	1.029	1.027	2.645	0.941
ORANGE COUNTY	1.136	1.029	3.619	0.791
Average	1.150	1.020	3.417	0.898
St Dev	0.016	0.065	0.697	0.019
Minimum	0.876	0.867	2.421	0.658
Maximum	1.487	1.192	4.893	1.603

Source: 1983 APTA Operating Reports, American Public Transit Association (Fiscal Year 1982) and National Urban Mass Transportation Statistics, U.S. DOT Urban Mass Transportation Administration, (Fiscal Year 1982).

TABLE 3-8
BUS LABOR INPUTS PER UNIT OF SERVICE BY TYPE OF EMPLOYEE

	Vehicle Operators Per 1,000 Total Hours	Vehicle Mechanics Per 10,000 Total Miles	Vehicle Mechanics and Vehicle Servicers Per 10,000 Total Miles	Other Personnel Per 1,000 Total Hours
NYCTA/MaB (NY)	0.705	0.210	0.268	0.268
SCRTD (LA)	0.618	0.106	0.148	0.254
CTA (CHICAGO)	0.619	0.088	0.116	0.231
SEPTA (PHILA.)	0.519	0.159	0.192	0.255
SEMTA (DETROIT)	0.569	0.086	0.109	0.273
AC (SF/OAKLAND)	0.627	0.049	0.070	0.201
SF MUNI	0.589	0.076	0.134	0.270
WMATA (WASH DC)	0.690	0.151	0.164	0.168
DTS (DALLAS)	0.616	0.049	0.088	0.296
HOUSTON	0.485	0.091	0.139	0.378
BISTATE (ST. LOUIS)	0.604	0.106	0.147	0.237
PAT (PITTSBURGH)	0.618	0.059	0.098	0.215
BALTIMORE	0.614	0.108	0.147	0.165
SDTC (SAN DIEGO)	0.654	0.085	0.123	0.186
MARTA (ATLANTA)	0.625	0.102	0.137	0.250
DENVER	0.546	0.095	0.118	0.297
MILWAUKEE	0.550	0.078	0.098	0.195
KANSAS CITY	0.662	0.078	0.123	0.195
NEW ORLEANS	0.615	0.151	0.194	0.268
PORTLAND, OR	0.666	0.057	0.092	0.232
BUFFALO	0.615	0.237	0.237	0.154
ORANGE COUNTY, CA	0.609	0.068	0.100	0.262
Average	0.610	0.104	0.138	0.239
St Dev	0.053	0.049	0.049	0.052
Minimum	0.485	0.049	0.070	0.154
Maximum	0.705	0.237	0.268	0.378

Source: 1983 APTA Operating Reports, American Public Transit Association (Fiscal Year 1982) and National Urban Mass Transportation Statistics, U.S. DOT Urban Mass Transportation Administration, (Fiscal Year 1982).

TABLE 3-9

BUS SYSTEM COSTS AND EMPLOYEES
PER UNIT OF CAPACITY

System	Cost Per Thousand Place Miles	Cost Per Thousand Place Hours	Employees Per Million Place Miles	Employees Per Million Place Hours
NYCTA/MaB (NY)	$103.30	$836.47	2.493	20.189
SCRTD (LA)	$64.00	$861.10	1.435	19.309
CTA (CHICAGO)	$74.50	$747.02	1.537	15.408
SEPTA (PHILA.)	$69.42	$699.07	1.649	16.607
SEMTA (DETROIT)	$63.98	$998.47	1.247	19.462
AC (SF/OAKLAND)	$50.55	$743.94	1.127	16.582
SF MUNI	$80.56	$769.10	1.813	17.313
WMATA (WASH DC)	$59.88	$1,062.87	1.387	24.625
DTS (DALLAS)	$32.90	$465.16	1.160	16.396
HOUSTON	$56.80	$827.02	1.358	19.777
ST. LOUIS	$67.35	$863.01	1.617	20.719
PAT (PITTSBURGH)	$57.55	$761.39	1.352	17.883
BALTIMORE	$66.34	$771.59	1.517	17.650
SDTC (SAN DIEGO)	$60.29	$937.52	1.536	23.883
MARTA (ATLANTA)	$47.25	$633.78	1.401	18.797
DENVER	$64.79	$1,089.99	1.422	23.917
MILWAUKEE	$43.11	$535.50	1.087	13.504
KANSAS CITY	$55.65	$794.58	1.297	18.521
NEW ORLEANS	$55.80	$582.04	1.647	17.179
PORTLAND, OR	$57.70	$937.26	1.449	23.540
BUFFALO	$52.89	$578.48	1.634	17.868
ORANGE COUNTY	$60.07	$862.22	1.297	18.619
Average	$61.12	$788.98	1.476	18.989
St. Dev.	$13.97	$164.32	0.029	2.911
Minimum	$32.90	$465.16	1.087	13.504
Maximum	$103.30	$1,089.99	2.493	24.625

TABLE 3-10

BUS AND TROLLEY COACH OPERATORS
NUMBER OF TOP HOURLY WAGE RATES REPORTED TO APTA BY TOP WAGE RATE AND SIZE FOR URBAN AREA (FEBRUARY, 1984)

Size Class of Urban Area (Population)	$14.00 Per Hour or More	$13.00 to $13.99 Per Hour	$12.00 to $12.99 Per Hour	$11.00 to $11.99 Per Hour	$10.00 to $10.99 Per Hour	$9.00 to $9.99 Per Hour	$8.00 to $8.99 Per Hour	$7.00 to $7.99 Per Hour	$6.00 to $6.99 Per Hour	$5.00 to $5.99 Per Hour	Less than $5.00 Per Hour	Totals
1,000,000 or More	0	1	13	17	12	17	9	6	6	0	1	83
500,000 to 1,000,000	0	0	1	2	5	10	4	2	4	1	3	32
200,000 to 500,000	0	0	0	5	9	18	11	7	3	5	1	59
100,000 to 200,000	2	0	0	1	7	8	14	11	8	6	2	59
Under 100,000	2	0	0	0	1	2	12	19	13	14	6	69
Totals	4	1	14	25	34	55	50	45	34	26	13	301

Source: American Public Transit Association, Labor Information Service, "Top Hourly Wage Rates -- Bus and Trolley Coach Operators," February 1, 1984.

Notes: Two or more top-hourly wage rates may be reported for operators with separate labor categories, such as full time vs. part time or bus vs. van. If a single operator serves more than one urbanized area, each top hourly wage rate for that operator is shown for only the largest size urban area served.

TABLE 3-10 (continued)

BUS AND TROLLEY COACH OPERATORS
PERCENTAGE OF TOP HOURLY WAGE RATES IN EACH SIZE CLASS OF URBAN AREA BY AMOUNT OF TOP HOURLY WAGE RATE PAID

Size Class of Urban Area (Population)	$14.00 Per Hour or More	$13.00 to $13.99 Per Hour	$12.00 to $12.99 Per Hour	$11.00 to $11.99 Per Hour	$10.00 to $10.99 Per Hour	$9.00 to $9.99 Per Hour	$8.00 to $8.99 Per Hour	$7.00 to $7.99 Per Hour	$6.00 to $6.99 Per Hour	$5.00 to $5.99 Per Hour	Less than $5.00 Per Hour	Totals
1,000,000 or More	0%	1%	16%	21%	15%*	21%	11%	7%	7%	0%	1%	100%
500,000 to 1,000,000	0%	0%	3%	6%	16%	31%*	13%	6%	13%	3%	9%	100%
200,000 to 500,000	0%	0%	0%	8%	15%	31%*	19%	12%	5%	8%	2%	100%
100,000 to 200,000	3%	0%	0%	2%	12%	14%	24%*	19%	14%	10%	3%	100%
Under 100,000	3%	0%	0%	0%	1%	3%	17%	28%*	19%	20%	9%	100%
Totals	1%	0%	5%	8%	11%	18%	17%*	15%	11%	9%	4%	100%

Source: American Public Transit Association, Labor Information Service, "Top Hourly Wage Rates -- Bus and Trolley Coach Operators," February 1, 1984.

Notes: Two or more top-hourly wage rates may be reported for operators with separate labor categories, such as full time vs. part time or bus vs. van. If a single operator serves more than one urbanized area, each top hourly wage rate for that operator is shown for only the largest size urban area served.

* Denotes median

TABLE 3-11

DIESEL BUS TRANSIT ENERGY CONSUMPTION AS A FUNCTION OF DUTY CYCLE AND PASSENGER LOADS

Duty Cycle	Average Fuel Economy		
	0 Passengers MPG	20 Passengers MPG	Seated Load MPG
CBD	3.68	3.44	3.17
ART	4.07	3.73	3.29
COM	5.43	5.19	4.89
ADB	4.14	3.87	3.54
J-4	2.59	2.39	2.06
ZOO	3.32	3.10	2.79

Source: Riviera, Archie M., and Silies, Jeannette, Transit Bus Energy Efficiency and Productivity, Bus Equipment Selection Handbook. NCTRP Report #1, July 1982.

Explanation of Cycles (Average for each cycle computed for same buses)

CBD: A cycle representative of bus operations in a central business district on level terrain

ART: A cycle representative of bus operations on an arterial on level terrain

COM: A cycle representative of bus operations for long distance commuter routes on level terrain

ADB: Advanced Design Bus duty cycle, which is a weighted composite of the CBD, ART, and COM cycles

J-4: A Washington Metropolitan Area Transit Authority (WMATA) route which is moderately hilly, with 20 uphill and 20 downhill grades ranging from 0.9 to 10 percent.

ZOO: A Tri-Met (Portland, Oregon) route which is flat except for three uphill grades of 9.5 to 14.2 percent and one downhill grade of -2 percent.

Note: The energy consumption figures presented here are based upon a simulation model for bus equipment and duty cycles developed by Booz, Allen and Hamilton, Inc. Actual fuel economy will differ based upon the specific bus equipment used and other factors. The average fuel economy for diesel buses varies significantly among transit operators due to specific local conditions. The types of buses for which these fuel economy simulations were run include "new look" buses, ADB's, and articulated buses.

TABLE 3-12

AVERAGE AND RANGE OF MPG FOR EACH DUTY CYCLE

Cycle	Average MPG	Range of MPG
CBD	3.68	2.74 to 4.00
ART	4.07	3.21 to 4.30
COM	5.43	4.47 to 5.87
ADB	4.14	3.24 to 4.41
J-4	2.59	1.96 to 3.08
ZOO	3.32	2.57 to 3.83

Note: For explanation of duty cycles, see Table 3-11.

TABLE 3-13

IMPLEMENTATION AND OPERATING COSTS FOR RESERVED FREEWAY BUS LANES

Facility	Length (Miles)	Start-up Costs ($)	Annual[1] Operating Costs ($)
I-495 (New York-New Jersey)	2.5	1,604,000 [2]	458,000
Long Island Expressway	2.0	115,000	344,000
San Francisco-Oakland Bay Bridge	1.0	134,000	29,000
Marin County Corridor (US-101)	5.0	458,000	--
Seattle Blue Streak (I-5)	8.5	1,374,000	--

[1]Annual operating costs include only the costs of providing the facility; they do not include vehicle operating costs.

[2]Includes sophisticated traffic signals and improved parking facilities.

Note: All reserved freeway bus lanes are labor intensive in that maintenance, police, and safety crews are needed to open and close the bus lanes during the hours of operation. Prices are in 1983 dollars, adjusted from the source values by using the Consumer Price Index.

Source: Levinson, H., Hoey, W., Sanders, D., Wynn, H., Bus Use of Highways: State of the Art, National Cooperative Highway Research Program Report 143, Washington, D.C., 1973.

TABLE 3-14

BUSWAY CONSTRUCTION COSTS

Location	Miles of Two Lane Facility	Stations	1980 Total Cost ($Millions)	1983 Total Cost ($Millions)	1983 Total Cost Per Two Lane Mile ($Millions)
Pittsburgh					
South	4.0	11	36	44	$11
East	6.8	6	110	135	$20
Washington					
Shirley	11	0	95	116	$11
Los Angeles					
San Bernardino	11	3	98	120	$11

Sources: Data compiled by TSC from various sources: Pittsburgh - PAT (1980); Washington, D.C. - TSC (1975); Los Angeles - NCHRP 143. All prices were inflated to 1980 dollars by TSC and then to 1983 dollars using the Engineering News Record Construction Cost Index. See Tables C-10 and C-11 for additional details.

TABLE 3-15

MAINTENANCE FACILITY CONSTRUCTION AND REHABILITATION COSTS BY MODE
(Per Vehicle Spot)

MODE	NEW CONSTRUCTION	REHABILITATION
Heavy Rail Transit		
Commuter	$1,000,000-2,000,000 1/	
Rapid Transit		$1,175,000 6/
Light Rail Transit	$350,000 2/	
Bus	$120,000-150,000 3/ $150,000-170,000 4/ $68,000- 72,000 5/	$50,000-78,000 7/ $45,000-55,000 5/
Articulated Diesel Bus	$55,000 2/	
Articulated Trolley Bus	$40,000 2/	

Maintenance shops and depots for which cost data was gathered:

1/Metro North and Long Island Rail Road

2/Minneapolis

3/ /NYCTA one-story depot in the Bronx

4/NYCTA two-story depot in Manhattan

5/NJ Transit

6/NYCTA 207th Street and Coney Island Shops

7/NYCTA Depot Modernization Program.

TABLE 3-16

REHABILITATION COSTS PER BUS (1980-1982) FOR AN ADDED LIFE OF AT LEAST 5 TO 8 YEARS

Average	$50,000
Range	$20,000 to $85,000

Source: M.S. Bridgman, H. Sveinsson, R.D. King, "Economic Comparison of New Buses Versus Rehabilitated Buses," February 1983, prepared for U.S. DOT Urban Mass Transportation Administration, Report Number DTUM60-81-C-71103-02-2.

Notes: The source study found no significant price trends in rehabilitation costs between 1979 and 1982. They note that this was a period of increasing competition and of great experience being gained in bus rehabilitation. It is likely that rehabilitation costs will rise in the future in response to general increases in labor rates. These costs should therefore be adjusted for future year estimates in accord with expected changes in the Consumer Price Index. Bus rehabilitation costs will vary substantially based upon initial condition, model, desired changes, and desired additional years and miles of service.

TABLE 3-17

COSTS OF STANDARD AND LARGE SIZE TRANSIT BUSES

Bus Type	Average Per Bus	Range Per Bus
40' ADB (Grumman)	$148,000	$141,000 to $157,000
40' ADB (GM)	$147,000	$143,000 to $152,000
35' ADB (GM)	$140,000	$140,000
40' New Look (GM)	$145,000	$130,000 to $152,000
35" New Look Gillig)	$130,000	$126,000 to $134,000
35' New Look (Ontario)	$132,000	$120,000 to $144,000

Sources: Bridgman, M.S., H. Sveinsson, R.D. King, "Economic Comparison of New Buses vs. Rehabilitated Buses," February 1983, Report Number DTUM60-81-C-71103-02-2.

TABLE 3-18

COSTS OF VANS AND MID-SIZE BUSES

	Base Vehicle	Equipment for Wheelchair	Air Conditioning
Standard Vans (11-14 Passengers)	$10,400 - $11,100	$800	$12,00
Converted Vans (11-14 Passengers)	$15,000 - $15,300	$2,100 - $2,400	$1,200
Light Transit Bus			
14 passenger	$19,400 - $19,700	$2,000 - $28,000	$1,400
17 Passenger	$22,600 - $23,100	$2,500 - $2,800	$2,300
21 Passnger	$26,700 - $27,200	$2,500 - $2,800	$2,800
25 Passenger	$29,700 - $30,400	$2,500 - $3,000	$3,300
Modified School Bus			
17-31 Passengers	$22,400 - $23,800	$2,600 - $3,300	$2,900 - $5,300
Light Bus			
17-31 Passengers	$23,800 - $26,800	$2,600 - $3,300	$2,900 - $5,300

Source: Meacham, D.G., W.D. Wood, H.S. James, "FY 1983 Vehicle Catalog" (Developed for Fiscal Year 1982 UMTA Section 16(b)(2) Program) April 1983, Report Number DOT-I-83-40, prepared by Ohio Department of Transportation

Notes: Above figures do not include other optional equipment, contingencies, or license fees and taxes. Price reflect expected FY 1983 costs.

TABLE 3-19

CAPACITIES OF SELECTED STANDARD SIZE TRANSIT BUSES

	Length (Ft.)	Gross Area (sq. ft.)	Capacity in Places1/	Stated Capacity Seated	Stated Capacity Study	Stated Capacity Total
AM Genl 9640	40'	316.8	59	51	26	77
10240	40'	316.8	59	51	26	77
Flexible 40 P + Newlook	40' (8')	320.0	59	53	53	106
	(8'.5')	340.0	63	53	53	106
GMC 53	8'	319.2	59	53	NA	NA
53	8'.5'	340.0	63	53	NA	NA
TRS-II	40.0	340.0	63	47	NA	NA
D-Begn	38.7	317.8	59	53	46	99
Leyland	37.2	305.0	57	52	23	75
M-A-N	36.09	295.9	55	44	59	103

Source: "Technical Guidance for Transit Project Planning: Estimation of Transit Supply Parameters" compiled by Michael Jacobs, Robert E. Skinner, and Andrew T. Lemer from N.D. Lea Transportation Research Corporation data, September 1982.

1/One place = 5.38 sq. ft. based on Pushkarev: Urban Rail in America: An Exploration of Criteria for Fixed Guideway Transit, Indiana University Press, 1982. A place is a measure of passenger capacity.

NA = not available.

TABLE 3-20

SELECTED SMALL AND MEDIUM BUS CAPACITIES

Manufacturer	Model or Type	Gross Area Square Feet	Capacity in Places[1/]	Stated Capacity: Seats	Stated Capacity: Standees Design	Stated Capacity: Standees Crush
Wayne	Transette	137.4	26	17	0	5
Steyr	City Bus	127.2	24	14	14	NA
Mercedes Benz	0309D	136.8	25	19	0	8
Winnebago	Series 19	161.3	30	19	0	6
Argosy	CB24	192.0	36	25	NA	NA
Chance	RT 50	201.4	37	25	15	25
Twin Coach	TC-HD-31-C	225.6	42	31	16	23
Flexible	31 Foot	247	46	35	35	NA

Source: Michael Jacobs, Robert E. Skinner, and Andrew T. Lemer, "Technical Guidance for Transit Project Planning: Estimation of Transit Supply Parameters," September 1982; compiled from N.D. Lea Transportation Research Corporation data.

1/Capacity in Places" is defined as 5.38 square feet, by Boris Pushkarev, et. al., Urban Rail in America: An Evaluation of Criteria for Fixed Guideway Transit, 1982, Indiana University Press.

NA = Not available.

TABLE 3-21

SELECTED ARTICULATED BUS CAPACITIES

Manufacturer	Model or Type	Gross Area Square Feet	Capacity in Places[1/]	Stated Capacity Seats	Stated Capacity Standees
AM General and MAN	55 ft.	467.5	87	65	32
	59.7 ft.	507.5	94	69	34
Daimler-Benz	0303G	461.7	86	49	135
Falken and Mercedes-Benz	#	457.3	85	57	116
Kassbohrer	SG 180S	454.0	84	55	130
	SG 180SL	480.9	89	59	127
M-A-N	SG192	443.6	82	50	110
NEOPLAN	N220	492.0	91	77	43
Volvo	B58	480.3	89	65	57

Source: Michael Jacobs, Robert E. Skinner, and Andrew T. Lemer, "Technical Guidance for Transit Project Planning: Estimation of Transit Supply Parameters," September 1982; compiled from N.D. Lea Transportation Research Corporation data.

1/"Capacity in Places" is defined as 5.38 square feet, by Boris Pushkarev, et. al., Urban Rail in America: An Evaluation of Criteria for Fixed Guideway Transit, 1982, Indiana University Press.

TABLE 3-22

BUS ACCIDENT RATES PER MILLION VEHICLE MILES

Type of Operation	Rates Per Million Vehicle Miles		
	Accidents	Deaths	Injuries
Intercity 1/	0.56 1/	0.0967 1/	1.42 1/
Charter and Local 1/	0.75 1/	0.0578 1/	2.08 1/
Urban Transit 2/	93.34 2/	0.0642 2/	44.9 2/1

1/Source: Bureau of Motor Carrier Safety, Federal Highway Administration, U.S. Department of Transportation, "Accidents of Motor Carriers of Passengers 1980-81." Data are for 1981.

2/Source: National Urban Mass Transportation Statistics, 1981, Section 15 Annual Report, Urban Mass Transportation Administration.

Notes: Accident data for Intercity and Charter and Local includes only those accidents where property damage exceeds $2,000 or if medical attention is required away from the scene of the accident. In addition, the data does not include accidents occurring at or near the terminals of Intercity carriers. This results in very serious under-reporting of total accidents and injuries.

Accident data published for transit buses covers all types of accidents, including minor property damage and other types not included in the Intercity and Charter and Local data.

Because of the differences between the sources of data, no comparisons can be drawn about the relative overall accident experience of these various types of bus systems. The fatality rates are similar.

CHAPTER IV

AUTOMOBILE-HIGHWAY SYSTEM

This chapter contains a set of quantitative values for selected supply parameters used to characterize automobile-highway systems (i.e., automobile and truck traffic): speed, capacity, operating cost, energy consumption, pollutant emissions, capital cost, and accident frequency. In most cases this section presents measures for automobiles, trucks, and for a mixed traffic stream. Appendix D contains supporting materials and more specific automobile-highway system information.

TABLE 4-1

MAJOR ASSUMPTIONS IN CALCULATING CAPACITY AND AVERAGE SPEED AS SHOWN IN TABLE 4-2

Facility Type	Location			
	Central Business District	Fringe	Residential	Outlying Business District
Freeway	uninterrupted flow 3 lanes each direction 12-foot lane width 4-foot lateral clearance 5 percent trucks rolling terrain peak hour factor -- 0.85 50 mph design speed		70 mph design speed	60 mph design speed
Expressway	3 lanes each direction 11-foot lane width 5 percent thru buses 10% right turn 10% left turn cycle length -- 90 seconds peak hour factor -- 0.85 acceleration -- 4 mphps amber time -- 5 seconds 50 mph design speed 2 signals/mile (g/c-.65)	1 signal/mile (g/c-.75)	1 signal/mile (g/c-.75) 60 mph design speed	
Arterial Two-Way With Parking	5 percent trucks 10% right turn 10% left turn cycle length -- 60 seconds peak hour factor -- 0.85 far side bus stops maximum speed -- 25 mph 5 signals/mile (g/c-.55) 22-foot approach width up to 50 buses/hour	maximum speed -- 30 mph 3 signals/mile (g/c-.60) 24-foot approach width up to 70 buses/ hour	maximum speed -- 35 mph 2 signals/mile (g/c-.65) 20-foot approach width	maximum speed -- 25 mph 3 signals/mile (g/c-.60) 24-foot approach width

TABLE 4-1 (continued)

MAJOR ASSUMPTIONS IN CALCULATING CAPACITY AND AVERAGE SPEED AS SHOWN IN TABLE 4-2

Facility Type	Location			
	Central Business District	Fringe	Residential	Outlying Business District
Arterial Two-Way Without Parking	up to 35 buses/hour maximum speed -- 25 mph 5 signals/mile (g/c-.55) 22-foot approach width	22-foot approach width maximum speed -- 30 mph up to 50 buses/hour 3 signals/mile (g/c-.60)	20-foot approach width maximum speed -- 35 mph 2 signals/mile (g/c-.65)	22-foot approach width maximum speed -- 25 mph 3 signals/mile (g/c-.60)
Arterial One-Way	44-foot approach width no parking up to 60 buses/hour maximum speed -- 25 mph 5 signals/mile (g/c-.51)	40-foot approach width parking one side maximum speed -- 30 mph up to 75 buses/hour 3 signals/mile (g/c-.60)	30-foot approach width parking one side maximum speed -- 35 mph 2 signals/mile (g/c-.65)	30 foot approach width parking both sides maximum speed -- 25 mph up to 110 buses/hour 3 signals/mile (g/c-.60)

Note: All data based on 1,000,000 population.

The assumptions for each facility type (freeway, expressway, and three types of arterials) are listed only once in the CBD column. The changes from the CBD assumptions are given in the columns for the other three locations (fringe, residential, OBD).

Source: Based on assumptions from Highway Research Board, <u>Highway Capacity Manual</u>, Washington, D.C., 1965.

TABLE 4-2

CAPACITY AND AVERAGE SPEED ON VARIOUS ROADWAYS
(Per Lane)

	Location							
	Central Business District		Fringe		Residential		Outlying Business District	
	Capacity[1]		Capacity[1]		Capacity[1]		Capacity[1]	
Facility Type	v/c	(mph)	v/c	(mph)	v/c	(mph)	v/c	(mph)
	1750 vph[2]		1750 vph[2]		1750 vph[2]		1750 vph[2]	
Freeway	0.00	48	0.00	48	0.00	67	0.00	58
	0.50	38	0.50	38	0.50	57	0.50	48
	0.75	33	0.75	33	0.75	50	0.75	41
	1.00	28	1.00	28	1.00	34	1.00	30
	800 vph		1000 vph		1100 vph		80 vph	
Expressway	0.00	37	0.00	44	0.00	47	0.00	37
	0.50	34	0.50	38	0.50	44	0.50	34
	0.75	33	0.75	35	0.75	41	0.75	33
	1.00	31	1.00	32	1.00	38	1.00	31
	400 vph		550 vph		550 vph		550 vph	
Arterial Two-Way With Parking	0.00	17-22	0.00	25-29	0.00	28-32	0.00	22-24
	0.50	17-20	0.50	20-27	0.50	25-30	0.50	20-22
	0.75	15-15	0.75	18-25	0.75	23-28	0.75	18-18
	1.00	12-12	1.00	15-15	1.00	15-15	1.99	13-13
	600 vph		800 vph		800 vph		800 vph	
Arterial Two-Way Without Parking	0.00	17-22	0.00	25-29	0.00	28-32	0.00	22-24
	0.50	17-20	0.50	20-27	0.50	25-30	0.50	20-22
	0.75	15-15	0.75	18-25	0.75	23-28	0.75	18-18
	1.00	12-12	1.00	15-15	1.00	15-15	1.00	13-13
	700 vph		550 vph		900 vph		650 vph	
Arterial One-Way	0.00	17-22	0.00	25-29	0.00	28-32	0.00	22-24
	0.50	17-20	0.50	20-27	0.50	25-30	0.50	20-22
	0.75	15-15	0.75	18-25	0.75	23-28	0.75	18-18
	1.00	12-12	1.00	15-15	1.00	15-15	1.00	13-13

1/Capacity calculated at level of service E -- absolute capacity.

2/For arterials, first value shows speed assuming lack of coordinated signal progression; second value shows speed assuming full signal progression.

Note: See Table 4-1 for major assumptions.

See Tables D-1 to D-5 in the Appendix for detailed capacity calculations of arterial street intersections.

Source: Based on Highway Research Board, Highway Capacity Manual, Washington, D.C., 1965.

TABLE 4-3

AVERAGE PASSENGER CAR OPERATING COSTS
FOR INTERMEDIATE SIZED CAR

Year	Variable Costs (Cents Per Mile) Gas & Oil	Maintenance	Tires	Total	Fixed Cost Per 10,000 Miles	Per Mile	Total Cost Per Mile
1982	6.74¢	1.00¢	.63¢	8.37¢	$2,398.00	23.98¢	32.35¢
1981	6.27¢	1.18¢	.72¢	8.17¢	2,375.00	23.75¢	31.92¢
1980	5.86¢	1.12¢	.64¢	7.62¢	2,033.00	20.33¢	27.95¢
1979	4.11¢	1.10¢	.65¢	5.86¢	1,811.00	18.11¢	23.97¢

Source: Compiled by Motor Vehicle Manufacturer's Association from "Your Driving Costs," published by the American Automobile Association. The primary source of the data is Runzheimer and Company.

Notes: All costs are in current dollars for year shown. Previous year data (prior to 1979) is not comparable.

TABLE 4-4

AVERAGE EXPENDITURE PER NEW CAR
1970-1982

Year	Expenditure Per Car: Average	Domestic	Import
1982	$9,663	$9,580	$9,874
1981	8,717	8,660	8,854
1980	7,526	7,593	7,342
1979	6,861	6,906	6,705
1978	6,382	6,481	5,937
1977	5,811	5,985	5,057
1976	5,414	5,504	4,912
1975	4,949	5,083	4,376
1974	4,439	4,523	4,022
1973	4,051	4,180	3,343
1972	3,879	4,034	2,994
1971	3,742	3,919	2,769
1970	3,542	3,708	2,648

Source: Unpublished data, U.S. Bureau of Economic Analysis, as compiled by Motor Vehicle Manufacturers Association, MVMA Facts and Figures, 1983.

Note: Data are in current dollars for the year shown.

TABLE 4-5

VARIATIONS OF OPERATING COSTS WITH SPEED OF VEHICLES

Vehicle Type	Percentage of Cost at 55 mph at a Constant Speed of							
	10 mph	20 mph	30 mph	40 mph	50 mph	55 mph	60 mph	70 mph
Small Auto	173%	126%	108%	101%	100%	100%	103%	113%
Medium Auto	125%	100%	94%	90%	94%	100%	104%	116%
Large Auto	122%	100%	93%	93%	97%	100%	104%	116%
Pickup Truck	111%	84%	84%	87%	97%	100%	104%	128%
3S2 Semitrailer	140%	92%	91%	93%	96%	100%	104%	113%

Note: Costs at 55 mph on level grade on good pavement for each vehicle type

Small Auto	10.0¢/mile
Medium Auto	12.6¢/mile
Large Auto	13.4¢/mile
Pickup Truck	12.7¢/mile
3S2 Semitrailer	36.9¢/mile

Source: Zaniewski, J.P., B.C. Butler, G. Cunningham, G.E. Elkins, M. Paggi, R. Machemehl, "Vehicle Operating Costs, Fuel Consumption, and Pavement Type and Condition Factors," prepared for Federal Highway Administration, March 1982.

TABLE 4-6

CONSTRUCTION COSTS FOR STREET IMPROVEMENTS
(Millions of 1983 Dollars)

Type of Improvement	Average Cost Per Highway Mile: 2 Lanes	4 Lanes	6 Lanes
New Location	$1.73	$3.37	$5.43
Pavement Reconstruction	0.99 - 1.14[1/]	1.50 - 1.188	2.85 - 3.14
Major Widening (Add Lanes)	.7 - 1.2/Lane Added		
Resurfacing	0.23 - 0.37	0.34 - 0.53	0.62 - 0.74

1/Cost ranges are nationwide average for built up (CBD and fringe) and outlying (predominantly residential) areas. As indicated below, costs for a given improvement can be outside of these ranges by several orders of magnitude.

Notes

Costs reported by selected states for highway improvements primarily during the late 1970s, updated to 1983 using the FHWA Federal-Aid Highway Construction Price Index (Urban).

Costs for highway improvements vary considerably depending upon design and other local considerations. Many of the highway improvements upon which the above unit costs are based took advantage of existing rights-of-way and other natural corridors; thus, these unit costs may seriously understate the cost for a given highway improvement, perhaps by several orders of magnitude if special construction techniques are required.

Source

FHWA tabulations of data collected as part of the Highway Performance Monitoring System Case Study: Highway Improvement Unit Costs.

TABLE 4-7

CONSTRUCTION COSTS FOR FREEWAY IMPROVEMENTS
(Millions of 1983 Dollars)

Type of Improvement	Average Cost Per Highway Mile: 4 Lane Freeways	Average Cost Per Highway Mile: 6 Lane Freeways
New Location	4.42 - 7.51[1]	7.32 - 13.41
Reconstruction to Freeway Design Standards	3.15 - 4.05	4.92 - 6.54
Pavement Reconstruction	3.35 - 3.87	5.33 - 5.75
Major Widening	1.5 - 2.3/Lane Added	
Resurfacing	0.49 - 0.61	0.68 - 0.84

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[1]Cost ranges are nationwide average for built up (CBD and fringe) and outlying (predominantly residential) areas. As indicated below, costs for a given improvement can be outside of these ranges by several orders of magnitude.

Notes

Costs reported by selected states for highway improvements primarily during the late 1970s, updated to 1983 using the FHWA Federal-Aid Highway Construction Price Index (Urban).

Costs for highway improvements vary considerably depending upon design and other local considerations. Many of the highway improvements upon which the above unit costs are based took advantage of existing rights-of-way and other natural corridors; thus, these unit costs may seriously understate the cost for a given highway improvement, perhaps by several orders of magnitude if special construction techniques are required.

Source

FHWA tabulations of data collected as part of the Highway Performance Monitoring System Case Study: Highway Improvement Unit Costs.

TABLE 4-8

ANNUAL COST OF MAINTENANCE
($ PER LANE MILE)

	Type of Maintenance		
Facility Type	General	Lighting	Total
Expressways	$5,120	$4,458	$9,578
Arterials	$2,632	$1,038	$3,670
Residential and CBD Streets	$1,961	$1,880	$3,849

Note: Data expressed in terms of 1983 costs, updated using FHWA's Maintenance Cost Index. These figures do not include periodic resurfacing costs. Periodic resurfacing is included in rehabilitation costs.

Source: Bhatt, K., and Olsson, M., "Analysis of Supply and Estimates of Revenue Costs," Technical Report 2, The Urban Institute, Washington, D.C., November 1973.

Skinner, L., Cost of Urban Transportation Alternatives, U.S. Department of Transportation, Federal Highway Administration, Washington, D.C.

TABLE 4-9

SURFACE PARKING COSTS

Land Cost (Per Sq. Ft.)	Land and Construction Cost[1] (Per Stall)	Annual Operating Costs[2] (Per Stall)
$20	$8,300	$690
15	6,400	560
12	5,300	500
10	4,500	460
8	3,800	410
5	2,600	360
2	1,500	290

1/ Costs include improvement costs and prorated land costs based on a 330 square foot stall.

2/ Includes property taxes.

Notes: Data projected from 1970 base to 1983, using the Construction Index in "Engineering New Record," the Bureau of Census Land Cost Index and The Consumer Price Index for Operating Costs.

Source: Parking Standards Report, Parking Standards Design Associates, Los Angeles, 1971.

TABLE 4-10

CONSTRUCTION COST FOR ABOVE-GRADE PARKING STRUCTURES

Levels	Cost Per Sq. Ft.	Cost at 315 Sq. Ft./Stall	Cost at 280 Sq. Ft./Stall	Cost at 400 Sq. Ft./Stall	Plus Land Cost Per Unit Divided By
One	$4.50	$1,418	$1,260	$1,800	1
Two	$13.50	4,253	3,780	5,400	2
Three	$16.33	5,144	4,572	6,532	3
Four	$18.25	5,749	5,111	7,300	4
Five	$19.40	6,111	5,432	7,760	5
Six	$20.46	6,445	5,729	8,184	6
Seven	$20.93	6,593	5,860	8,372	7
Eight	$21.28	6,703	5,958	8,512	8
Nine	$21.56	6,791	6,037	8,624	9
Ten	$21.80	6,867	6,104	8,720	10

Costs in 1982 Dollars

Source: Derived from Urban Land Institute and the National Parking Association The Dimensions of Parking, Second Edition, 1983,

TABLE 4-10 (continued)

TOTAL COST OF PARKING CONSTRUCTION PER STALL, BASED ON LAND VALUE PER SQUARE FOOT

Land Cost Per Square Foot	Land Cost Per Unit (315 Sq. Ft.)	Optimal Number of Levels	Total Cost Per Stall
$5.00	$1,575	one	$2,993
$10.00	3,150	one	4,568
$15.00	4,725	two	6,616
$20.00	6,300	three	7,244
$25.00	7,875	ten	7,655
$30.00	9,450	ten	7,812
$35.00	11,025	ten	7,970
$40.00	12,600	ten	8,127
$45.00	14,175	ten	8,285
$50.00	15,750	ten	8,442

Note: After land price reaches $25 per square foot, the total cost per stall increases $31.50 for each $1 per square foot increase in land costs. All costs in 1982 dollars.

Source: Derived from National Parking Association and Urban Land Institute, "The Dimensions of Parking: Second Edition," 1983.

TABLE 4-11

UNDERGROUND STRUCTURE PARKING COSTS[1/]

Parking Method	Construction Cost Per Stall	Annual Operating Cost Per Stall
Self park - single depth[2/]	$12,600	$520
Self park - tandem	10,500	480
Attendant assist - tandem	10,500	540
Attendant park - tandem	10,500	620

1/Cost include construction costs, based on 330 square foot stall.

2/Single depth stall is 360 square feet.

Note: Data projected from 1970 to 1983, using the Construction Index in "Engineering News Record," The Bureau of Census Land Cost Index and The Consumer Price Index for Operating Costs.

Source: Parking Standards Report, Parking Standards Design Associates, Los Angeles, 1971.

TABLE 4-12

AVERAGE GALLONS PER MILE OF FUEL CONSUMPTION
BY VEHICLE TYPE 1977-1995
(Average For All Roads)

Type of Vehicle	1977	1985	1990	1995
Auto				
Large	0.0787	0.0629	0.0564	0.0556
Small	0.0481	0.0382	0.0344	0.0338
Total	0.0724	0.0524	0.0435	0.0406
Motorcycle	0.0200	0.0200	0.0200	0.0200
Pickups and Vans	0.0848	0.0682	0.0601	0.0557
Single Unit Trucks	0.1740	0.1683	0.1621	0.1521
Combination Trucks	0.2164	0.1924	0.1857	0.1860
Total Vehicles	0.0829	0.0654	0.0569	0.0543

Source: System Design Concepts, Inc., and Jack Faucett Associates, Inc., "Transportation System Descriptors Used in Forecasting Federal Highway Revenues" Final Report, June 1981.

TABLE 4-13

PERCENT OF AVERAGE AUTO FUEL CONSUMPTION FOR DIFFERENT ROAD TYPES

Type of	Factor to Adjust Average Fuel Consumption in Gallons Per Mile
Urban Interstate	0.94
Urban Arterial	1.07
Urban Collector and Local	1.10
Rural Interstate	0.98
Rural Arterial	0.98
Rural Collector and Local	0.85

Source: System Design Concepts and Jack Faucett Associates, Inc., "Transportation System Descriptors Used in Forecasting Federal Highway Revenues," Final Report, June 1981. The adjustment factors were developed based upon average speeds, speed changes, and stop cycles on the nation's roadways in each class, as contained in FHWA's Highway Investment Analysis Package (HIAP).

Note: To compute average auto or light truck fuel consumption on each type of road in each year, multiply the factors shown above by the values in the previous table.

TABLE 4-14

EFFECTS OF DIFFERENT CONSTANT SPEEDS AND GRADES ON FUEL CONSUMPTION
OF A MEDIUM SIZED AUTOMOBILE

Percent Grade	Constant Speed Fuel Consumption (Gallons Per 1,000 Miles) SPEED IN MPH											
	5	10	15	20	25	30	35	40	45	50	55	60
8	91.00	91.00	83.30	75.00	76.00	77.00	82.00	86.50	90.00	93.50	102.00	110.00
6	77.50	77.50	70.80	64.00	63.00	62.00	65.30	68.50	73.00	77.30	87.00	96.00
4	73.00	73.00	66.50	60.00	57.80	55.50	58.30	60.50	64.50	68.00	73.00	77.50
2	68.00	68.00	60.80	53.50	52.30	50.50	53.00	55.50	56.80	58.00	60.50	62.50
0	55.40	55.40	47.30	38.70	38.00	37.30	37.60	38.00	40.50	43.00	47.90	52.80
-2	50.80	50.80	39.70	28.00	25.80	22.50	26.30	29.50	30.30	31.00	34.80	38.50
-4	52.00	52.00	39.90	27.30	24.00	20.30	20.70	21.00	23.00	25.00	28.80	32.00
-6	53.50	53.50	40.60	27.30	23.50	19.80	18.00	16.30	18.90	21.00	29.00	27.00
-8	54.50	54.50	41.20	27.30	23.00	19.30	16.80	14.30	15.40	16.50	18.30	20.00

Source: J.P.Zaniewski, B.C. Butler, Jr., G. Cunningham, G.E. Elkins, M. Paggi, R. Machemehl, Vehicle Operating Costs, Fuel Consumption, and Pavement Type and Condition Factors, prepared for Federal Highway Administration by the Texas Research and Development Foundation, March 1982.

TABLE 4-15

EFFECTS OF CHANGES IN SPEED ON FUEL CONSUMPTION
OF A MEDIUM SIZED AUTOMOBILE

Initial Speed mph	Excess Fuel Consumed in Gallons Per 1,000 Cycles SPEED REDUCED TO AND RETURNED FROM, mph											
	0	5	10	15	20	25	30	35	40	45	50	55
5	1.00											
10	1.98	.98										
15	3.02	2.02	1.04									
20	4.18	3.18	2.20	1.16								
25	5.43	4.43	3.45	2.41	1.25							
30	6.81	5.81	4.83	3.79	2.63	1.38						
35	8.68	7.68	6.70	5.66	4.50	3.25	1.87					
40	10.70	9.71	8.73	7.69	6.53	5.28	3.90	2.03				
45	12.90	11.90	10.90	9.87	8.71	7.46	6.08	4.21	2.18			
50	15.30	14.30	13.30	12.30	11.10	9.86	8.48	6.61	4.58	2.40		
55	17.90	16.90	15.90	14.90	13.70	12.40	11.10	9.19	7.16	4.98	2.58	
60	20.80	19.80	18.80	17.80	16.60	15.30	14.00	12.10	10.10	7.87	5.47	2.89

Source: J.P.Zaniewski, B.C. Butler, Jr., G. Cunningham, G.E. Elkins, M. Paggi, R. Machemehl, Vehicle Operating Costs, Fuel Consumption, and Pavement Type and Condition Factors, prepared for Federal Highway Administration by the Texas Research and Development Foundation, March 1982.

TABLE 4-16

COMPOSITE POLLUTANT EMISSION FACTORS (1977)
FREEWAYS AND SURFACE ARTERIALS[1]

	Autos			Trucks[2]		
Speed	Carbon Monoxide	NMHC	NO_x	CO	NMHC[3]	NO_x
55	24.45	3.79	4.66	46.01	4.67	11.11
50	26.08	3.90	4.36	44.62	4.83	10.21
45	27.24	3.99	4.21	44.49	5.01	9.57
40	29.44	4.15	4.10	46.59	5.31	9.16
35	33.33	4.43	3.98	51.36	5.78	8.89
30	39.05	4.84	3.81	59.48	6.47	8.71
25	46.66	5.36	3.59	71.68	7.42	8.63
20	56.84	6.05	3.34	89.84	8.82	8.70
15	73.16	7.14	3.13	118.83	10.99	8.97

These footnotes and notes apply to Tables 4-16 through 4-19.

[1]Emissions include cold starts, hot soaks, hot operation, and diurnal evaporation. All emission estimates are based on MOBILE 2.5.

[2]The projected truck vehicle mix varies over time as follows:

Year	Light-Duty Trucks (6000 lb. cap)	Light-Duty Trucks (6000-8500 lb. cap)	Light Duty Diesel	Heavy-Duty Gasoline	Heavy-Duty Diesel
1977	40.5%	22.9%	0.0%	20.5%	16.1%
1982	40.0%	22.4%	1.0%	20.5%	16.1%
1987	37.6%	22.4%	3.4%	20.5%	16.1%
1995	33.3%	22.2%	8.2%	20.3%	15.9%

The projected share of registered cars and trucks is the following:

Year	Autos	Trucks
1977	78.6%	20.5%
1982	78.6%	20.5%
1987	78.6%	20.5%
1995	78.4%	20.7%

[3]Hydrocarbon emissions include reactive hydrocarbons only, methane excluded.

Source: Environmental Protection Agency, Office of Air, Noise, and Radiation, Ann Arbor, Michigan. February 1984.

TABLE 4-17

COMPOSITE POLLUTANT EMISSION FACTORS (1982)
FREEWAYS AND SURFACE ARTERIALS[1]

	Autos			Trucks[2]		
Speed	Carbon Monoxide	NMHC	NO_x	CO	NMHC[3]	NO_x
55	17.11	2.01	3.54	37.73	2.90	10.26
50	18.62	2.11	3.30	36.40	3.01	9.37
45	19.01	2.17	3.17	35.82	3.12	8.75
40	20.20	2.28	3.08	37.09	3.33	8.36
35	22.96	2.48	2.98	40.81	3.68	8.11
30	27.45	2.79	2.83	47.28	4.15	7.95
25	33.41	3.20	2.63	57.19	4.83	7.87
20	40.69	3.70	2.41	71.68	5.79	7.92
15	50.98	4.45	2.19	94.25	7.25	8.20

[1,2,3] See footnotes on Table 4-16.

TABLE 4-18

COMPOSITE POLLUTANT EMISSION FACTORS (1987)
FREEWAYS AND SURFACE ARTERIALS[1]

	Autos			Trucks[2]		
Speed	Carbon Monoxide	NMHC	NO_x	CO	NMHC[3]	NO_x
55	8.41	0.78	2.81	20.39	1.47	7.51
50	9.26	0.83	2.61	19.35	1.53	6.86
45	9.24	0.86	2.51	18.90	1.57	6.41
40	9.63	0.90	2.43	19.47	1.71	6.13
35	10.90	1.00	2.34	21.31	1.87	5.97
30	13.12	1.14	2.21	24.61	2.13	5.85
25	16.05	1.34	2.04	29.73	2.51	5.81
20	19.34	1.57	1.84	37.49	3.01	5.82
15	23.41	1.90	1.65	49.45	3.78	6.02

[1,2,3] See footnotes on Table 4-16.

TABLE 4-19

COMPOSITE POLLUTANT EMISSION FACTORS (1995)
FREEWAYS AND SURFACE ARTERIALS[1]

	Autos			Trucks[2]		
Speed	Carbon Monoxide	NMHC	NO_x	CO	NMHC[3]	NO_x
55	8.75	0.53	2.59	9.08	.76	3.89
50	9.65	0.57	2.40	8.82	.82	3.58
45	9.58	0.59	2.30	8.67	.89	3.33
40	9.94	0.63	2.23	8.93	.94	3.20
35	11.24	0.72	2.15	9.78	1.06	3.08
30	13.54	0.84	2.03	11.36	1.22	3.02
25	16.57	1.01	1.87	13.76	1.51	2.96
20	19.90	1.22	1.68	17.24	1.78	2.98
15	23.87	1.49	1.49	22.41	2.33	3.06

[1,2,3] See footnotes on Table 4-16.

TABLE 4-20

POLLUTANT EMISSION FACTOR COMPONENTS[1] (1977)

A. EMISSIONS FROM HOT STABILIZED OPERATION
FREEWAYS AND SURFACE ARTERIALS

Speed (mph)	Autos (Grams/Mile) CO	Autos NMHC[2]	Autos NO_x	Trucks (Grams/Mile) CO	Trucks NMHC[2]	Trucks NO_x
55	20.12	3.44	3.91	43.12	4.43	10.57
50	21.42	3.53	3.66	41.48	4.56	9.67
45	22.40	3.60	3.53	41.26	4.73	9.05
40	24.23	3.74	3.44	43.09	5.01	8.66
35	27.41	3.94	3.34	47.41	5.43	8.41
30	32.07	4.30	3.19	54.77	6.04	8.26
25	38.25	4.73	3.01	65.98	6.95	8.21
20	46.59	5.29	2.80	82.82	8.22	8.28
15	60.05	6.19	2.63	109.88	10.25	8.55

(1982)

Speed	Autos CO	Autos NMHC[2]	Autos NO_x	Trucks CO	Trucks NMHC[2]	Trucks NO_x
55	13.64	1.78	2.96	35.47	2.76	9.82
50	14.82	1.86	2.76	33.88	2.84	8.93
45	15.16	1.90	2.65	33.30	2.98	8.38
40	16.14	1.99	2.57	34.45	3.12	8.01
35	18.36	2.15	2.48	37.77	3.43	7.76
30	21.93	2.40	2.36	43.68	3.89	7.63
25	26.68	2.72	2.20	52.77	4.52	7.55
20	32.52	3.13	2.01	66.39	5.38	7.63
15	40.89	3.72	1.82	87.67	6.77	7.95

TABLE 4-20 continued

(1987)

Speed	Autos CO	Autos NMHC[2]	Autos NO_x	Trucks CO	Trucks NMHC[2]	Trucks NO_x
55	6.58	0.69	2.32	19.63	1.42	7.29
50	7.24	0.73	2.16	18.48	1.47	6.58
45	7.23	0.75	2.07	18.06	1.54	6.20
40	7.54	0.79	2.01	18.63	1.63	5.89
35	8.54	0.87	1.93	20.27	1.82	5.74
30	10.28	0.99	1.83	23.35	2.06	5.61
25	12.57	1.15	1.69	28.29	2.39	5.57
20	15.15	1.35	1.52	35.70	2.86	5.66
15	18.37	1.61	1.36	47.30	3.64	5.86

(1995)

Speed	Autos CO	Autos NMHC[2]	Autos NO_x	Trucks CO	Trucks NMHC[2]	Trucks NO_x
55	6.86	0.48	2.08	8.53	.75	3.71
50	7.57	0.52	1.93	8.14	.81	3.36
45	7.52	0.54	1.85	7.98	.84	3.20
40	7.80	0.58	1.80	8.21	.88	3.00
35	8.82	0.65	1.73	8.99	1.02	2.90
30	10.62	0.76	1.63	10.43	1.17	2.87
25	13.00	0.91	1.50	12.64	1.42	2.82
20	15.61	1.09	1.35	15.88	1.72	2.85
15	18.73	1.34	1.20	20.74	2.19	2.91

These footnotes apply to all Tables 4-20 through 4-22.

[1]Mobile source emissions are generated in four ways:

1. From vehicles traveling in hot, stabilized mode; that is, after the engine and catalytic converter (if any) have warmed up to their most efficient operating temperature range. (CO, HC, and NOx emission.)
2. From vehicle starts; additional emissions arise when an engine is started, regardless of the travel distance. (CO, HC, and NOx emission.)
3. From hot soaks; when an engine is turned off, hydro-carbons are evaporated from unburned fuel in the crankcase (HC only).
4. From diurnal evaporation; daily temperature cycles cause evaporation of hydrocarbons from fuel tanks, whether or not the vehicles are used. (HC only)

[2]Hydrocarbon emissions include reactive hydrocarbons only; methane is excluded.

Source: Environmental Protection Agency Office of Air, Noise, and Radiation, Ann Arbor, Michigan, February 1984.

TABLE 4-21

EMISSIONS FROM AUTO STARTS

(1977)

Percentage of Trips Starting Cold	Emissions CO	(No) NMHC (Evap)	NO_x
0	52.80	4.74	3.98
10	58.78	5.04	3.97
20	64.76	5.34	3.96
30	70.74	5.63	3.94
40	76.72	5.93	3.93
50	82.70	6.23	3.92
60	88.68	6.53	3.91
70	94.66	6.83	3.90
80	100.64	7.13	3.88
90	106.62	7.43	3.87
100	112.60	7.72	3.86

(1982)

Percentage of Trips Starting Cold	Emissions CO	(No) NMHC (Evap)	NO_x
0	32.67	3.02	2.75
10	37.69	3.26	2.76
20	42.71	3.31	2.76
30	47.73	3.75	2.77
40	52.74	4.00	2.78
50	57.76	4.24	2.78
60	62.78	4.49	2.79
70	67.80	4.73	2.79
80	72.81	4.98	2.80
90	77.83	5.22	2.80
100	82.85	5.47	2.81

TABLE 4-21 continued

(1987)

Percentage of Trips Starting Cold	CO	Emissions NMHC (No) (Evap)	NO_x
0	16.45	1.43	2.10
10	18.64	1.51	2.11
20	20.83	1.59	2.11
30	23.03	1.67	2.12
40	25.22	1.75	2.13
50	27.41	1.82	2.13
60	29.60	1.90	2.14
70	31.79	1.98	2.14
80	33.98	2.06	2.15
90	36.17	2.13	2.15
100	38.36	2.21	2.16

(1995)

Percentage of Trips Starting Cold	CO	Emissions NMHC (No) (Evap)	NO_x
0	20.10	1.52	2.02
10	21.84	1.52	2.02
20	23.58	1.52	2.01
30	25.32	1.51	2.01
40	27.05	1.51	2.00
50	28.79	1.51	1.99
60	30.53	1.51	1.99
70	32.26	1.50	1.98
80	34.00	1.50	1.98
90	35.74	1.50	1.97
100	37.48	1.50	1.97

Source: Environmental Protection Agency, Office of Air, Noise, and Radiation, Ann Arbor, Michigan, February 1984.

TABLE 4-22

OTHER EMMISSIONS

Auto Diurnal Evaporative Emissions (HC)

1977	15.4 g/auto/day
1982	7.2
1987	2.7
1995	1.2

Hot Soak Emissions (HC)

1977	10.6 g/auto trip
1982	5.6
1987	2.0
1995	0.7

Gasoline Truck Diurnal Evaporative Emissions (HC)

1977	23.8 g/truck/day
1982	14.0
1987	6.8
1995	1.9

Source: Environmental Protection Agency, Office of Air, Noise, and Radiation, Ann Arbor, Michigan, February 1984.

TABLE 4-23

AVERAGE 1981 TAXI COMPANY UNIT COSTS
BY SIZE OF COMPANY

Taxicabs Organization	Annual, Per Taxi	Per Vehicle Mile	Per Vehicle Trip	Per Passenger
0-2	$18,630	$.65	$7.13	$4.74
3-9	24,250	.69	4.33	3.24
10-24	31,420	.64	4.47	2.92
25-49	28,860	.66	4.16	2.90
50-74	28,980	.58	3.89	2.51
75-99	35,880	.54	3.78	2.16
100-199	28,970	.76	5.07	3.62
200+	37,310	.70	4.77	3.15
All	$26,970	$.66	$4.76	$3.29

Source: Gilbert, Gorman C., Raymond J. Burby, and Charles E. Feibel, "Taxicab Operating Characteristics" Center for Urban and Regional Studies, University of North Carolina at Chapel Hill, September 1982.

CHAPTER V

AUTOMATED GUIDEWAY TRANSIT SYSTEMS

This chapter contains a set of values for parameters that characterize automated guideway systems. Because of the rapidly changing state of the art for these systems, and the relative rareness of installations, two points must be made: the data are limited, and those presented must be used with care. Data are presented only for systems which are actually in use, under construction, or for which firm quotes for construction have been submitted. The set of systems included here is not exhaustive.

TABLE 5-1

AUTOMATED GUIDEWAY TRANSIT FLEET SIZES, CAPACITIES, AND SPEEDS

	Fleet Size	Vehicle Capacity Seated/Standing	Vehicle Speed (MPH) Maximum/Average
Airtrans	52	16/24	17/10
Atlanta	17	16/24	27/13
Busch Gardens	1 (2 Car Train)	16/176	30/11
Disneyworld	30 (5 Car Train)	20/0	14/5
Duke	4	4/18	28/14
Fairlane	2	10/14	30/10
Houston	6 (3 car Train)	18/18	15/6
King's Dominion	6 (9 Car Train)*	96/0	18/6
Miami Airport	2 (3 Car Train)	6/291	30/11
Miami Zoo	3 (10 Car Train)	149/0	10/8
Minnesota Zoo	3 (6 Car Train)	94/0	8/7
Morgantown	73	8/12	30/17
Orlando	4 (2 Car Train)	0/200	28/14
Pearlridge	1 (4 Car Train)	32/32	8/7
Sea-Tac	24	12/90	26/12
Tampa	8	0/100	30/9

* Includes non-passenger lead car.

Source: Dynatrend Incorporated, and U.S. DOT Research and Special Programs Administration "Supplement V - Cost Experience of Automated Guideway Transit Systems, Final Report," October 1983, p. D-5.

TABLE 5-2

OPERATING COST FOR AUTOMATED GUIDEWAY TRANSIT SYSTEMS
(1982 Dollars)

	Cost Per Vehicle Mile Traveled	Cost Per Equivalent Place Mile[1/]	Cost Per Vehicle Hour
Airtrans	$1.89	$0.051	$18.86
Atlanta	3.98	0.044	38.66
Busch Gardens	7.70	0.045	121.76
Disneyworld	0.73	0.015	3.51
Duke	5.43	0.175	N/A
Fairlane	N/A	N/A	N/A
Houston	4.06	0.075	22.62
King's Dominion	N/A	N/A	N/A
Miami Airport	2.22	0.009	58.62
Miami Zoo	24.03	0.100	62.09
Minnesota Zoo	46.34	0.386	106.46
Morgantown	2.50	0.096	N/A
Orlando	3.11	0.017	26.45
Pearlridge	30.20	0.302	94.16
Sea-Tac	1.45	0.017	17.35
Tampa	2.53	0.030	14.19

Source: Dynatrend Incorporated, and U.S. DOT Research and Special Programs Administration "Supplement V - Cost Experience of Automated Guideway Transit Systems, Final Report," October 1983, p. 5-6.

[1/]Equivalent place miles are computed by multiplying equivalent passenger places per vehicle by the vehicle miles traveled for each system.

Note: Averages are not shown for these systems because they are substantially different in terms of vehicle sizes and operating characteristics.

N/A/ Not Available

TABLE 5-3

AUTOMATED GUIDEWAY SYSTEM VEHICLE COSTS (1982 Dollars)

	Cost Per Vehicle ($1,000)	Cost Per Equivalent Passenger Place[1] ($1,000)	Cost Per Pound (Dollars)
Airtrans	$386.3	$10.4	$27.6
Atlanta	867.2	9.5	31.5
Busch Gardens	678.0	8.0	25.6
Disneyworld	35.0	3.5	37.2
Duke	353.8	11.4	34.7
Fairlane	602.5	14.7	48.2
Houston	74.4	4.1	31.0
King's Dominion	68.6	3.8	36.1
Miami Airport	599.3	7.1	23.2
Miami Zoo	95.0	4.0	30.2
Minnesota Zoo	172.2	8.6	21.6
Morgantown	311.7	12.0	36.2
Orlando	747.8	8.2	29.2
Pearlridge	N/A	N/A	N/A
Sea-Tac	807.5	9.4	31.7
Tampa	555.8	6.6	25.9

Source: Dynatrend Incorporated, and U.S. DOT Research and Special Programs Administration "Supplement V - Cost Experience of Automated Guideway Transit Systems, Final Report," October 1983, p. 5-6.

N/A Not Available

[1] A "place" is defined as 5.38 square feet in order to give a measure of passenger capacity.

TABLE 5-4

LABOR INPUTS
AUTOMATED GUIDEWAY SYSTEMS

System	Personnel Per 1,000 Vehicle Hours	Personnel Per 10,000 Vehicle Miles	Personnel Per 100,000 Equivalent Place Miles
Airtrans	0.518	0.518	0.140
Atlanta	0.724	0.746	0.082
Busch Gardens	14.360	9.087	0.535
Disneyworld	0.116	0.243	0.049
Duke	N/A	1.583	0.511
Fairlane	N/A	N/A	N/A
Houston	0.333	0.598	0.111
King's Dominion	N/A	8.807	0.612
Miami Airport	1.735	0.657	0.026
Minnesota Zoo	4.008	17.449	1.454
Morgantown	N/A	0.609	0.234
Orlando	0.441	0.519	0.029
Pearlridge	3.576	11.471	1.147
Sea-Tac	0.262	0.218	0.026
Tampa	0.139	0.247	0.029

Source: Derived from Table E-3

Note: Averages are not shown because of the very different configurations of these systems.

TABLE 5-5

DETAILED BREAKDOWN OF ENERGY REQUIREMENTS FOR AUTOMATED GUIDEWAY MODES
(Btu's per place-mile[1/])

Mode	Speed MPH[2/]	Vehicle Operation[3/]	Maintenance[4/]	Wayside and Station[5/]	Vehicle Manufacture[6/]	Guideway Construction[7/]	Total[8/]
Automated Guideway[9/] at Grade	10	580	68	780	19	1,000	2,447
	20	580	68	390	19	500	1,557
	50	580	68	156	19	200	1,023
Automated Guideway Underground	10	580	68	1,032	19	1,233	2,932
	20	580	68	516	19	617	1,800
	50	580	68	206	19	245	1,118

Source: Pushkarev, Boris S., with Jeffrey M. Zupan and Robert S. Cumella, Urban Rail In America, A Regional Plan Association Book, Indiana University Press 1982, pp. 85-98.

[1/] Energy use is given per place-mile to take account of different vehicle sizes. One place = 5.38 sq. ft. or $0.5 m^2$ of vehicle area.

[2/] Miles per hour.

[3/] Vehicle operation is nearly independent of speed: the energy needed for frequent acceleration on the slower systems roughly balances that needed to attain high speed on the faster systems.

[4/] Energy used for vehicle maintenance depends on fleet size.

[5/] Wayside and station energy is mostly a fixed value that declines per place-mile as traffic density per line-mile increases. It varies with the spacing of stations, the type of construction (aboveground or underground), and the type of ventilation (with or without air conditioning).

[6/] The energy needed to manufacture vehicles varies among modes according to the longevity of the different equipment.

[7/] Based on the construction cost per mile of line of 1977 dollars, the average energy content of a fixed guideway construction dollar (30,000 Btu) in 1977 prices, and the useful life of the various types of guideways.

[8/] The total energy requirement of a mode is not a fixed number but a variable, strongly dependent on traffic volume and additional factors such as regenerative braking on rapid transit cars and air-conditioning of stations.

[9/] Includes rubber-tired trolleybus systems propelled by electricity.

CHAPTER VI

PEDESTRIAN ASSISTANCE SYSTEMS

This chapter presents some capacity, cost, and operating characteristics of pedestrian assistance systems. Systems in this category include elevators, escalators, and moving walkways.

TABLE 6-1

SPEED OF WALKING

Speed		Percent of Population	Cumulative Percent
Feet per Minute	Miles per Hour		
less than 120	less than 1.36	0	0
120-180	1.36-2.05	8	8
180-210	2.05-2.39	11	19
210-240	2.39-2.73	16	35
240-270	2.73-3.07	20	55
270-300	3.07-3.41	20	75
300-330	3.41-3.75	13	88
330-360	3.75-4.09	9	97
360-390	4.09-4.43	3	100

Average Speed = 262 feet/minute or 2.98 miles/hour

Source: Jackson and Moreland, "The Feasibility Study of Moving Walkways," Boston Redevelopment Authority, January 1971.

TABLE 6-2

PEDESTRIAN STAIR SPEEDS
HORIZONTAL TIME-MEAN-SPEEDS
(Feet/Minute)

	Outdoor Stairs[1]				Indoor Stairs[2]			
	Speed		Steps/Minute		Speed		Steps/Minute	
Age Group	Up	Down	Up	Down	Up	Down	Up	Down
29 and Under	115	160	117	163	108	149	116	160
30-50	114	153	116	160	99	127	106	136
Over 50	83	117	84	119	83	108	89	116
Average	113	150	115	153	100	132	107	141

---

[1] 6 inch riser, 12.0 inch tread, 27 degree angle.

[2] 7 inch riser/ 11.25 inch tread, 32 degree angle.

Source: Fruin, J.J., Pedestrian Planning and Design, Metropolitan Association of Urban Designers and Environmental Planners Inc., Churchill, N.Y., 1971.

TABLE 6-3

PRACTICAL OPERATING CAPACITY OF STANDARD TURNSTILES

Type of turnstile	Capacity (Persons Per Minute)
Registering:	
Free admission	40-60
With ticket collector	25-35
Cashier operated	12-18
Coin Operated, Low:	
Single Slot	25-50
Multiple Fare	12-25
Coin Operated, High (7 ft.)	10-15
Non-Registering:	
Low traffic controller	40-60
7 ft. high traffic controller (roto-gate)	25-40

Source: Baerwald, John, (Editor), Traffic Engineering Handbook, Institute of Traffic Engineers, Washington, D.C., 1965.

TABLE 6-4

MAXIMUM STAIRWAY CAPACITY
(ppm/ft)[1]

Up	Down
18.9	20.0

[1]/Values in pedestrians/minute/foot of stair width.

Source: Fruin, J.J., Designing for Pedestrians - A Level of Service Concept. A dissertation submitted in partial fulfillment for the degree of Doctor of Philosphy, Polytechnic Institute of Brooklyn, Brooklyn, New York, 1970.

TABLE 6-5

ESCALATOR CAPACITIES AND BOARDING TIMES

Incline Speed (fpm)1/	90	120	90	120
Width at Hip (inches)	32	32	48	48
Width at Tread (inches)	24	24	40	40
Maximum Theoretical Capacity (persons/hour)	5,000	6,700	8,000	10,700
Nominal Capacity2/ (persons/hour)	3,750	5,025	6,000	8,025
Nominal Capacity (persons/minute)	63	84	100	133

1/Incline speed 90 feet per minute (fpm) is 68 steps per minute. Include speed 120 feet per minute is 89 steps per minute.

2/Nominal capacity is 75 percent of theoretical maximum capacity.

Boarding Time (seconds)

Light Traffic		Heavy Traffic
No Baggage	Baggage	No Baggage
.98	1.05	1.17

Source: Fruin, J.J., Pedestrian Planning and Design, Metropolitan Association of Urban Designers and Environmental Planners, Inc., Churchill, N.Y., 1971.

TABLE 6-6

MOVING WALKWAY CAPACITIES[1]

Treadway Incline-Speed (feet/minute)	Maximum Capacity Persons/Minute (persons/hour)	Maximum Capacity Persons/Minute per Foot of Width (persons/hour per foor of width)	Nominal Capacity[2] Persons/Minute (persons/hour)
0 degree incline-180	240 (14,400)	72 (4,320)	180 (10,000)
5 degree incline-140	186 (11,180)	56 (3,354)	140 (8,400)
10 degree incline-130	173 (10,400)	52 (3,120)	130 (7,800)
15 degree incline-125	167 (10,0000	50 (3,000)	125 (7,500)

[1]/40-inch nominal width (2 persons per 1.5 foot treadway). Speed, angles, and capacities will vary with width per ASA 17.1 (code) part xiii.

[2]/Nominal capacity is 75 percent of theoretical maximum capacity.

Source: Strakosch, G., Vertical Transportation, Elevators and Escalators, Otis Elevator Co., Wiley, N.Y., 1967.

TABLE 6-7

ELEVATOR CAPACITY CONSIDERATIONS

Building Type	Population Served	Desirable Directional Capacity	Desirable Frequency
Office Buildings	1 person per 120-175 sq. ft. of usable area	(a) diversified tenants 11-12.5% population served per 5 minutes (b) single purpose tenants 12.5-18% population served per 5 minutes	30 seconds
Apartments	1.5 to 2 persons per bedroom	5-7% population served per 5 minutes	60-90 seconds
Motels and Hotels	(a) convention type hotels 1.5-1.9 persons per room at 85-95% occupancy (b) motels, limited service hotels, 1.3-1.5 persons per room at 60-70% occupancy	10-12% of population served per 5 minutes	40-90 seconds; target 50 seconds
Hospitals	(a) pedestrian traffic 3.0-3.5 persons per bed	10-20% of population served per 5 minutes	40 seconds
	(b) equipment traffic 4 vehicles per 100 beds	100% of vehicles per 5 minutes	50 seconds

Source: Vertical Transportation 1974, Otis Elevator Company, 1973.

TABLE 6-8

ELEVATOR CAPACITIES

Building Type	Suggested Elevator Capacities (persons per car)
Apartment	8
Apartment and Small Factory	13-16
Apartment and Office	16
Small Office and Factory	20
Office/Hotel	20
Large Office	23-27
Store	23

Note: The number of shafts required is usually calculated in a cost minimization format given standards of service to be provided. The number of shafts is a function of the kind of motor used (gearless, geared, hydraulic), the peak demand to be served, the number of floors in the building, and the access to elevators (single deck, double deck). In general terms it is expressed as:

No. of Shafts =

$$\frac{\text{(Peak Demand (persons/min)) x (Floors in Buidling) x (Floor Height (ft))}}{\text{(Car Capacity (persons/car)) x (Average Car Speed (feet per minute))}} \times \frac{1}{\text{(Access Factor}}$$

The access factor accounts for the possibility of simultaneous loading at different floors. The average car speed will depend on the distribution of demand, the number of stops, the floor height, etc., which will vary from facility to facility. It is not the operating speed presented in Table 6-9.

Source: Vertical Transportation 1974, Otis Elevator Company, 1973.

TABLE 6-9

ELEVATOR SPEEDS

Type of Motor	Range of Speeds Available (Feet Per Minute)	Comments
Hydraulic	75	maximum rise 40 feet
Hydraulic	125	maximum rise 40 feet
Geared	150	(These are the standard speed ranges)
Geared	200	
Gearless	350	
Gearless	500	Speeds above 400 fpm are used for large multi-story buildings and cost $8,000-$12,000 more per unit
Gearless	600	
Gearless	700 up to 1600 1/	

1/Speeds above 700 fpm and rises of 300 feet require special equipment.

Source: Vertical Transportation 1974, Otis Elevator Company, 1973.

Discussion with Westinghouse Elevator, Washington, D.C., 1975.

TABLE 6-10

PEDESTRIAN ASSISTANCE SYSTEMS CAPITAL AND MAINTENANCE COSTS

Escalator

Width (Inches)	Rise (Feet)	Capital Cost	Maintenance Cost ($ Per Month)
32	13-14	$120,000-$130,000	350 - 500
48	13-14	$140,000-$150,000	350 - 750
48	30[1]	$340,000-$450,000	700 - 1,000

Elevator

For a standard 10-12 story application
4 elevator units, 200-350 fpm

Capital Cost/Unit[2]	Maintenance/Unit
$130,000 - $150,000	$550 - $650 per month

Moving Walkway

Width (Inches)	Capital Cost ($ Per Linear Ft)	Maintenance ($ Per Month)
26	$1,700 - $3,000	$600 - $800
40	$3,000 - $3,750	$600 - $800

1 A typical subway application, with special safety features.

2 For speeds above 500 feet per minute the cost would be $20,000 - $25,000 more. For each additional floor the cost would be $3,500 - $5,000.

Sources: Otis Elevator Company, Washington, D.C., 1984.
Westinghouse Elevator, Washington, D.C., 1984.

Appendix A

Miscellaneous Supporting Material

TABLE A-1

TYPICAL LIFE TIMES FOR SELECTED VEHICLES AND GUIDEWAYS

	Average Life (Years)
Rail Rapid Transit	
Track	20-25
Structures	50-60
Cars	25-30
Commuter Rail	
Track (no freight service)	20-25
Structures	50-60
Cars	40
Engines	30
Light Rail	
Track	20-25
Structures	50-60
Cars	20-30
Bus	
Normal Coach	10-15
Dial-a-Bus (heavy)	6
Dial-a-Bus (light)	3
Automobile	10
Roadway	
Bridges	30
Freeway	20
Expressway	20

Source: Normally expected industry experience, subject to very substantial undertainties.

TABLE A-2

COMPOSITE PRICE INDICES
(1967 BASE)

Year	Consumer Price Index	FHWA Construction Index	FHWA Maintenance Index	ENR[1] Construction Index	ENR[1] General Index
1967	100.0	100.0	100.0	100.0	100.0
1968	104.2	103.4	102.8	107.4	107.8
1969	109.8	111.8	110.4	117.7	118.7
1970	116.3	125.6	116.8	124.4	128.9
1971	121.3	131.7	122.7	140.5	146.8
1972	125.0	138.2	131.7	155.2	163.0
1973	133.1	152.4	141.8	168.4	176.5
1974	147.7	201.8	158.7	178.3	188.2
1975	161.2	203.8	173.0	193.3	205.9
1976	170.5	199.3	188.1	210.9	223.4
1977	181.5	213.4	202.9	229.0	240.0
1978	195.4	254.8	218.8	248.0	258.0
1979	217.4	304.3	239.8	269.0	280.0
1980	246.8	347.8	273.1	288.0	302.0
1981	272.4	334.4	296.8	310.0	329.0
1982	289.1	313.3	324.7	331.0	356.0
1983	298.4	312.6	337.4	353.0	379.0

Sources: Federal Highway Administration, "Highway Maintenance and Operation Cost Trend Index," U.S. Department of Transportation, Washington, D.C.

U.S. Bureau of the Census, Statistical Abstract of the United States: 1982-83.

Engineering News Record, "Quarterly Cost Roundup," Vol. 212, No. 13, March 29, 1984.

TABLE A-3

COST INDEX OF RAILROAD MATERIAL AND WAGE RATES
(1977 Base)

Year	Fuel	Material and Supply	Wages and Benefits	Composite
1967	25.7	46.0	39.7	39.2
1968	26.6	47.2	42.2	41.4
1969	27.4	48.6	45.2	44.0
1970	28.4	50.4	49.9	48.2
1971	29.4	52.3	55.4	52.3
1972	30.1	54.7	61.0	57.0
1973	35.0	56.6	69.1	64.0
1974	69.8	65.4	75.2	73.1
1975	82.6	87.6	82.3	83.2
1976	89.9	93.6	92.2	92.2
1977	100.0	100.0	100.0	100.0
1978	104.4	106.2	109.8	108.6
1979	155.5	116.4	120.8	123.5
1980	233.1	134.2	132.5	143.3
1981	280.2	145.2	149.4	162.2
1982	267.1	146.3	167.0	173.6
1983	232.2	140.0	184.2	181.1

Source: Association of American Railroads, Indices of Railroad Material Prices and Wage Rates, Economics and Finance Department, Washington, D.C.

TABLE A-4

CONSUMER PRICE INDICES FOR TRANSPORTATION GOODS
(1967 BASE)

Year	Overall Private Transport Index	Auto Repairs and Maintenance	New Automobile Price Index	Gasoline Price Index	Local Transit Fares
1967	100.0	100.0	100.0	100.0	100.0
1968	103.0	105.5	102.8	101.4	105.9
1969	106.5	112.2	104.4	104.7	114.4
1970	111.1	120.6	107.6	105.6	134.5
1971	116.6	129.2	112.0	106.3	143.4
1972	117.5	135.1	111.0	107.6	150.1
1973	121.5	142.2	111.1	118.1	150.1
1974	136.4	156.4	117.5	159.9	148.0
1975	149.8	176.6	127.6	170.8	155.5
1976	164.6	189.7	135.7	177.9	173.3
1977	176.6	203.7	142.9	188.2	178.5
1978	185.0	220.6	153.8	196.3	181.8
1979	212.3	242.6	166.0	265.6	189.8
1980	249.2	268.3	179.3	369.1	217.6
1981	277.5	293.6	190.2	410.9	274.8
1982	287.5	315.8	197.5	389.4	310.9
1983	293.9	330.0	202.4	376.4	322.1

Source: Bureau of Labor Statistics, Consumer Price Index Detailed Reports, Washington, D.C.

TABLE A-5

HIGHWAY AND STREET CONSTRUCTION HOURLY WAGE RATES
(SIC 161)

Year	Hourly Rate ($)
1967	3.57
1968	3.90
1969	4.19
1970	4.51
1971	4.91
1972	5.12
1973	5.12
1974	5.84
1975	6.31
1976	6.73
1977	7.00
1978	7.56
1979	8.25
1980	8.68
1981	9.42
1982	9.97
1983	10.35

Source: U.S. Department of Labor Supplement to Employment and Earnings, 1909-78, Washington, D.C., July 1983.

U.S. Department of labor, Employment and Earnings, Vol. 31, No. 3, March 1984, p. 82.

Appendix B

Rail Transit

TABLE B-1

EXTENT OF RAIL RAPID SYSTEMS
(1974, 1983)

Location	Route Miles Of Track		Location	Route Miles of Track	
	1974	1983		1974	1983
London	252.0	250.8	Cleveland	19.0	15.6
New York	231.7	222.0	Budapest	3.0	15.6
Paris	154.0	174.0	Athens	20.2	15.4
Tokyo	38.4	118.2	Rome	6.8	15.3
Moscow	98.0	110.4	Atlanta	-	14.6
Chicago	89.4	88.5	Sao Paulo	-	14.4
San Francisco	75.0	75.0	Seoul	-	14.2
W. Berlin	48.8	65.0	Prague	4.0	14.1
Stockholm	42.9	63.7	PATH/(NY-NJ)	14.0	14.0
Madrid	29.9	61.1	Rotterdam	0	14.0
Hamburg	55.6	53.7	Santiago	0	14.0
Osaka	43.5	53.5	Brussels	2.2	13.2
Leningrad	30.2	42.0	E. Berlin	-	12.5
Washington	-	39.0	Baku	-	11.2
Toronto	23.8	34.1	Kharkov	-	10.4
Barcelona	24.8	32.5	Amsterdam	-	10.3
Boston	38.6	29.8	Kobe	-	10.1
Frankfurt	-	28.1	Tashkent	-	9.2
Montreal	16.1	28.1	Lyon	-	7.8
Peking	-	24.0	Baltimore	-	7.7
Philadelphia	29.0	23.8	Lisbon	5.0	7.2
Hanover	-	23.7	Yokohama	-	6.9
Oslo	21.7	22.0	Helsinki	-	6.7
Munich	9.9	21.0	Nuremburg	-	6.6
Buenos Aires	19.6	20.4	Glasgow	6.6	6.2
Sapparo	-	19.0	Lille	-	5.4
Rio Di Janeiro	.9	18.6	Bonn	-	3.6
Vienna	16.6	18.6	Marseilles	-	3.6
Tbilisi	-	16.1	Seville	-	2.4
Bucharest	-	16.0	Kyoto	2.2	2.2
Hong Kong	-	15.7	Bochum	-	2.0
Kiev	11.3	15.7			

Sources: Figures for 1983 are from "Subways" Mass Transit, Vol. X., No. 10, October 1983.

Figures for 1974 are from Jane's World Railways and Rapid Transit Systems 1980, Ed. by Paul Goldsack, Jane's Yearbooks, 1981.

TABLE B-1a

NEW RAIL RAPID SYSTEMS UNDER CONSTRUCTION
(1983)

City	Country
Alma Ata,	U.S.S.R.
Ankara,	Turkey
Baghdad,	Iraq
Bangkok,	Thailand
Belgrade,	Yugoslavia
Bielefeld,	Federal Republic of Germany
Cairo,	Egypt
Calcutta,	India
Caracus,	Venezuela
Duisburg,	Federal Republic of Germany
Gorki,	U.S.S.R.
Guangzhou,	China
Kuybishev,	U.S.S.R.
Lagos,	Nigeria
Lodz,	Poland
Miami,	Florida, U.S.A.
Minsk,	U.S.S.R.
Naples,	Italy
Novosibirsk,	U.S.S.R.
Porto Alegre,	Brazil
Pusan,	South Korea
Sendai,	Japan
Szczecin,	Poland
Teheran,	Iran
Tunis,	Tunisia
Turin,	Italy
Warsaw,	Poland
Yukarigaoka,	Japan

Source: "Subways" Mass Transit, Vol. X, No. 10, October 1983. Many extensions were also underway in the cities with operating systems.

TABLE B-2

TYPICAL EXISTING RAIL RAPID SPEEDS

Location	Facility	Average Speed (mph)	Average Station Spacing (Miles)
New York	IND 6th-8th Avenue Express	24.5	1.3
New York	IRT-Lexington Avenue Express	19.6	1.0
New York	IND-8th Avenue Express	28.6	1.6
New York	IRT-7th Avenue Express	19.5	0.8
Toronto	Yonge Street Subway	17.6	0.5
Chicago	Congress Street Expressway	24.5	0.5
Cleveland	Rapid Transit Line	28.0	1.2
Chicago	CTA-Dan Ryan Line	30.0	--
Boston	MBTA (Red Line)	32.0	0.8-1.27[1]
Philadelphia	PATCO (lindenwold)	39.0	0.19-3.20[1]
San Francisco	BART	47.0	0.35-5.85[1]

1/Different sections of these lines have different average station spacing.

Sources: Institute of Traffic Engineers, "Capacity and Limitations of Urban Transportation Modes," Washington, D.C., 1965.

Transportation Systems Center, Safety and Automatic Train Control for Rail Rapid Transit Systems, U.S. Department of Transportation, July 1974.

TABLE B-3

THEORETICAL EQUATIONS FOR DETERMINING AVERAGE RAIL SPEEDS

Case 1: Station Spacing Sufficient to Reach Cruise Speed

$$\bar{v} = \frac{3600s}{\frac{v}{2a} + \frac{v}{2b} + \frac{3600s}{v} + t_d}$$

where:

$$s \geq \frac{v^2}{7200a} + \frac{v^2}{7200b}$$

Case 2: Station Spacing not Sufficient to Reach Cruise Speed

$$\bar{v} = \frac{3600}{(7200\ (a+b)/sab)^{1/2} + \frac{t_d}{s}}$$

where:

$$s = \frac{v^2}{7200a} + \frac{v^2}{7200b}$$

With:

a = Acceleration Rate (Constant)(mphps)

b = Deceleration Rate (Constant)(mphps)

v = Cruising (Maximum) Speed (mph)

s = Station Spacing (miles)

t_d = Dwell Time (seconds)

$\bar{v}$ = Average Speed (mph)

TABLE B-4

THEORETICAL EQUATION FOR DETERMINING RAIL TRANSIT CAPACITIES

$$h = t + (2l/a)^{1/2} + r$$

where:

- h = train headway (seconds)
- t = dwell time (seconds); typical average dwell times range from 10 to 30 seconds for new rail rapid transit systems
- l = length of train (feet); off peak train lengths are typically 150 feet; peak are 750 feet
- a = average acceleration or deceleration (miles per hour per second); 3 mph/sec is a typical value
- r = emergency response time (seconds); ranges from 5.0 seconds for fully automatic systems, to 10 seconds for semi-automatic, to 20 seconds for commuter railroads.

Source: Lang, A., and Soberman, R., Urban Rail Transit: Its Economics and Technology, MIT Press, Cambridge, Massachusetts, 1964.

TABLE B-5

SERVICE VOLUME OF TYPICAL RAIL RAPID TRANSIT LINES (PEAK HOURS)

Location-Facility	Trains Per Hour	Headway (seconds)	Cars Per Train	Cars Per Hour	Seating Capacity Per Car	Seating Capacity Per Train	Seating Capacity Total	Actual Passenger Loads
New York-IND-6th-8th-Ave. Express	32	112	10	320	60	600	19,200	61,400
New York-IRT-Lexington Ave. Express	31	116	9	279	40	360	11,160	44,510
New York-IND - 8th Ave. Express	30	120	10	300	60	600	18,000	62,030
New York-IRT - 7th Ave. Express	24	150	9	216	40	360	8,640	36,770
Toronto-Yonge St. Subway	28	128	8	224	62	496	13,888	35,166
Chicago Congress St. Expressway	25	144	6	150	49	294	7,350	10,376
Cleveland-Rapid Transit Line	20	180	6	120	53	318	6,360	6,211
Philadelphia PATCO	30	120	6	180	80	480	14,400	36,000
San Francisco BART1/	6	600	10	60	72	720	4,320	12,720
Boston MBTA - Red Line	15	240	4	60	64	256	3,840	14,340
Chicago Dan Ryan Line	30	120	8	240	50	400	12,000	24,000

1/Headways were improved after opening of Transbay Tunnel.

Sources: Institute of Traffic Engineers, Capacity and Limitations of Urban Transportation Modes, Washington, D.C., 1965.

Transportation Systems Center, Safety and Automatic Train Control for Rail Rapid Transit System, U.S. Department of Transportation, July 1974.

TABLE B-6

SERVICE VOLUME OF TYPICAL LIGHT RAIL TRANSIT SYSTEMS (PEAK HOUR)

Location	Vehicles Per Hour	Headway[1/] (seconds)	Actual Passenger Loads	Average Trip Length (Miles)
Cologne	59	61	9,600	3.2
Rotterdam	37	97	4,600	n/a
Dusseldorf	92	39	14,000	2.9
Frankfurt	23	157	8,200	2.7
Stuttgart	40	90	1,200	3.5
Hanover	80	45	18,000	3.4
Gothenburg	88	41	7,200	2.7
Bielefeld	24	150	4,300	2.5

1/Numbers are based on a single one-way track; as service volume increases, special signals are necessary.

Source: Vuchic, V., Light Rail Transit Systems - A Definition and Evaluation, U.S. Department of Transportation, October 1972.

TABLE B-7

RAIL RAPID TRANSIT LABOR INFORMATION-SERVICE PROVIDED

System	Revenue Car Miles	Total Car Miles	Revenue Car Hours	Total Car Hours
NYCTA	255,500,030	257,950,470	13,906,859	16,683,356
CTA	49,687,800	50,318,700	1,832,740	1,851,810
PATCO	4,287,508	4,377,909	147,880	151,028
SEPTA	13,154,290	13,170,059	860,723	861,541
BARTD	28,343,955	28,343,955	1,031,668	1,031,668
WMATA	17,409,454	18,071,587	974,425	1,011,343
MARTA	3,772,531	3,836,314	198,504	205,474

Source: National Urban Mass Transportation Statistics, U.S. DOT Urban Mass Transportation Administration, Fiscal Year 1982

Key:

NYCTA: New York City Transit Authority
CTA: Chicago Transit Authority
PATCO: Port Authority Transit Corporation (Lindenwold)
SEPTA: Southeastern Pennsylvania Transportation Authority (Phildelphia)
BARTD: Bay Area Rapid Transit District, San Francisco-Oakland, Calif.
WMATA: Washington Metropolitan Area Transit Authority
MARTA: Metropolitan Atlanta Rapid Transit Authority

TABLE B-8

RAIL RAPID LABOR INFORMATION-EMPLOYEES BY CATEGORY

System	Vehicle Operators	Vehicle Mechanics	Vehicle Servicers	Other Personnel
NYCTA (NY)	5,965	2,980	804	21,163
CTA (CHICAGO)	1,866	316	103	1,754
PATCO (NJ/PA)	48	54	15	206
SEPTA (PHILA.)	225	267	51	1,333
BARTD (SF/OAKLAND)	215	228	26	1,462
WMATA (WASH DC)	530	814	218	1,091
MARTA (ATLANTA)	55	55	0	401

Source: National Urban Mass Transportation Statistics, U.S. DOT Urban Mass Transportation Administration, Fiscal Year 1982.

TABLE B-9

RAIL RAPID LABOR INFORMATION-VEHICLES AND EMPLOYEES

System	Peak Vehicles	Midday Vehicles	Peak/Base Ratio	Total Personnel
NYCTA (NEW YORK)	4,849	2,186	2.218	30,912
CTA (CHICAGO)	888	304	2.921	4,039
PATCO (NJ/PA)	96	14	6.857	323
SEPTA (PHILA.)	261	136	1.919	1,876
BARTD (SF/OAKLAND)	311	140	2.221	1,931
WMATA (WASH DC)	250	126	1.984	2,653
MARTA (ATLANTA)	54	40	1.350	511

Source: National Urban Mass Transportation Statistics, U.S. DOT Urban Mass Transportation Administration, Fiscal Year 1982.

TABLE B-10

LIGHT RAIL INFORMATION-SERVICE PROVIDED

System	Revenue Miles	Total Miles	Revenue Hours	Total Hours
Philadelphia	5,760,390	5,765,197	622,152	623,976
Newark	569,563	569,563	29,033	29,033
Boston	1,020,549	1,020,549	67,402	67,402
Cleveland	1,289,757	1,289,757	79,718	79,718
SF Muni	3,929,236	3,929,236	344,069	344,069
Pittsburgh	1,708,471	1,708,471	114,458	114,458
New Orleans	704,616	704,616	81,212	81,212
San Diego	1,061,170	1,064,820	59,130	59,495

Key:

Philadelphia: SEPTA
Newark: NJT
Boston: MBTA
Cleveland: GCRTA
San Francisco: MUNI
Pittsburgh: PAT
New Orleans: NOPSI
San Diego: SDTI

Source: National Urban Mass Transportation Statistics, U.S. DOT, Urban Mass Transportation Administration, Office of Technical Assistance, (Fiscal Year 1982).

TABLE B-11

LIGHT RAIL LABOR INFORMATION-VEHICLES AND EMPLOYEES

System	Peak Vehicles	Midday Vehicles	Peak/Base Ratio	Total Personnel
SEPTA (PHILA.)	165	87	1.897	1,264
NJT (NEWARK)	16	7	2.286	42
MBTA (BOSTON)	68	66	1.030	279
GCRTA (CLEVELAND)	43	8	5.375	318
MUNI (SAN FRANCISCO)	82	63	1.302	846
PAT (PITTSBURGH)	54	18	3.000	297
NOPSI (NEW ORLEANS)	20	17	1.176	129
SDTI (SAN DIEGO)	12	10	1.200	64

Source: National Urban Mass Transportation Statistics, U.S. DOT, Urban Mass Transportation Administration, Office of Technical Assistance, (Fiscal Year 1982).

TABLE B-12

LIGHT RAIL LABOR INFORMATION-EMPLOYEES BY CATEGORY

System	Vehicle Operations	Vehicle Mechanics	Vehicle Servicers	Other Personnel
SEPTA (PHILA.)	493	174	33	564
NJT (NEWARK)	17	14	4	7
MBTA (BOSTON)	110	39	12	118
GCRTA (CLEVELAND)	95	43	7	173
MUNI (SAN FRANCISCO)	295	203	35	313
PAT (PITTSBURGH)	107	43	21	126
NOPSI (NEW ORLEANS)	52	30	9	38
SDTI (SAN DIEGO)	21	6	2	35

Source: National Urban Mass Transportation Statistics, U.S. DOT, Urban Mass Transportation Administration, Office of Technical Assistance, (Fiscal Year 1982).

TABLE B-13

CHARACTERISTICS OF RECENTLY CONSTRUCTED RAPID RAIL INFRASTRUCTURE

Location	Miles of Two Track Facility			Number of Stations			Years of Construction	Actual Cost Cost ($M)	Source	Percent Completed As of 6/81
	UG	EL	AG	UG	EL	AG				
CLEVELAND										
Initial	0	0	14.9	0	0	15	1955	38.9	(Boyd, 1973)	100%
Extension	.3	0	3.8	0	0	3	1968	15.2	(Dyer, 1977)	100%
PHILDELPHIA										
Lindenwold	0	0	14.5	0	0	13	1967	78.3	(Boyd, 1973)	100%
SAN FRANCISCO										
BART	20	24	27.	14	13	7	1963-80	1305.	(BART Impact, 1978)	100%
WASHINGTON										
Metrorail Phase I	34.	8.5	17.5	42	3	15	1968-76	4000.	(Hearings, 1981)	95%
Metrorail Full	49	11	41.	53	5	27	1968-90	7600.	(Hearings, 1981)	55%
ATLANTA										
MARTA Phase A	6.8	4.0	5.5	8	2	7	1975-1980	1054	(MARTA)	95%
BALTIMORE										
MTA Phase I	4.5	3.5	0	6	3	0	1977-83	704.	(MTA, 1981)	75%
BOSTON										
MBTA Red Line South	0	0	9.5	0	0	5	1966-80	194.	(MBTA, 1970, 1981)	100%
MBTA Red line NW	3.2	0	0	4	0	0	1978-84	619.	(MBTA, 1980)	50%
MBTA Orange Line N	1.0	0	4.9	2	0	5	1967-75	126.1	(Dyer, 1977)	
MIAMI										
Initial	2.0	19.3	1.7	0	20	0	1979-84	767.	(APTA, 1978)	
NEW YORK										
NYCTA 63D Street	6	0	0	0	0	0	1972	360.	(Boyd, 1973)	
NYCTA 2nd Avenue	6	0	0	0	0	0	1972	36.3	(Boyd, 1973)	
NYCTA 2nd Avenue	3.6	0	0	0	0	0	1973	240.	(Boyd, 1973)	
CHICAGO										
CTA Dan Ryan	0	0	10.5	0	0	9	1968-72	43.7	(CTA, 1981)	100%
CTA Kennedy	1.2	0	4.0	2	0	4	1968-72	50.2	(CTA, 1981)	100%
CTA O'Hara	.6	0	6.6	1	0	3	1980-84	180.2	(CTA, 1981)	10%

Source: Thomas Dooley, Transportation Systems Center, U.S. DOT.

REMARKS:

Cleveland	Initial system built on RR right-of-way (ROW), one line.
Philadelphia (Lindenwold)	4 miles of rehabilitated track, 10.5 miles of new track or existing (ROW), one line.
San Francisco	Includes transbay tube, excludes $156 million in joint or direct MUNI (Light rail) costs.
Washington	$3.9B expended by 9/80; 62% of total system miles complete as of miles 9/80, 51% of total system dollars experience as of 9/80.
Atlanta	Phase A has 2 lines, E/W and N/S. 50% complete by 1978. Estimates to complete, $1130 million, as of 4/1/80 $1 Billion committed as of 4/1/181.
Baltimore	1 line 50% complete as of 6/80.
Boston	Red line extension south and northwest. Orange line extension north. $300 M committed through 4/80 on Red line NW.
Miami	1 line.
New York	63d Street and 2nd Avenue sections are predominantly four tracks, two over two. Extension of existing line.
Chicago	Dan Ryan constructed in freeway median. Kennedy Line constructed in freeway median except 6200 feet of tunnel.

TABLE B-14

DISTRIBUTION OF RAPID RAIL SUBSYSTEM COSTS
(All Costs in Millions)

Subsystem	BART (Actual $)	Percent	MARTA (Phase A) (Actual $)	Percent	MBTA Red Line South (1980 $)	Percent	MTA Section A (Actual $)	Percent	CTA O'Hare Extension (Actual $)	Percent	MBTA Red Line Northwest (Actual $)	
Lane	103.	7	107.	9	24.3	11	17.4	2	0	0	12.	2
Guideway	547. (1)	37	369.5 (1)	33	32.7	15	194.8	25	44.7 (1)	20	201. (1)	32
Station	289.2 (2)	20	229.8	20	75.3 (1)	34	226.2	30	62.9 (2)	28	242. (2)	39
Trackwork	48.	3	24.8 (2)	2	14.9	7	15.9	2	14.8	7	19.	3
Power	37.	3	15. (2)	1	12.6	6	17.7	2	11.4	5	24	4
Control	52.	4	19.8 (2)	2	14.9	7	32.4	4	17.8	8	23.	4
Facilities	23.	2	27.2	2	-	0	17.7	2	9.8	4	-	0
E/Mgt/Test	205. (3)	14	261.1 (3)	23	12.8	6	181.7 (1)	24	18.7	8	98. (3)	16
Vehicles	175.	12	74.	7	33.8	15	64.1	9	44.4	20	0	
	1480.		1128.		221.1		768.		224.5		619	

Source: Thomas Dooley, Transportation Systems Center, U.S. DOT.

NOTES:

A. BART Source: (BART Impact, 1978)
(1) Guideway includes utility work $102 million incorporated costs deleted for direct or joint MUNI expenditures.
(2) $43 million in reported costs deleted for direct/indirect MUNI expenditures.
(3) Engineering/management includes $78 million in capitalized operating expenses.

B. MARTA Phase A Source: (MARTA, 1981)

(1) Guideway includes $46.4 million in Force Account work (interagency transfer) for railroad relocation, traffic maintenance, utility work.
(2) Track, power, control costs estimated from $67.6 million support equipment total.
(3) Engineering/management includes $31.4 million in insurance and $39.5 million in MARTA support services.

C. MBTA Red Line South Source: (MBTA, 1970-81)
(1) Station construction includes approximately $31 million for parking facilities.

D. MTA Baltimore Phase I Source: (MTA, 1981)
(1) Engineering management includes approximately $44.3 million in insurance and $35.9 million in project administration in addition to design engineering and construction management.

E. CTA O'Hare Extension Source: (CTA, 1981)
(1) Includes 2 million for tunnel work, 13 million for median and 8 million for bridge modifications.
(2) Includes 2 garages.

F. MBTA Red Line North Source: (MBTA, 1980)
(1) Includes $18 million for railroad relocation.
(2) Includes 2000-car garage at one station and 2 temporary stations and an underground bus intercept at another.
(3) $52.3 million contingency allocated to other categories.

TABLE B-15

1980 DOLLAR COSTS OF RECENTLY CONSTRUCTED RAPID RAIL INFRASTRUCTURE

Location	Miles of Two Track Facility		Percent UG	Stations	Stations/Mile	Stations/Mile	1980 $ Total Cost	1980 $ Cost/Two Track Mile
	AG & EL	UG			AG & EL	UG		
Cleveland	18.7	.3	2	18	.96	.0	233	12.3
Lindenwold	14.5	0	0	13	.90	.0	236	16.3
Chicago (3 projects)	21.1	1.8	8	19	.76	1.67	369	16.4
Miami	21.0	0	0	20	.95	0	602	28.7
San Francisco	51.0	20.0	28	34	.41	.70	3756	52.0
Boston (2 projects)	9.5	3.2	25	9	.53	1.25	713	56.1
Atlanta	9.5	6.8	42	17	.95	1.18	1167	71.2
Baltimore	4.5	3.5	44	9	.86	1.33	727	91.3
Washington	26.	34.	57	60	.70	1.23	5600	93.3

Infrastructure includes land, guideway, stations, power, track, signal, yards/shops, project design/mgt. unless noted.

Total or Unit Cost Models

(1) Cost/Mile ($M) = 16.02 + 1.34 (%UG) $R^2 = .96$

(2) Total Cost ($M) = -450 + 20 (Miles (AG & EL)) + 145 (Miles UG) $R^2 = .99$.

All coefficients significant @ .95 level.

Source: Thomas Dooley Transportation Systems Center, U.S. DOT.

TABLE B-16

CHARACTERISTICS OF RECENTLY CONSTRUCTED LIGHT RAIL INFRASTRUCTURE

Location	Miles of Two Track Facility			Number of Stations			Years of Construction	Actual Cost Cost ($M)	Source	Percent Completed As of 6/81
(Type of ROW)	UG (Exclusive)	EL (Semi)	AG (Mix)	UG	EL	AG				
BUFFALO										
Initial	5.2 (5.2)	0 (0)	1.2 (1.2)	8	0	6	1978-82	450.**	(PT, 6/79) (Diamant, 1980)	25
CALGARY										
Initial (1.0)	0.6 (3.5)	0 (0)	7.6	0	0	12	1979	123.3	(PT, 6/79) (Diamant, 1980)	100
EDMONTON										
Initial	1.0 (1.0)	0 (3.5)	3.5 (0)	2	0	3	1976	57.	(Bakker, 1979) (Diamant, 1980)	100
SAN DIEGO										
Initial	0	0 (14.4)	16.0 (1.6)	0	0	18	1979-83	92.3**	(San Diego, 1981) (Diamant, 1980)	100
San Francisco*										
MUNI MOD "	5.7 (7)	0 (4)	13.3 (8)	4	0	?	1971	225.0	(UMTA, 5/79) (BART, Impact 1978)	100
BOSTON*										
Riverside Line Modernization	0 (12.0)	0	12	0	0	13	1970-75	48.5	(UMTA), 5/79)	100
PITTSBURGH*										
South Hills	1.0	0	7.2	3	0	5	1982-84	330**	(PT, 6/79)	10

*Modernization

**Estimate as of 6/81

NOTES:

Pittsburgh: South Hills line totals 10.5 miles. Funded portion consists of 8.2 miles including construction and finishing of 3 underground stations, construction of shell only for 5 at-grade stations and construction of 17 station stops. Parts of this line exist now.

Boston: Modernization of the Riderside line included electrification and trackwork improvements $36.5, station improvements $2.0, on a new LRV maintenance facility $10.0 million.

MUNI: 19 miles of track 37% exclusive, 21% semi-exclusive and 42% mixed. Costs for MUNI Metro include $155 million of BART costs ($70 million for 1-7 mile section and $85 million of joint station costs. Also included are $47.9 million for track and $23.2 million for power modernization.

TABLE B-17

1980 DOLLAR COSTS OF RECENTLY CONSTRUCTED LIGHT RAIL SYSTEMS

Location	Miles of Two Track Facility AG & EL	UG	% UG	Stations	Stations/ Mile AG & EL	Stations/ Mile UG	1980 $ Total Cost ($ M)	1980 $ Cost/ Track Mile ($ M)
San Diego	16.0	0.0	0	18	1.13	0	82	5.0
Calgary	7.6	0.7	7	12	1.58	0	132	16.2
Edmonton	3.5	1.0	22	5	0.86	2.00	80	17.7
Buffalo	1.2	5.2	81	14	5.0	1.54	450.	70.4

Light Rail

Cost/Mile - 5.70 + .70 ($UG)
($ M)
R^2 = .98

TABLE B-18

EXPECTED COST AND RANGE OF COST
LIGHT RAIL

Percentage Underground	Expected Cost/Mile ($M)	95% Probable Range ($M)	80% Probable Range ($M)
20	21	5-37	14-28
40	37	22-54	29-45
60	53	33-72	44-61
80	68	44-92	57-79
100	84	54-114	71-97

Source: Expected cost and possibility range derived by Thomas Dooley of U.S. Transportation Systems Center.

TABLE B-19

DISTRIBUTION OF LIGHT RAIL SUBSYSTEM COSTS

Subsystem	San Diego Actual ($M)	San Diego Actual (%)	Calgary Actual ($M)	Calgary Actual (%)	Edmonton Actual ($M)	Edmonton Actual (%)
Land	$22.5	26	$16.1	11	$1.2	2
Guideway	12.5	14	49.5	34	15.6	24
Station	4.3	5	13.7	9	20.2	31
Track	9.2	11	5.7	4	6.4	10
Power	3.5	4	8.1	6	3.1	5
Signal	4.0	5	2.6	2	2.7	4
Facilities	1.6	2	8.0	5	.6	1
Management	16.7	19	20.4	14	8.1	12
Vehicles	12.0	14	22.7	16	7.4	11
TOTAL	86.4		146.2		65.2	

Source: Compiled by Thomas Dooley, U.S. Transportation Systems Center.

Sources defined in Table B-16.

TABLE B-20

ACTUAL LAND COSTS

Source	City, Property, Line	Length	Actual Cost ($M)	1980 Dollar Cost ($M)	Construction Year
	San Francisco (BART)				
(Bart Impact, 1978	Alameda (Freemont-Fruitvale)	20.45	$31.580	$105.2 (1)	1965
	Contra Costa (Concord-Rockridge)	18.36	11.788	41.9	1965
	Richmond Line (Richmond-Ashby)	12.42	28.896	102.9	1965
	Central Oakland (19th-Oakland)	3.13	8.869	29.5	1965
	Mission Line (16th St.-Daly City)	5.23	10.950	36.5	1966
	S.F. Line (Embarcadero-Civic)	2.98	1.910	6.4	1966
	Transbay Tube/Misc.	5.68	6.600	19.8	1966
	Total	(68.25)	101.1	342.2	
	Atlanta (MARTA)				
(MARTA, 1981)	Phase A	16.3	107.2 (3)	144.9	1976
	Boston (MBTA)				
(MBTA, 1970)	Red Line South	9.5	12.9	22.0	1970-80
(MBTA, 1980)	Red Line North	3.2	12.0	13.5 (5)	1978
(Dyer, 1977)	Orange Line North	16.9	18.	35.4	1971
	Baltimore (MTA)				
(MTA, 1981)	Section 1	8.0	17.4	22.6	1977
	Washington WMATA				
(Hearings, 1972 1980)	To Date 9/80	6.0	210.	289. (6)	1973-80
	Through 1990	101.	345.	372.	1973-90
	Chicago				
(Dyer, 1977)	Dan Ryan	10.5	1.0	2.3	1968
(Dyer, 1977)	Kennedy	5.2	2.0	4.6	1968
(Dyer, 1977)	Englewood	.6	1.2	2.8	1968
		16.3	4.2	9.7	
	Philadelphia				
(Dyer, 1977)	Lindenwold	10.5	6.2	19.3	1964
	Calgary (Light Rail)				
(City/Sub. Travel, 1978)		8.2	16.1	18.	1979
	Edmonton (Light Rail)				
(Bakker, 1980)		4.5	4.2	5.9	1976
	San Diego (Light Rail)				
(SDAG, 1981)		16.0	22.1	24.3	1979
	Pittsburgh (Busway)				
(PAT, 1981)	East Busway	6.8	15.3	15.3	1980
	South Busway	4.0	1.0	1.3	1975

NOTES:

(1) Actual costs escalated to 1980 dollar costs using the local ENR BCI index values in the year construction starts and 1980.

(2) The BART Impact (1978) study stated that 1100 acres were acquired for BART. This wculd indicate an average cost of $2.32/square foot in actual dollars or $8.31/square foot in 1980 dollars.

(3) Land costs for MARTA Phase A include acquisition, appraisal and relocation costs.

(4) A total of 1135 parcels of unknown size have been acquired.

(5) Annual real estate acquisition costs as reported in Hearings (1973-1980) have been escalated to 1980 dollars using the 20-city average ENR BCI value for 1980.

(6) The real estate expenditures forecasted (Hearings 1980) for 1980-1990 have been deflated to 1980 by assuming a 1985 expenditure midpoint and deflating the estimated expenditure by the same number which was used (1.61) to escalate costs from 1975 to 1980.

(7) Actual costs escalated to 1980 dollars using the 20 city national ENR BCI index for 1980 and the same index for the year construction started.

(8) Actual costs escalated to 1980 dollars using the Los Angeles ENR BCI index.

Source: Thomas Dooley, U.S. Transportation Systems Center.

TABLE B-21

DETAILED BREAKDOWN OF RAIL RAPID TRANSIT SYSTEM EMPLOYEES

		Number of Employees				
System	Total	Vehicle Operation	Vehicle Maintenance	Way, Power and Signals	Station	Administrative
NYCTA (New York)	25,683	7,225	4,895	6,974	4,917	1,672
CTA (Chicago)	4,392	1,370	570	1,196	789	467
BART (SF)	1,817	272	357	562	165	461
WMATA (D.C.)	1,435	192	327	349	317	250
SEPTA (Phila.)	1,342	246	254	609	153	80
MBTA (Boston)	2,028	500	339	693	310	186
PATH (NY/NJ)	996	338	211	231	33	183
MARTA (Atlanta)	308	61	80	56	51	60
PATCO (Phila./NJ)	263	58	69	48	26	62
GCRTA (Cleveland)	333	84	85	68	45	51
SIRT (NY)	266	107	52	65	14	28
TTC (Toronto)	2,141	328	953	131	446	283
MUCTC (Montreal)	1,788	345	360	418	342	323

Source: Pushkarev, Boris et. al., Urban Rail in America: An Exploration of the Criteria for Fixed-Guideway Transit, Indiana University Press, 1982, Table A-6, Part I.

TABLE B-22

DETAILED BREAKDOWN OF LIGHT RAIL LABOR BY CATEGORY

System	Total Number of Employees	Employees by Type				
		Vehicle Operation	Vehicle Maintenance	Way, Power and Signals	Station	Administrative
MBTA (Boston)	1,391	435	341	389	98	128
MUNI (SF)	329	210	20	45	-	54
SEPTA (Phila)						
(subway/surface)	407	166	62	107	32	40
(P & W)	73	26	18	23	1	5
PAT (Pittsburgh)	403	138	92	140	-	33
GCRTA (Cleveland)	147	65	33	27	-	22
NJT (Newark)	44	21	8	7	6	2
TTC (Toronto)	1,048	525	300	86	-	137
ETS (Edmonton)	113	28	15	20	37	13

Source: Pushkarev, Boris et. al., Urban Rail in America: An Exploration of the Criteria for Fixed-Guideway Transit, Indiana University Press, 1982, Table A-6, Part II (All data for 1976).

TABLE B-23

DETAILED BREAKDOWN OF RAIL RAPID TRANSIT EMPLOYEES PER MILLION PLACE HOURS OF SERVICE

		Number of Employees				
System	Total	Vehicle Operation	Vehicle Maintenance	Way, Power and Signals	Station	Administrative
NYCTA (New York)	16.51	4.65	3.14	4.48	3.16	1.08
CTA (Chicago)	20.11	6.27	2.61	5.48	3.61	2.14
BART (SF)	19.02	2.86	3.73	5.88	1.71	4.84
WMATA (D.C.)	11.40	1.53	2.61	2.77	2.50	1.99
SEPTA (Phila.)	14.42	2.64	2.73	6.54	1.65	0.86
MBTA (Boston)	30.54	7.53	5.10	10.44	4.66	2.81
PATH (NY/NJ)	21.20	7.20	4.50	4.91	0.70	3.89
MARTA (Atlanta)	12.93	2.57	3.36	2.35	2.13	2.52
PATCO (Phila./NJ)	14.42	3.19	3.78	2.63	1.43	3.39
GCRTA (Cleveland)	20.17	5.08	5.15	4.13	2.73	3.08
SIRT (NY)	18.51	7.45	3.62	4.52	0.98	1.94
TTC (Toronto)	9.50	1.45	4.24	0.57	1.98	1.26
MUCTC (Montreal)	16.65	3.22	3.36	3.88	3.18	3.01

Source: Pushkarev, Boris et. al., Urban Rail in America: An Exploration of the Criteria for Fixed-Guideway Transit, Indiana University Press, 1982, Table A-6, Part I. A place is 5.38 square feet.

TABLE B-24

DETAILED BREAKDOWN OF LIGHT RAIL LABOR BY CATEGORY
IN EMPLOYEES PER PLACE-HOUR

System	Total Number of Employees	Employees per Million Place Hour of Service				
		Vehicle Operation	Vehicle Maintenance	Way, Power and Signals	Station	Administrative
MBTA (Boston)	36.46	11.41	8.93	10.20	2.56	3.36
MUNI (SF)	13.30	8.49	0.81	1.82	-	2.18
SEPTA (Phila)						
(subway/surface)	18.95	7.73	2.88	4.99	1.49	1.86
(P & W)	27.32	9.72	6.73	8.60	0.37	1.90
PAT (Pittsburgh)	37.36	12.79	8.53	12.98	0	3.06
GCRTA (Cleveland)	24.09	10.65	5.41	4.42	-	3.61
NJT (Newark)	16.47	7.86	3.00	2.61	2.25	0.75
TTC (Toronto)	13.77	6.90	3.94	1.13	-	1.80
ETS (Edmonton)	22.00	5.45	2.92	3.89	7.20	2.54

Source: Pushkarev, Boris et. al., Urban Rail in America: An Exploration of the Criteria for Fixed-Guideway Transit, Indiana University Press, 1982, Table A-6, Part II (All data for 1976). A "place" is 5.38 square feet.

TABLE B-25

DETAILED BREAKDOWN OF RAIL RAPID TRANSIT EMPLOYEES PER MILLION PLACE MILES OF SERVICE

System	Total	Number of Employees				
		Vehicle Operation	Vehicle Maintenance	Way, Power and Signals	Station	Administrative
NYCTA (New York)	0.902	0.254	0.172	0.245	0.173	0.059
CTA (Chicago)	1.064	0.332	0.138	0.290	0.191	0.113
BART (SF)	0.566	0.085	0.111	0.175	0.051	0.114
WMATA (D.C.)	0.551	0.074	0.126	0.134	0.121	0.096
SEPTA (Phila.)	0.824	0.151	0.156	0.374	0.094	0.149
MBTA (Boston)	1.958	0.483	0.327	0.669	0.299	0.180
PATH (NY/NJ)	1.140	0.387	0.242	0.264	0.038	0.209
MARTA (Atlanta)	0.528	0.105	0.137	0.096	0.087	0.103
PATCO (Phila./NJ)	0.515	0.114	0.135	0.094	0.051	0.121
GCRTA (Cleveland)	0.885	0.223	0.226	0.181	0.120	0.135
SIRT (NY)	1.058	0.425	0.207	0.258	0.056	0.111

Source: Pushkarev, Boris et. al., Urban Rail in America: An Exploration of the Criteria for Fixed-Guideway Transit, Indiana University Press, 1982, Table A-6, Part I. A place is 5.38 square feet.

TABLE B-26

DETAILED BREAKDOWN OF LIGHT RAIL EMPLOYEES PER PLACE MILE OF SERVICE

System	Employees per Million Place Miles of Service					
	Total	Vehicle Operation	Vehicle Maintenance	Way, Power and Signals	Station	Administrative
MBTA (Boston)	3.628	1.135	0.889	1.015	0.255	0.334
MUNI (SF)	1.418	0.905	0.086	0.194	-	0.233
SEPTA (Phila)						
(subway/surface)	2.106	0.859	0.320	0.554	0.166	0.207
(P & W)	1.242	0.442	0.306	0.391	0.017	0.086
PAT (Pittsburgh)	3.167	1.084	0.723	1.100	-	0.259
GCRTA (Cleveland)	1.434	0.634	0.322	0.263	-	0.215
NJT (Newark)	1.098	0.524	0.200	0.174	0.150	0.050
TTC (Toronto)	1.530	0.766	0.438	0.126	-	0.200
ETS (Edmonton)	1.222	0.303	0.162	0.216	0.400	0.141

Source: Pushkarev, Boris et. al., Urban Rail in America: An Exploration of the Criteria for Fixed-Guideway Transit, Indiana University Press, 1982, Table A-6, Part II (All data for 1976). A "place" is 5.38 square feet.

TABLE B-27

COMMUTER RAIL ACCIDENTS
(1977-80)

Commuter Rail Company	Reported Fatalities	Reported Injuries	Passenger Miles (Millions)	Rates per Million Passenger Miles: Fatalities	Rates per Million Passenger Miles: Injuries
Baltimore & Ohio	4	249	96.5	.041	2.58
Burlington Northern	40	226	227.2	.144	0.82
Chicago & N.W.	6	92	86.6	.069	1.06
Chi, Milw & St. P.	9	84	58.1	.154	1.45
Illinois Central	20	748	102.5	.195	7.30

Note: Does not include injuries and fatalities to employees or other persons involved who are not passengers.

Fatal accidents are not included in injury rate calculations.

Injury rate for passengers may be lower for new systems since many of the above accidents were caused by defects in equipment maintenance of rolling stock and structures. Above accidents caused by track defects (42 percent), equipment failures (19 percent), human factors (26 per cent), other (13 percent). Commuter rail injury and fatality rates have generally increased by more than a factor of 10 over the last decade.

Source: U.S. Department of Transportation, Federal Railroad Summary and Analysis of Accidents on 146-149, U.S. Department of Transportation, Washington, D.C., 1977-81.

Appendix C

Local Bus and Bus Rapid Transit

TABLE C-1

CENTRAL BUSINESS DISTRICT BUS LANES

Location and Street	Length of Bus Lanes (Miles)	Approximate Average Speed (mph)	Date of Survey
Atlanta, Georgia			
Peachtree Street	0.30	5.7	1958
Baltimore, Maryland			
Paca Street	0.36	5.0	1958
Chicago, Illinois			
Washington Street	0.60	6.3	1971
Newark, New Jersey			
Market Street	0.34	6.0	1969
New York, New York			
5th Avenue	2.50	11.6	1969
Madison Avenue	1.12	1.9	1969
San Francisco, California			
O'Farrel Street	0.65	7.3	1971
Geary Street	1.20	7.3	1971
Vancouver, B.C.			
Georgia Street	0.80	10.7	1967
Minneapolis, Minnesota			
Second Avenue (contra flow)	0.61	6.5	1978
Marquette Avenue (contra flow)	0.61	6.2	1978

Sources: Wilbur Smith and Associates, "Design and Analysis of Bus and Truck Roadway Systems in Urban Areas, Phase I," New Haven, Connecticut, November 1973.

R. Edminster and D. Koffman, "Street for Pedestrians and Transit -- An Evaluation of Three Transit Malls in the United States, Final Report," February 1979, Report Number UMTA-MA-06-0049-79-1.

TABLE C-2

ARTERIAL BUS LANES

Location and Street	Length of Bus Lane (Miles)	Approximate Average Speed (mph)	Date of Survey
New York, New York			
2nd Avenue	1.90	13.9	1969
1st Avenue	1.90	17.5	
Toronto, Ontario			
Eglinton Avenue	1.40	14.3	1972
Eglinton Avenue	2.00	18.2	1972
Dublin, Ireland			
Fairview District	1.20	11.1	1971
Weighted Average	1.68	15.4	--

Sources: Wilbur Smith and Associates, "Design and Analysis of Bus and Truck Roadway Systems in Urban Areas, Phase I," New Haven, Connecticut, November 1973.

American Public Transit Association, Transit Operating Reports, Washington, D.C., 1971-72.

TABLE C-3

BUS SPEEDS FOR CENTRAL BUSINESS DISTRICT BUS MALLS

Location and Time of Day	Length of Mall in CBD	Approximate Average Speed (MPH)	Date of Survey
Nicollet Mall, Minneapolis	0.61 Miles		1978
Northbound A.M.		4.87	
Northbound Noon		5.07	
Northbound P.M.		5.49	
Southbound A.M.		4.80	
Southbound Noon		5.14	
Southbound P.M.		3.96	
Chestnut Street Transitway, Philadelphia			1977
Eastbound A.M.	1.00 Miles	4.59	
Eastbound Noon	1.00	5.00	
Eastbound P.M.	1.00	5.34	
Westbound A.M.	0.83	6.04	
Westbound Noon	0.83	3.98(a)	
Westbound P.M.	0.83	5.11	

(a) Based on two runs.

Source: R. Edminster and D. Koffman, "Streets for Pedestrians and Transit - An Evaluation of Three Transit Malls in the United States, Final Report," February 1979 #UMTA-MA-06-0048-79-1.

TABLE C-4

KEY TO CITIES AND BUS TRANSIT SYSTEMS

New York, New York	New York City Transit Authority (NYCTA) and Manhattan and Bronx Surface Transit Operating Authority (MaBSTOA)
Los Angeles, California	Southern California Rapid Transit District (SCRTD)
Chicago, Illinois	Chicago Transit Authority (CTA)
Philadelphia, Pennsylvania	Southeastern Pennsylvania Transportation Authority (SEPTA)
Detroit, Michigan	Southeastern Michigan Transportation Authority and City of Detroit Department of Transportation (SEMTA)
San Francisco-Oakland, California	Alameda-Contra Costa Transit District (AC)
Washington, D.C.	Washington Metropolitan Area Transit Authority (WMATA)
Dallas-Fort Worth, Texas	Dallas Transit System (DTS)
Houston, Texas	Metropolitan Transit Authority of Harris County, Texas (MTA)
Saint Louis, Missouri	Bi-State Development Agency (BISTATE)
Pittsburgh, Pennsylvania	Port Authority of Allegheny County (PAT)
Baltimore, Maryland	Mass Transit Administration (MTA)
San Diego, California	San Diego Transit Corporation (SDTC)
Atlanta, Georgia	Metropolitan Atlanta Rapid Transit Authority (MARTA)
Denver, Colorado	Regional Transportation District (RTD)
Milwaukee, Wisconsin	Milwaukee County Transit System
Kansas City, Missouri-Kansas	Kansas City Area Transportation Authority (KCATA)
New Orleans, Louisiana	New Orleans Public Service, Inc. (NOPSI)

TABLE C-4 (continued)

KEY TO CITIES AND BUS TRANSIT SYSTEMS

Portland, Oregon	Tri-County Metropolitan Transportation District of Oregon (Tri-Met)
Buffalo, New York	Niagara Frontier Transit Metro System, Inc.
Orange County, California	Orange County Transit District (OCTD)

TABLE C-5

BUS LABOR INFORMATION-SERVICE PROVIDED

System	Revenue Miles	Revenue Hours	Total Miles	Total Hours
NYCTA/MaB (NY)	95,359,635	11,775,995	104,322,145	12,825,544
SCRTD (LA)	90,591,516	6,732,771	104,620,957	7,314,399
CTA (CHICAGO)	75,884,335	7,567,500	75,884,335	7,567,500
SEPTA (PHILA.)	33,441,316	3,320,963	36,031,979	3,571,117
SEMTA (DETROIT)	34,170,991	2,189,644	39,813,568	2,661,130
AC (OAKLAND, CA.)	32,601,000	2,215,000	37,654,155	2,270,375
SF MUNI (SF)	14,891,956	1,559,832	17,125,964	1,684,566
WMATA (WASH. DC)	52,633,000	2,965,046	53,235,000	4,126,576
DTS (DALLAS)	14,597,872	1,032,604	14,597,872	1,032,604
HOUSTON	22,122,612	1,519,365	25,723,968	1,766,703
ST. LOUIS	20,402,509	1,592,305	24,898,550	1,897,451
PITTSBURGH	32,842,423	2,482,316	35,458,690	2,556,785
BALTIMORE	21,729,334	1,868,185	24,560,657	2,081,876
SDTC (SAN DIEGO)	9,678,495	622,416	10,949,103	820,566
MARTA (ATLANTA)	26,668,667	1,988,410	30,293,885	2,193,932
DENVER	19,355,202	1,150,496	23,056,975	1,608,002
MILWAUKEE	20,510,481	1,651,051	20,736,505	1,669,075
KANSAS CITY	8,421,177	589,830	8,939,227	629,544
NEW ORLEANS	12,393,880	1,188,172	12,393,880	1,188,172
PORTLAND	19,349,474	1,191,251	22,061,661	1,577,117
BUFFALO	10,371,128	948,314	10,388,067	949,896
ORANGE COUNTY, CA	16,555,198	1,153,392	20,034,714	1,272,619

Source: 1983 APTA Operating Reports, American Public Transit Association (Fiscal Year 1982) and National Urban Mass Transportation Statistics, U.S. DOT Urban Mass Transportation Administration, (Fiscal Year 1982).

TABLE C-6

BUS LABOR INFORMATION-VEHICLES AND EMPLOYEES

System	Peak Buses	Midday Buses	Peak/Bases Ratio	Total Personnel
NYCTA/MaB (NEW YORK)	3,124	2,108	1.482	15,287
SCRTD (LOS ANGELES)	1,898	1,229	1.544	7,930
CTA (CHICAGO)	1,946	992	1.962	7,311
SEPTA (PHILADELPHIA)	1,095	535	2.047	3,458
SEMTA (DETROIT)	802	388	2.067	2,672
AC (OAKLAND, CA)	732	336	2.179	2,145
MUNI (SAN FRANCISCO, CA)	396	268	1.478	1,677
WMATA (WASHINGTON, DC)	1,519	507	2.996	4,410
DTS (DALLAS)	442	136	3.250	1,070
HOUSTON	386	201	1.920	1,881
BISTATE (ST. LOUIS)	653	712	0.917	1,963
PITTSBURGH	775	350	2.214	2,477
BALTIMORE	704	263	2.677	1,985
SDTC (SAN DIEGO)	196	177	1.107	825
MARTA (ATLANTA)	640	261	2.452	2,336
DENVER	526	273	1.927	1,629
MILWAUKEE	516	249	2.072	1,447
KCATA (KANSAS CITY)	246	120	2.050	650
NOPSI (NEW ORLEANS)	380	149	2.550	1,290
TRIMET (PORTLAND, OR)	473	240	1.971	1,618
BUFFALO	369	119	3.101	976
OCTD (ORANGE COUNTY, CA)	362	298	1.215	1,310

Source: <u>1983 APTA Operating Reports</u>, American Public Transit Association (Fiscal Year 1982) and National Urban Mass Transportation Statistics, U.S. DOT Urban Mass Transportation Administration, (Fiscal Year 1982).

TABLE C-7

BUS LABOR INFORMATION-EMPLOYEES BY CATEGORY

System	Vehicle Operators	Vehicle Mechanics	Vehicle Servicers	Other Personnel
NYCTA/MaB (NEW YORK)	9,047	2,194	604	3,442
SCRTD (LOS ANGELES)	4,520	1,113	439	1,858
CTA (CHICAGO)	4,681	664	216	1,750
SEPTA (PHILADELPHIA)	1,855	574	119	910
SEMTA (DETROIT)	1,514	343	89	726
AC (OAKLAND, CA)	1,424	184	81	456
NUMI (SAN FRANCISCO)	993	131	99	454
WMATA (WASHINGTON, DC)	2,846	804	68	692
DTS (DALLAS)	636	71	57	306
HOUSTON	856	233	125	667
BISTATE (ST. LOUIS)	1,147	263	104	449
PITTSBURGH	1,579	208	141	549
BALTIMORE	1,280	266	95	344
SDTC (SAN DIEGO, CA)	537	93	42	153
MARTA (ATLANTA)	1,372	310	105	549
DENVER	878	220	53	478
MILWAUKEE	918	161	43	325
KCATA (KANSAS CITY)	417	70	40	123
NOPSI (NEW ORLEANS)	731	187	53	319
TRIMET (PORTLAND, OR)	1,050	126	76	366
BUFFALO	584	246	0	146
OCTD (ORANGE COUNTY, CA)	775	137	64	334

Source: <u>1983 APTA Operating Reports</u>, American Public Transit Association (Fiscal Year 1982) and National Urban Mass Transportation Statistics, U.S. DOT Urban Mass Transportation Administration, (Fiscal Year 1982).

TABLE C-8

BUS SERVICE VOLUME PER LANE THEORETICAL AND OBSERVED

Type of Condition	Number of Buses (per hour)	Headway (seconds)	Number[1/] of Persons (per hour)	Theoretical or Observed
Uninterrupted Flow on Test Track(a)	1450	2.5	72,500	Observed[2/]
Highway Capacity Manual - Freeway Level of Service (a)	940	3.8	47,000	Theoretical
DOT - Cherniack ITE (1963) (a)	720	5.0	36,000	Theoretical[3/]
Highway Capacity Manual - Freeway Level of Service C (a)	690	5.1	34,500	Theoretical
I-495 Exclusive Bus Lane (New York-New Jersey) (a)	490	7.4	24,500	Observed
Arterial Bus Lane (b)	170	21.2	8,500	Observed[4/]
CBD Curb Bus Lane (b)	160-120	23.0-30.0	8,000 - 6,000	Observed[5/]
Bus Lane - On Line Stops (b)	120	30.0	6,000	Theoretical[6/]
Highway Capacity Manual - Arterial Bus Lane (b)	120	30.0	6,000	Theoretical
CBD Bus Streets, Contra Flow, Median Lanes (b)	100	36.0	5,000	Observed[7/]

Notes for Table C-8

1/Assuming a capacity of 50 persons per bus.

2/Observed at the General Motors Proving Grounds under ideal conditions; no traffic fluctuation and perfect geometrics, 1964.

3/Theoretical policy established in 1963.

4/On Hillside Avenue, Queens, New York.

5/Highest recorded to date.

6/20 second on-line stops, 10 second station clearance, perfect headway geometrics.

7/Highest recorded to date.

(a) These operations do not include on-line bus stops.

(b) These operations include on-line stops.

Note: Above data represent one lane only.

Source: Levinson, H., Hoey, W., Sanders, D., Wynn, H., Bus Use of Highways: State of the Art, National Cooperative Highway Research Report 143, Washington, D.C., 1973.

TABLE C-9

SUMMARY OF BUS REHABILITATION EXPERIENCE (1979-1982)

System	Capital Cost Per Bus	Date	Added Life (Years)	Miles Per Year	Number of Buses
A	22,000	1979-80	3-5	40,000	21
B	20,000	1979-80	3-5	50,100	79
C	35,000	1980-81	5-8	40,000	20
D	35,000	1980-81	5-8	50,100	30
E	55,000	1979-80	5-8	19,800	17
F	49,000	1981	5-7	25,000	15
G	53,500	1978-79	5-7	24,000	43
H	50,000	1982	5-8	Unknown	105
I	51,000	1981-82	5-8	Unknown	250
J[a]	60,000	1980-82	5-8	30,000	156
K[b]	50,000	1982	8-10	35,000	51
L	85,000	1980-81	5-8	Unknown	70
M[c]	20,000	1980-82	5-8	Unknown	49
N[a,c]	30,000	1981	5-8	10,000-15,000	20
P[c]	52,000	1982	8-10	Unknown	24
Q[c,d]	63,000	1980	8-10	N/A	N/A
R	55,000	1980	8-10	24,000	4
S[e]	47,000	1981	5-8	24,000	7
T	65,000	1981	5-8	Unknown	60

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[a]Includes purchase cost of used buses.

[b]Currently underway. Potential for cost increase exists.

[c]In-house effort. May not include all overhead costs.

[d]Detailed estimate for in-house work. No work actually performed.

[e]Actual total was $54,000 of which $7,000 was for wheelchair lift.

Source: M.S. Bridgman, H. Sveinsson, R.D. King, op. cit. Economic Comparison of New Buses vs. Rehabilitated, February 1983, Report November DTUM60-81-C-71103-02-2.

TABLE C-10

CHARACTERISTICS OF RECENTLY CONSTRUCTED BUSWAY INFRASTRUCTURE

	Miles of Two Lane Facility Number		Number of Stations				Years of Const.	Actual Cost ($M)	Source
	UG	EL	AG	UG	EL	AG			
Pittsburgh									
South	0	0	4.0	0	0	11	1975-77	27	(PAT, 1980)
East	0	.3	6.5	0	0	6	1978-82	110	(PAT, 1980)
Washington									
Shirley	0	0	11.	0	0	0	1967-74	43	(TSC, 1975)
Los Angeles									
San Bernardino	0	0	11.	0	0	3	1972-74	53	(NCHRP 143, 1974)

TABLE C-11

1980 DOLLAR COSTS OF RECENTLY CONSTRUCTED BUSWAY INFRASTRUCTURE

Location	Miles of Two Lane Facility AG & EL	Miles of Two Lane Facility UG	% UG	Stations	Stations/ Mile AG & EL	Stations/ Mile UG	1980 $ Total Cost ($M)	1980 $ Cost/Two Lane Mile ($M)
Pittsburgh								
South	4.0	0	0	11	3.24	0	36	9.0
East	6.8	0	0	6	.88	0	110	16.0
Washington								
Shirley	11	0	0	0	0	0	95	8.64
Los Angeles								
San Bernadino	11	0	0	3	.35	0	98	9.93

Notes:

Pittsburgh
The South Busway has 3500 feet of refurbished tunnel.

East Busway
Includes access ramps at three locations. The acquisition of railroad right of way and the moving of railroad tracks cost approximately $31 million.

Washington
Shirley - Express median
The Shirley busway was built in the median of the expanded Shirley Highway.

Los Angeles
The San Bernadino busway was built in the median of the San Bernadino freeway.

TABLE C-12

AVERAGE PLACES PER VEHICLE FOR MAJOR U.S. BUS SYSTEMS

System	Active Vehicles in Fixed-Route Service	Average Places Per Vehicle
New York (NYCTA)	4,452	63.2
Los Angeles (SCRTD)	2,609	62.3
Chicago (RTD)	2,292	64.9
Philadelphia (SEPTA	1,475	59.0
Detroit (SEMTA	238	62.0
Oakland (AC Transit)	892	61.3
San Francisco (Muni)	517	61.0
Washington, D.C. (WMATA)	2,137	60.1
Dallas (DTS)	561	63.7
Houston (Metro)	1,045	62.4
St. Louis (Bi-State)	947	58.5
Pittsburgh (PAT)	1,094	62.2
Baltimore (MTA)	930	60.2
San Diego (SDTC)	315	65.9
Atlanta (MARTA)	749	65.0
Denver (RTD)	754	65.8
Milwaukee (MCTS)	594	63.0
Kansas City (KCATA)	288	60.9
New Orleans (RTA)	470	62.6
Portland (Tri-Met)	670	63.9
Buffalo (NFTMS)	473	58.6
Orange County (OCTD)	482	60.0

Note: A "place" is 5.38 square feet.

Source: APTA Transit Passenger Vehicle Fleet Inventory, 1984 Edition.

Appendix D

Automobile-Highway System

TABLE D-1

DESIGN CAPACITY (vph)1/ OF SIGNALIZED INTERSECTIONS
LEVEL OF SERVICE 'c'2/
ONE-WAY STREET OPERATION IN CBD3/

G/C	Intersection Approach Width - No Parking						
	20'	22'	24'	26'	27'	30'	33'
0.20	325	355	375	415	445	500	540
0.25	400	440	470	520	545	620	670
0.30	475	530	570	625	650	740	810
0.33	530	575	630	680	715	815	890
0.35	560	630	670	740	760	865	945
0.40	640	700	760	840	865	980	1070
0.45	730	800	860	940	970	1120	1215
0.50	810	875	955	1045	1075	1240	1340
0.55	890	975	1060	1150	1200	1360	1480
0.60	960	1050	1150	1255	1300	1480	1600
0.66	1060	1160	1255	1375	1430	1625	1775
0.70	1130	1230	1330	1460	1515	1725	1875
0.75	1210	1320	1435	1565	1630	1860	2020
0.80	1300	1410	1530	1675	1730	1985	2150
0.90	1455	1590	1710	1880	1945	2220	2420
1.00	1615	1760	1905	2090	2165	2475	2690

G/C	Intersection Approach Width - No Parking						
	36'	40'	44'	48'	50'	55'	60'
0.20	600	665	730	805	835	910	1000
0.25	750	835	915	1000	1050	1145	1250
0.30	900	1000	1100	1200	1255	1360	1500
0.33	990	1100	1215	1330	1375	1510	1650
0.35	1050	1160	1275	1400	1465	1600	1750
0.40	1190	1320	1455	1600	1660	1820	2000
0.45	1350	1500	1650	1805	1880	2055	2250
0.50	1490	1660	1830	2020	2090	2280	2500
0.55	1650	1830	2010	2205	2300	2510	2750
0.60	1800	2000	2200	2410	2510	2740	3000
0.66	1965	2180	2415	2650	2750	3000	3295
0.70	2085	2320	2560	2800	2930	3180	3480
0.75	2250	2490	2750	3010	3140	3430	3755
0.80	2400	2660	2925	3200	3350	3645	4000
0.90	2690	2980	3295	3600	3755	4100	4500
1.00	2990	3305	3655	4010	4185	4560	4900

Note: G/C stands for the ratio of green time to cycle time of a traffic signal.

TABLE D-2

DESIGN CAPACITY (vph)[1] OF SIGNALIZED INTERSECTIONS
LEVEL OF SERVICE 'c'[2]
ONE-WAY STREET OPERATION IN CBD[3]

G/C	Intersection Approach Width - Parking - One Side Only											
	20'	22'	30'	32'	38'	41'	44'	48'	52'	56'	58'	60'
0.20	160	200	325	355	450	500	545	610	670	730	760	790
0.25	200	250	405	450	555	625	680	755	840	910	950	990
0.30	250	305	490	540	680	755	815	910	1005	1095	1145	1185
0.33	270	330	535	590	745	820	900	1000	1100	1200	1250	1300
0.35	290	355	565	625	780	870	950	1055	1165	1265	1320	1370
0.40	330	400	650	720	900	995	1080	1210	1335	1450	1510	1570
0.45	370	455	735	810	1000	1120	1225	1360	1500	1635	1700	1770
0.50	415	505	815	900	1125	1250	1355	1515	1670	1815	1900	1970
0.55	455	550	900	990	1230	1370	1490	1660	1830	2000	2080	2160
0.60	500	610	975	1080	1345	1500	1630	1810	2000	2180	2270	2360
0.66	550	660	1070	1180	1470	1640	1790	1985	2190	2380	2500	2600
0.70	580	710	1150	1255	1560	1745	1900	2115	2335	2540	2650	2745
0.75	625	765	1220	1350	1680	1865	2040	2260	2510	2730	2850	2955
0.80	665	805	1300	1440	1790	1995	2160	2415	2660	2900	3035	3140
0.90	755	920	1475	1620	2025	2250	2450	2725	3000	3280	3415	3550
1.00	830	1020	1630	1790	2235	2485	2720	3030	3335	3640	3800	3930

1/The design capacities indicated for level of service 'C' are based on the following 'average conditions':

A. 5 percent trucks and through buses
B. 10 percent right turns
C. 10 percent left turns
D. Metro population size 250,000 4/ with corresponding peak hour factor of 0.85 5/.

2/To obtain design capacities other than level of service 'C', multiply volumes shown by the following factors:

Level of Service	Approach Width 20'	25'	30'	35'	40'	50'	60'
D	1.07	1.08	1.10	1.12	1.14	1.10	1.22
E	1.10	1.13	1.16	1.18	1.20	1.25	1.30

3/To obtain design capacities for areas other than CBD, multiply volumes shown by the following factors:

Area	Factor
CBD	1.00
Fringe	1.00
OBD	1.20
Residential	1.20

4/To obtain design capacities for metro population sizes other than 250,000, multiply the volumes by the following factors:

Metro Population Size	Factor
Over 1,000,000	1.20
1,000,000	1.15
750,000	1.10
500,000	1.05
250,000	1.00
175,000	0.95
100,000	0.90
50,000	0.85

5/To obtain design capacities for peak hour factor other than 0.85, divide the volume shown by 0.85 and multiply the result by known or measured phf.

Source: Tables prepared by M. O. O'Dwyer from J.E. Leisch Nomographs and 1965 Highway Capacity Manual.

TABLE D-3

DESIGN CAPACITY (vph)1/ OF SIGNALIZED INTERSECTIONS
LEVEL OF SERVICE 'c'2/
ONE-WAY STREET OPERATION IN CBD3/

G/C	Intersection Approach Width - Parking Both Sides 26'	27'	28'	36'	38'	40'	46'	49'	52'	56'	60'
0.20	185	205	220	345	380	410	500	545	590	645	705
0.25	230	255	280	425	480	510	625	690	745	815	895
0.30	280	310	335	520	565	615	760	830	895	975	1065
0.33	315	345	370	580	630	680	845	920	990	1075	1185
0.35	330	370	395	610	660	725	895	975	1050	1150	1250
0.40	380	420	450	700	760	830	1020	1115	1195	1305	1480
0.45	435	470	505	800	860	940	1160	1250	1340	1460	1600
0.50	475	525	555	875	955	1030	1260	1400	1500	1630	1775
0.55	525	575	620	970	1050	1145	1400	1535	1645	1800	1960
0.60	580	635	675	1055	1155	1250	1530	1675	1800	1965	2145
0.66	635	695	745	1160	1265	1370	1680	1840	1975	2155	2350
0.70	670	735	795	1230	1340	1460	1775	1950	2095	2230	2500
0.75	725	800	850	1330	1445	1560	1910	2100	2250	2460	2680
0.80	760	845	905	1400	1530	1665	2040	2235	2400	2615	2850
0.90	870	955	1020	1580	1725	1870	2290	2505	2695	2935	3200
1.00	970	1055	1140	1765	1920	2080	2550	2795	2995	3270	3570

1/The design capacities indicated for level of service 'C' are based on the following 'average conditions':

A. 5 percent trucks and through buses
B. 10 percent right turns
C. 10 percent left turns
D. Metro population size 250,000 4/ with corresponding peak hour factor of 0.85 5/.

2/To obtain design capacities other than level of service 'C', multiply volumes shown by the following factors:

Level of Service	Approach Width 25'	30'	35'	40'	50'	60'
D	1.17	1.17	1.17	1.18	1.22	1.25
E	1.25	1.25	1.25	1.27	1.32	1.37

3/To obtain design capacities for areas other than CBD, multiply volumes shown by the following factors:

Area	Factor
CBD	1.00
Fringe	1.00
OBD	1.15
Residential	1.25

4/To obtain design capacities for metro population sizes other than 250,000, multiply the volumes by the following factors:

Metro Population Size	Factor
Over 1,000,000	1.20
1,000,000	1.15
750,000	1.10
500,000	1.05
250,000	1.00
175,000	0.95
100,000	0.90
50,000	0.85

5/To obtain design capacities for peak hour factor other than 0.85, divide the volume shown by 0.85 and multiply the result by known or measured phf.

Source: Tables prepared by M. O. O'Dwyer from J.E. Leisch Nomographs and 1965 Highway Capacity Manual.

TABLE D-4

DESIGN CAPACITY (vph)[1/] OF SIGNALIZED INTERSECTIONS
LEVEL OF SERVICE 'c'[2/]
TWO-WAY STREET OPERATION IN CBD[3/]

G/C	Intersection Approach Width - No Parking							
	10'	11'	12'	13'	18'	20'	22'	24'
0.20	130	145	155	175	245	265	300	330
0.25	155	175	200	210	300	335	375	410
0.30	190	220	240	260	370	405	460	500
0.33	210	235	255	275	400	435	500	550
0.35	215	255	280	300	435	470	535	575
0.40	255	280	310	345	500	540	610	660
0.45	290	325	355	400	555	615	680	750
0.50	325	360	400	435	620	675	765	835
0.55	355	400	430	460	680	740	840	915
0.60	390	430	470	520	740	810	915	1000
0.66	440	500	545	600	830	900	1020	1100
0.70	450	500	550	600	860	945	1060	1155
0.75	480	545	600	650	920	1015	1140	1240
0.80	515	570	625	695	1000	1090	1215	1330
0.90	585	645	715	775	1110	1215	1380	1490
1.00	645	715	790	855	1230	1355	1530	1655

G/C	Intersection Approach Width - No Parking							
	26'	27'	30'	33'	36'	40'	44'	48'
0.20	360	375	415	455	495	550	600	650
0.25	455	465	520	570	620	685	750	815
0.30	550	570	630	690	750	830	905	980
0.33	600	620	680	750	815	905	980	1075
0.35	635	660	730	800	860	960	1055	1150
0.40	725	750	835	910	1000	1100	1200	1310
0.45	820	850	940	1030	1120	1240	1355	1470
0.50	910	950	1040	1140	1240	1380	1510	1650
0.55	1005	1040	1150	1260	1360	1515	1660	1805
0.60	1100	1135	1255	1370	1490	1650	1805	1960
0.66	1210	1255	1390	1505	1640	1815	1990	2160
0.70	1270	1320	1460	1600	1730	1925	2105	2295
0.75	1370	1415	1565	1710	1850	2060	2260	2455
0.80	1460	1510	1675	1825	1980	2200	2400	2620
0.90	1640	1700	1880	2055	2220	2470	2700	2940
1.00	1825	1885	2080	2280	2480	2740	3000	3265

1/The design capacities indicated for level of service 'C' are based on the following 'average conditions':

A. 5 percent trucks and through buses
B. 10 percent right turns
C. 10 percent left turns
D. Metro population size 250,000 4/ with corresponding peak hour factor of 0.85 5/.

2/To obtain design capacities other than level of service 'C', multiply volumes shown by the following factors:

Level of Service	Approach Width 10'	15'	20'	25'	30'	35'	40'	50'	60'
D	1.14	1.14	1.14	1.14	1.15	1.16	1.17	1.18	1.20
E	1.20	1.20	1.20	1.20	1.21	1.23	1.25	1.27	1.30

3/To obtain design capacities for areas other than CBD, multiply volumes shown by the following factors:

Area	Factor
CBD	1.00
Fringe	1.25
OBD	1.25
Residential	1.25

4/To obtain design capacities for metro population sizes other than 250,000, multiply the volumes by the following factors:

Metro Population Size	Factor
Over 1,000,000	1.20
1,000,000	1.15
750,000	1.10
500,000	1.05
250,000	1.00
175,000	0.95
100,000	0.90
50,000	0.85

5/To obtain design capacities for peak hour factor other than 0.85, divide the volume shown by 0.85 and multiply the result by known or measured phf.

Source: Tables prepared by M. O. O'Dwyer from J.E. Leisch Nomographs and 1965 Highway Capacity Manual.

TABLE D-5

DESIGN CAPACITY (vph)1/ OF SIGNALIZED INTERSECTIONS
LEVEL OF SERVICE 'c'2/
TWO-WAY STREET OPERATION IN CBD3/

G/C	Intersection Approach Width - With Parking 20'	22'	24'	26'	27'	30'	33'	36'	40'	44'	48'
0.20	200	225	240	265	270	305	335	360	400	440	480
0.25	245	275	295	330	340	380	415	455	500	550	600
0.30	300	340	365	400	405	455	500	550	605	660	725
0.33	330	370	400	435	445	500	550	600	665	720	795
0.35	345	385	420	460	470	535	580	630	700	770	845
0.40	400	450	490	530	545	610	665	730	805	875	965
0.45	445	500	550	595	610	680	750	815	900	980	1095
0.50	500	560	605	670	685	765	840	910	1015	1100	1210
0.55	550	610	670	720	750	840	910	1000	1100	1200	1330
0.60	600	675	730	800	815	920	1000	1100	1210	1320	1455
0.66	655	730	800	865	885	1000	1100	1195	1325	1450	1585
0.70	700	780	850	915	955	1065	1170	1270	1400	1530	1680
0.75	750	835	910	990	1010	1140	1250	1380	1505	1645	1815
0.80	800	900	970	1060	1090	1215	1330	1455	1615	1755	1935
0.90	900	1005	1095	1190	1225	1370	1500	1645	1800	1970	2170
1.00	1000	1115	1200	1330	1355	1530	1670	1820	2000	2195	2415

1/The design capacities indicated for level of service 'C' are based on the following 'average conditions':

A. 5 percent trucks and through buses
B. 10 percent right turns
C. 10 percent left turns
D. Metro population size 250,000 4/ with corresponding peak hour factor of 0.85 5/.

2/To obtain design capacities other than level of service 'C', multiply volumes shown by the following factors:

	Approach Width						
Level of Service	20'	25'	30'	35'	40'	50'	60'
D	1.06	1.09	1.11	1.14	1.17	1.22	1.24
E	1.10	1.14	1.18	1.21	1.25	1.31	1.34

3/To obtain design capacities for areas other than CBD, multiply volumes shown by the following factors:

Area	Factor
CBD	1.00
Fringe	1.25
OBD	1.25
Residential	1.25

4/To obtain design capacities for metro population sizes other than 250,000, multiply the volumes by the following factors:

Metro Population Size	Factor
Over 1,000,000	1.20
1,000,000	1.15
750,000	1.10
500,000	1.05
250,000	1.00
175,000	0.95
100,000	0.90
50,000	0.85

5/To obtain design capacities for peak hour factor other than 0.85, divide the volume shown by 0.85 and multiply the result by known or measured phf.

Source: Tables prepared by M. O. O'Dwyer from J.E. Leisch Nomographs and 1965 Highway Capacity Manual.

TABLE D-6

HOURLY DISTRIBUTION OF ACCIDENTS - 1978

Hours	Fatal Accidents (percent)	All Accidents (percent)
Midnight to 3 a.m.	16.8	7.7
3 a.m. to 6 a.m.	7.3	3.3
6 a.m. to 9 a.m.	7.4	10.7
9 a.m. to noon	7.7	12.8
Noon to 3 p.m.	11.0	17.2
3 p.m. to 6 p.m.	16.3	23.5
6 p.m. to 9 p.m.	16.3	13.9
9 p.m. to Midnight	17.2	10.9

Source: National Safety Council, "Accident Facts," 1979 edition.

TABLE D-7

TYPES OF URBAN ACCIDENTS (1976-78)

	Fatal Accidents (Percent)	All Accidents (Percent)
Pedestrian	20.3	.7
Intersection	4.3	.2
Non Intersection	16.0	.5
Two Motor Vehicle	40.3	80.8
Intersection	14.9	37.2
Non Intersection	25.4	43.6
Other collisions	11.2	5.4
Intersection	.9	.8
Non Intersection	10.3	4.6
Non Collision	28.2	13.1
Ran Off Road	25.9	10.6
Other	2.3	2.5

Source: National Safety Council, "Accident Facts," 1979 edition.

Appendix E

Automated Guideway Transit Systems

TABLE E-1

GENERAL SYSTEM CHARACTERISTICS

System	Site Description	System Configuration	Guideway Elevation	Guideway Length (Lane Miles)	Number of Stations	Number of Vehicles	Vehicle Capacity	Period of Operation	
								Hrs/Day or Week	Days/Hr
Airtrans	Airport	Single-lane Multi-loops	Elevated/ At-Grade	12.8	14	52	40	24 hrs/day	365
Atlanta	Airport	Dual-lane shuttle with bypass	Underground	2.29	10	17	40	21 hrs/day	365
Busch Gardens	Recreation Center	Single-lane loop	Elevated/ at-Grade	1.33	2	1 (2 car train)	192	11 hrs/day** (Apr.-Oct.)	136
Disneyworld	Recreation Center	Single-lane loop	Elevated	0.87	1	30 (5 car train)	20	12 hrs/day**	365
Duke	Medical Center	Double-lane and Single lane Shuttle	Elevated/at Grade/ Underground	0.56	3	4	22	24 hrs/day	365
Fairlane	Shopping Center	Single-lane Shuttle with Bypass	Elevated	0.61	2	2	24	78.0 hrs/wk	365
Houston	Airport	Single-lane Loop	Underground	1.48	9	6 (3 car train)	36	21 hrs/day	365
King's Dominion	Recreation Center	Single-lane loop	Elevated/ at-Grade	2.06	1	6 (9 car train)*	96	8 hrs/day** (Mar.-Oct.)	124
Miami Airport	Airport	Dual-lane Shuttle	Elevated	0.51	2	2 (3 car train)	297	24 hrs/day	365
Miami Zoo	Recreation Center	Single-Lane Loop	Elevated/ at-Grade	1.97	4	3 (10 car train)	149	7 hrs/day	365
Minnesota Zoo	Recreation Center	Single-Lane Loop	Elevated/ at-Grade	1.25	1	3 (6 car train)	94	7 hrs/day***	365
Morgantown	University	Dual-Lane Shuttle with Off-line Stations	Elevated/ at-Grade	8.60	5	73	20	76 hrs/wk	304
Orlando	Airport	2 Dual-Lane Shuttles	Elevated	1.48	4	4 (2 car train)	200	24 hrs/day	365
Pearlridge	Shopping Center	Single-Lane Shuttle	Elevated	0.23	2	1 (4 car train)	64	69 hrs/wk	358
Sea-Tac	Airport	2 Single-Lane Loops with Shuttle Connection	Underground	1.71	6	24	102	20-24 hrs/day	358
Tampa	Airport	4 Dual-Lane Shuttles	Elevated	1.35	8	8	100	24 hrs/day	365

* Includes a non-passenger lead car.

** Annual Average.

Source: Dynatrend Incorporated, and U.S. DOT Research and Special Programs Administration "Supplement V - Cost Experience of Automated Guideway Transit Systems, Final Report," October 1983, p. 3-6.

TABLE E-2

AUTOMATED GUIDEWAY SYSTEM CAPITAL COST SUMMARY
(THOUSANDS OF 1982 DOLLARS)

	AIRTRANS	ATLANTA	BUSCH GARDENS	DISNEYWORLD	DUKE (1)	FAIRLANE	HOUSTON	KING'S DOMINION
Guideway								
Total Cost	20,501	22,262	2,732	3,131	2,629	3,306	9,265	1,716
Percent of Total System Cost	.21	.30	.36	.16	.22	.33	.36	.19
Cost Per Lane Mile	1,602	9,721	2,054	3,599	4,695	5,420	6,260	833
Stations								
Total Cost	11,061	11,702	207	2,560	269	663	5,603	286
Percent of Total System Cost	.11	.16	.03	.13	.02	.07	.22	.03
Cost Per Station	790	1,170	104	2,560	269	332	623	286
Maint. & Spt. Capabililities								
Total Cost	6,116	4,324	365	956	N/A	189	407	329
Persent of Total System Cost	.06	.06	.05	.05		.02	.02	.04
Cost Per Lane Mile	478	1,888	274	1,099		310	275	160
Power & Utilities								
Total Cost	8,141	4,136	621	1,297	N/A	1,534	650	526
Percent of Total System Cost	.06	.06	.08	.06		.15	.03	.06
Cost Per Lane Mile	636	1,806	467	1,491		2,515	439	255
Vehicles								
Total Cost	20,087	14,742	1,356	5,253	1,415	1,205	1,340	3,705
Percent of Total System Cost	.20	.20	.18	.26	.12	.12	.05	.41
Cost Per Single Vehicle	386	867	678	35	354	603	74	69
Command, Control, & Commu.								
Total Cost	10,636	5,431	835	5,301	4,261	1,206	2,820	57
Percent of Total System Cost	.11	.07	.11	.26	.37	.12	.11	.01
Cost Per Lane Mile	831	2,372	628	6,093	7,609	1,977	1,905	28
Engineering & Project Mgt.								
Total Cost	22,431	10,641	1,423	1,380	3,112	1,838	5,374	2,395
Percent of Total System Cost	.23	.15	.19	.07	.27	.19	.21	.26
Cost Per Lane Mile	1,752	4,647	1,070	1,586	5,557	3,013	3,631	1,163
Total System Cost	98,973	73,238	7,539	19,878	11,686	9,941	25,459	9,014

TABLE E-2 (continued)

	MIAMI AIRPORT (2)	MIAMI ZOO	MINNESOTA ZOO	MORGANTOWN	ORLANDO	PEARL-RIDGE (3)	SEA-TAC (4)	TAMPA
Guideway								
Total Cost	3,907	4,414	3,491	42,885	6,121	N/A	19,707	5,483
% of Total System Cost	.22	.39	.34	.26	.20		.29	.24
Cost Per Lane Mile	7,661	2,241	2,793	4,987	4,136		11,525	4,061
Stations								
Total Cost	4,293	1,192	416	7,826	4,895	N/A	8,804	3,576
Percent of Total System Cost	.24	.10	.04	.05	.16		.13	.15
Cost Per Station	2,147	298	416	1,565	1,224		1,467	447
Maint. & Spt. Capabilities								
Total Cost	1,187	850	867	6,732	2,546	N/A	4,577	1,454
Percent of Total System Cost	.07	.07	.08	.04	.08		.07	.06
Cost Per Lane Mile	2,327	431	694	783	1,720		2,677	1,077
Power & Utilities								
Total Cost	657	755	974	10,604	1,120	N/A	2,656	3,491
Percent of Total System Cost	.04	.07	.10	.06	.04		.04	.15
Cost Per Lane Mile	1,288	383	779	1,233	757		1,553	2,586
Vehicles								
Total Cost	3,596	2,850	3,099	22,129	5,982	N/A	19,380	4,446
Percent of Total System Cost	.21	.25	.30	.13	.20		.28	.19
Cost Per Single Vehicle	599	95	172	303	748		806	556
Command, Control, & Commu.								
Total Cost	1,303	58	459	32,147	6,661	N/A	3,347	2,272
Percent of Total System Cost	.07	.01	.05	.19	.22		.05	.10
Cost Per Lane Mile	2,555	29	367	3,738	4,501		1,957	1,683
Engineering & Project Mgt.								
Total Cost	2,688	1,243	914	45,256	3,,032	N/A	8,735	2,480
Percent of Total System Cost	.15	.11	.09	.27	.10		.13	.11
Cost Per Lane Mile	5,271	631	731	5,262	2,049		5,108	1,837
Total System Cost	17,631	11,362	10,220	167,579	30,357	2,006 (est.)	67,206	23,202

(1) Station cost is for just one station. The second station, maintenance and support capabilities, and power and utilities were provided as part of the North Building Facility and could not be separated.

(3) Two new vehicles were added in 1981 at a cost of $1,798K.

(3) A breakdown by cost category was not available. However, since the initial cost was known, an estimate of total cost in current year dollars was made

(4) Twelve new vehicles were added in 1982 at a cost of $11,230K.

N/A Not Available.

Source: Dynatrend Incorporated and U.S. DOT Research and Special Programs Administration "Supplement V - Cost Experience of Automated Guideway Transit Systems, Final Report," October 1983, p. 4.6.

TABLE E-3

SERVICE AND EMPLOYEE DATA FOR LABOR INPUTS-AUTOMATED GUIDEWAY TRANSIT SYSTEMS

System	Vehicle Miles	Equivalent Place Miles	Vehicle Hours	Equivalent Full Time Employees
Airtrans	2,817,668	104,253,716	281,767	146
Atlanta	818,140	74,450,740	84,222	61
Busch Gardens	24,210	4,115,700	1,532	22
Disneyworld	618,154	30,907,700	129,183	15
Duke	92,845	2,878,194	N/A	14.7
Fairlane	72,749	2,982,709	3,859	N/A
Houston	200,621	10,833,534	35,989	12
King's Dominio	13,626	1,962,144	N/A	12
Miami Airport	289,230	73,753,650	10,950	19
Minnesota Zoo	6,648	797,760	2,894	11.6
Morgantown	911,857	23,708,282	N/A	55.5
Orlando	288,888	52,577,616	33,983	15
Pearlridge	11,420	1,142,000	3,663	13.1
Sea-Tac	596,200	50,677,000	49,683	13
Tampa	328,022	27,553,848	58,400	8.1

Source: Dynatrend Incorporated, and U.S. DOT Research and Special Programs Administration "Supplement V - Cost Experience of Automated Guideway Transit Systems, Final Report," October 1983.

TABLE E-4

AUTOMATED GUIDEWAY SYSTEM
OPERATIONS AND MAINTENANCE COST BREAKDOWN
(1982 DOLLARS)

	Airtrans	Atlanta	Busch Gardens	Disneyworld	Duke	Fairlane	Houston	Kings' Dominion
LABOR								
Administrative and Engineering	364,988	-	-	PAC	30,800	N/A	0	-
Operations	381,656	-	59,939	173,170	70,500	N/A	PUC	-
Maintenance	2,343,528	-	PUC	79,294	306,500	N/A	PUC	-
Other	796,017	2,690,696	0	0	0	N/A	0	
UTILITIES								
Electricity	357,886	143,383	54,100	69,782	16,000	N/A	29,416 *	21,432
Other	0	0	0	0	0	N/A	0	0
MATERIALS AND SERVICES								
Spare Parts & Materials	660,414	155,011	21,703	36,303	80,000	N/A	PUC	
Contract Services	297,510	266,671	50,795	0	0	N/A	784,639	-
Other	0	0	0	0	0		0	-
GENERAL AND ADMINISTRATIVE								
Pro Rata Share	110,736	PUC	PAC	34,620	PAC	N/A	PUC	-
Other	0	0	0	60,802	0	N/A	0	-
Total O&M Cost	5,312,735	3,255,761	186,537	453,971	503,800	N/A	814,055	N/A

TABLE E-4 (continued)

	Miami Airport	Miami Zoo (1)	Minnesota Zoo	Morgantown	Orlando	Pearlridge	Sea-Tac	Tampa
LABOR								
Administrative and Engineering	PAC	3,789	0	252,177	PAC	60,563	130,490	15,373
Operations	PAC	11,558	91,100	222,513	PAC	55,340	-	6,232
Maintenance	PUC	7,421	130,600	638,722	515,413	125,942	-	9,707
Other	0	0	0	0	0	58,509	572,964	0
UTILITIES								
Electricity	41,852	2,643	28,000	243,883	124,385	10,598	25,912	85,285
Other	0	0	0	131,872	0	2,379	0	0
MATERIALS AND SERVICES								
Spare Parts & Materials	PUC	2,011	35,900	261,019	85,110	21,697	PUC	104,335
Contract Services	600,000	0	0	227,638	38,089	0	132,745	591,230
Other	0	0	0	208,097	7,746	0	0	0
GENERAL AND ADMINISTRATIVE								
Pro Rata Share	PAC	1,500	22,500	90,000	PAC	9,892	PAC	PAC
Other	0	2,558	0	0	128,246	0	0	16,500
TOTAL O&M COST	641,852	31,480	308,100	2,275,921	898,989	344,920	862,111	828,662

- No entry in this category in the accounting records of the system.

* Total reflects cost for eight months (May-December) data for January-April invalid due to faulty meters.

(1) Totals reflect cost for one month of service (December).

N/A Not Available

PAC Provided as Part of the Activity Center

PUC Provided Under Contract

Source: Dynatrend Incorporated, and U.S. DOT Research and Special Programs Administration, "Supplement V - Cost Experience of Automated Guideway Transit Systems, Final Report," October 1983, p. 5-3.

Appendix F

Pedestrian Assistance Systems

TABLE F-1

SELECTED MOVING WALKWAYS (LOCATIONS AND PARAMETERS)

	Type of Application				
Cities: Domestic	CBD	Commuter Station	Airport	Campus	Public Parks/Zone
Akron	x	x	x	x	
Atlanta	x		x		
Boston	x	x	x	x	
Chicago			x		
Cleveland	x				
Columbus	x				
Hartford	x				
Houston	x		x		
Inglewood	x				
Las Vegas	x		x		
Los Angeles	x		x		
Miami	x		x		
Minneapolis					x
New York	x	x	x		x
Philadelphia	x				
Pittsburgh	x				
Portland	x				
Reston		x			
San Diego	x				
San Francisco	x		x		
San Jose	x			x	
Seattle			x		
St. Louis			x		
Washington		x			
Cities: Foreign					
Manchester, England					
Montreal, Canada					
Munich, Germany			x		
Paris, France	x		x		
Ottawa, Canada	x				
Toronto, Canada	x				

TABLE F-1 (continued)

Cities: Domestic	Typical Parameters: System Length (ft)	Operating Speed (ft/sec)	Carrying Capacity (Pass/hr)
Akron	600-3,600	1.5-15	500
Atlanta	1,300		
Boston	1,300-5,600	6.5-15	3,000-14,000
Chicago			
Cleveland			
Columbus	2,800		5,000
Hartford			
Houston	2,500	1.5-15	4,000-6,000
Inglewood			
Las Vegas			
Los Angeles			
Miami	1,300	6.0	
Minneapolis			
New York	1,100	1.5-15	10,000
Philadelphia			
Pittsburgh			
Portland			
Reston			
San Diego			
San Francisco	600-1,300	1.5-9	
San Jose	4,000	1.5-15	8,000
Seattle			
St. Louis			
Washington			
Cities: Foreign:			
Manchester, England			
Montreal, Canada			
Munich, Germany			
Paris, France	600-2,900	1.5-15	20,000
Ottawa, Canada			
Toronto	13,000		

Source: Proceedings of the Workshop on Moving Way Transportation Systems, held at Boston, Massachusetts, November, 1973.

CUTS Comment/Update Form

This manual is continually revised to reflect new information on transportation system characteristics as it becomes available to UMTA. To assist in this revision process, please send any comments you may have to the following address, using this form:

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