

UMTA-75-22, Rev. 1

UMTA-MA-06-0025-77-12

RAIL TRANSIT SYSTEM COST STUDY

THOMAS K. DYER, INC.
1762 MASSACHUSETTS AVENUE
LEXINGTON MA 02173



MARCH 1977
REVISION 1
FINAL REPORT

DOCUMENT IS AVAILABLE TO THE U.S. PUBLIC
THROUGH THE NATIONAL TECHNICAL
INFORMATION SERVICE, SPRINGFIELD,
VIRGINIA 22161

Prepared for
U.S. DEPARTMENT OF TRANSPORTATION
URBAN MASS TRANSPORTATION ADMINISTRATION
Office of Technology Development and Deployment
Office of Rail Technology
Washington DC 20590

NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof.

NOTICE

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

Technical Report Documentation Page

1. Report No. UMTA-MA-06-0025-76-3 Rev. 1		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle RAIL TRANSIT SYSTEM COST STUDY				5. Report Date March 1977 Rev. 1	
7. Author(s) T.K. Dyer, W.K. Hale, F.A. Ingalls, R.B. Whelan				6. Performing Organization Code	
9. Performing Organization Name and Address Thomas K. Dyer, Inc.* 1762 Massachusetts Avenue Lexington MA 02173				8. Performing Organization Report No. DOT-TSC-UMTA-75-22 Rev. 1	
12. Sponsoring Agency Name and Address U.S. Department of Transportation Urban Mass Transportation Administration Office of Tech. Development and Deployment Office of Rail Technology Washington DC 20590				10. Work Unit No. (TRAIS) UM704/R7706	
15. Supplementary Notes *Under contract to:				11. Contract or Grant No. DOT-TSC-808	
U.S. Department of Transportation Transportation Systems Center Kendall Square Cambridge MA 02142				13. Type of Report and Period Covered Final Report May 1974-July 1975	
16. Abstract The Transportation Systems Center serves as Systems Manager for the Rail Supporting Technology Program of the Urban Mass Transportation Administration. One task under this program has been to assess the cost of constructing, operating and maintaining three kinds of urban rail systems: light rail, rapid rail and commuter rail. Cost data from several North American and European transit authorities were collected and analyzed. These data, together with recent experience of the Consultant in several transit construction projects, served as the basis of the cost projections. Factors influencing appreciable cost variations in construction and operations were reviewed and included as criteria for cost projections.				14. Sponsoring Agency Code	
17. Key Words Rapid Rail Light Rail Commuter Rail			18. Distribution Statement DOCUMENT IS AVAILABLE TO THE U.S. PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 122	22. Price

PREFACE

This document reports the findings of a study to determine current costs for construction, operation, and maintenance of urban light rail vehicles, rapid transit, and commuter rail systems. This project is sponsored by the Office of Rail Technology, Office of Technology Development and Deployment, U.S. Department of Transportation (DOT) Urban Mass Transportation Administration (UMTA), under the direction of the Transportation Systems Center (TSC). Systems management for UMTA's Rail Supporting Technology Program, was provided by Frederick J. Rutyna, Project Manager and Robert F. Casey, Technical Representative.

In the process of developing the cost data contained in this report, valuable information was obtained from transit authorities in the following cities:

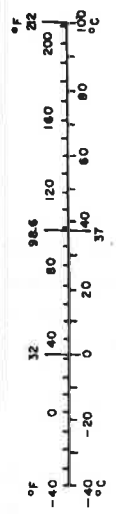
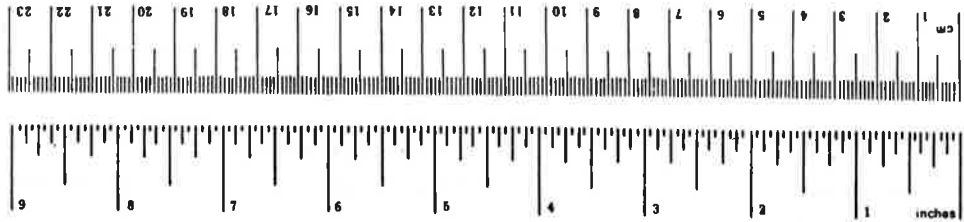
Boston, Mass. - Massachusetts Bay Transportation Authority
Camden, N.J. - Port Authority Transit Corporation
Chicago, Illinois - Chicago Transit Authority
Cleveland, Ohio - Cleveland Transit System
New York, New York - New York City Transit Authority
Philadelphia, Pa. - Southeastern Pennsylvania Transportation Authority
San Francisco/Oakland, Calif. - Bay Area Rapid Transit District
Toronto, Ontario, Canada - Ministry of Transportation and Communications,
and
- Toronto Transit Commission
Washington, D.C. - Washington Metropolitan Area Transit Authority
Bern, Switzerland - Verkehrsbetriebe Bern
Cologne, West Germany - Kölner Verkehrsbetriebe
Gothenburg, Sweden - Göteborgs Spårvägar
Hamburg, West Germany - Hamburger Hochbahn AG
Munich, West Germany - München Verkehrsbetriebe
Zurich, Switzerland - Zurich Transport Authority.

The State, municipal, local and foreign transit authority personnel assigned to assist our representatives in obtaining data for this report were very cooperative and rendered invaluable assistance in providing construction plans, project descriptions, capital and operating cost data, and arranging for field inspections of various operating and fixed plant facilities.

To single out individuals that were especially helpful would risk overlooking others who also provided valuable assistance. Therefore, our sincere gratitude is extended to all who were contracted and assisted on the project.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures				Approximate Conversions from Metric Measures			
Symbol	When You Know	Multiply by	To Find	Symbol	When You Know	Multiply by	To Find
LENGTH							
in	inches	2.5	centimeters	mm	millimeters	0.04	inches
ft	feet	30	centimeters	cm	centimeters	0.4	inches
yd	yards	0.9	meters	m	meters	3.3	feet
mi	miles	1.6	kilometers	km	kilometers	1.1	yards
						0.6	miles
AREA							
in ²	square inches	6.5	square centimeters	cm ²	square centimeters	0.16	square inches
ft ²	square feet	0.09	square meters	m ²	square meters	1.2	square yards
yd ²	square yards	0.8	square meters	km ²	square kilometers	0.4	square miles
mi ²	square miles	2.6	square kilometers	ha	hectares (10,000 m ²)	2.5	acres
	acres	0.4	hectares				
MASS (weight)							
oz	ounces	28	grams	g	grams	0.035	ounce-
lb	pounds	0.45	kilograms	kg	kilograms	2.2	pounds
	short tons	0.9	tonnes	t	tonnes (1000 kg)	1.1	short tons
VOLUME							
teaspoon	teaspoons	5	milliliters	ml	milliliters	0.03	fluid ounces
tablespoon	tablespoons	15	milliliters	l	liters	2.1	pints
fluid ounce	fluid ounces	30	milliliters	qt	quarts	1.06	quarts
c	cups	0.24	liters	l	liters	0.26	gallons
pt	pints	0.47	liters	m ³	cubic meters	35	cubic feet
qt	quarts	0.95	liters	m ³	cubic meters	1.3	cubic yards
gal	gallons	3.8	cubic meters				
ft ³	cubic feet	0.03	cubic meters				
yd ³	cubic yards	0.76	cubic meters				
TEMPERATURE (exact)							
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature



CONTENTS

<u>Section</u>	<u>Page</u>
1 INTRODUCTION.....	1
1.1 Purpose and Scope.....	1
1.2 Definition of Systems.....	2
1.3 Capital Costs.....	7
1.4 Operating Costs.....	7
2 SYSTEM CAPITAL COSTS.....	9
2.1 General.....	9
2.2 Route Construction.....	10
2.3 Guideways.....	11
2.4 Train Control Systems.....	12
2.5 Electrification.....	17
2.6 Land Acquisition.....	18
2.7 Stations.....	18
2.8 Yard, Repair and Maintenance Facilities.....	18
3 SYSTEM OPERATING COSTS.....	21
3.1 Operating Costs.....	21
3.2 Major Factors Influencing Operating Costs.....	21
4 LIGHT RAIL CAPITAL AND OPERATING COSTS.....	23
4.1 General.....	23
4.2 Light Rail Capital Costs.....	24
4.3 Light Rail Cost Projections.....	26
4.4 Operating Costs.....	46
5 RAIL RAPID TRANSIT CAPITAL AND OPERATING COSTS.....	49
5.1 General.....	49
5.2 Rail Rapid Transit Capital Costs.....	49
5.3 Rail Rapid Transit Cost Projections.....	52
5.4 Operating Costs.....	71
6. COMMUTER RAIL REHABILITATION AND OPERATING COSTS....	77
6.1 General.....	77
6.2 Commuter Rail Capital Costs (Rehabilitation Only).....	77
6.3 Commuter Rail Upgrading Cost Projections.....	79
6.4 Operating Costs.....	79
APPENDIX A - NORTH AMERICAN RAIL RAPID TRANSIT SYSTEMS RECENT CAPITAL COST EXPERIENCE.....	95
APPENDIX B - WMATA ESCALATION FACTORS.....	107

ILLUSTRATION

<u>Figure</u>		<u>Page</u>
1-1	CONSTRUCTION COST INDEX.....	6

TABLES

<u>Table</u>		<u>Page</u>
1-1	CHARACTERISTICS OF URBAN RAIL SYSTEMS.....	5
1-2	CAPITAL COST SUMMARY FOR DOUBLE TRACK SYSTEMS.....	8
4-1	LIGHT RAIL VEHICLE COSTS.....	45
4-2	LIGHT RAIL OPERATING COST COMPARISONS FOR 1973.....	45
4-3	LIGHT RAIL SYSTEMS' EXPENSE COMPARISONS.....	47
5-1	RAIL RAPID TRANSIT 1973 OPERATING COST COMPARISONS.....	72
5-2	RAIL RAPID TRANSIT POWER AND TRANSPORTATION EXPENSE COMPARISONS.....	73
5-3	RAIL RAPID TRANSIT MAINTENANCE EXPENSE COMPARISONS.....	74
5-4	TRAIN MANNING REQUIREMENT COMPARISONS.....	75
6-1	COMMUTER RAIL VEHICLE COST COMPARISONS.....	91
6-2	COMMUTER RAIL 1973-1974 COST COMPARISONS.....	92
6-3	COMMUTER RAIL TRANSPORTATION AND MAINTENANCE EXPENSE COMPARISONS.....	93
6-4	TRAIL MANNING REQUIREMENT COMPARISONS.....	94
A-1	SUMMARY OF CONSTRUCTION COSTS (RAIL RAPID TRANSIT).....	96
A-2	ROUTE CONSTRUCTION AT GRADE.....	97
A-3	ROUTE CONSTRUCTION BELOW GRADE.....	98
A-4	GUIDEWAY CONSTRUCTION - DOUBLE TRACK.....	99

TABLES (CONT'D)

<u>Table</u>		<u>Page</u>
A-5	SIGNAL, COMMUNICATIONS, AND WAYSIDE CONTROL.....	100
A-6	POWER AND ELECTRIC TRACTION.....	101
A-7	LAND ACQUISITION BY RAPID TRANSIT PROPERTIES.....	102
A-8	RAPID TRANSIT STATION CONSTRUCTION.....	103
A-9	RAPID TRANSIT VEHICLES.....	104
B-1	AERIAL ESCALATION FACTORS.....	108
B-2	CUT & COVER ESCALATION FACTORS.....	109
B-3	ROCK TWINBORE TUNNEL ESCALATION FACTORS.....	110
B-4	SOFT GROUND TUNNEL ESCALATION FACTORS.....	111
B-5	TRACKWORK ESCALATION FACTORS.....	112
B-6	TRAIN CONTROL ESCALATION FACTORS.....	113
B-7	TRACTION POWER ESCALATION FACTORS.....	114

1 INTRODUCTION

1.1 PURPOSE AND SCOPE

The primary objectives of this study were to develop up-to-date estimates of the various cost elements encountered in constructing, operating, and maintaining urban rail transportation systems.

It was the intent of this study to develop cost information that would be useful to transportation planners, policy makers, and others involved in the preliminary evaluation and selection of rail transportation alternatives.

Rail transit systems in several North American cities, representing a cross-section of the industry, were selected as a basis for developing recent cost experience data. Because the number of light-rail vehicle systems in the United States is limited, and no new systems have been built in many years, several cities in Europe were studied in order to include their experience in light rail construction and operation.

The following United States and Canadian cities were selected as the data base for rapid rail, light rail and commuter rail cost comparisons:

- Boston, Massachusetts
- Camden, New Jersey
- Chicago, Illinois
- Cleveland, Ohio
- New York, New York
- Philadelphia, Pennsylvania
- San Francisco, California
- Toronto, Ontario
- Washington, D. C.

In addition, the following European cities were used to gather additional light rail information:

- Bern, Switzerland
- Cologne, W. Germany

Gothenburg, Sweden
Hamburg, W. Germany
Munich, W. Germany
Zurich, Switzerland.

Each city was visited, the transportation facilities inspected, operations observed, and cost records obtained and analyzed as they were available.

Data were collected on all types of pertinent construction, including subway, elevated, and at-grade route construction, stations, signals and communications, power, utilities, main and yard tracks. Actual contract bid documents, including unit prices and plans, were obtained for selected projects.

Property acquisition costs and conditions imposed were obtained and analyzed.

Engineering and administration costs for construction projects were obtained as a percentage of overall construction project costs.

Operating costs, including maintenance expenses, were obtained in the format available on each property.

Considerable additional data that would serve to influence cost projections, such as passenger traffic statistics, equipment ownership and miles operated, railroad commuter agreement provisions, annual reports, and other system statistics were obtained and reviewed.

1.2 DEFINITION OF SYSTEMS

Light Rail Transit (LRT), also known as street railway, city rail, tram, or pre-metro, may be defined as a rail guideway system wherein the route configuration may include non-grade-separated portions. As an outgrowth of streetcar systems, LRT may operate in city streets with vehicular traffic, or in reserved or median strips with vehicular crossings at intersections. In other areas, LRT may operate on grade-separated right-of-way, in the same manner as rail rapid transit.

Light rail vehicles (LRV) are electrically powered, capable of operating singly or in trains, and can be constructed to accommodate loading from either high or low platforms which is important for mixed high platform and street level operation. In at-grade service, stations may be identical to bus facilities, i.e., as little as a sign. Fare collection may be at stations in grade-separated rights-of-way, but is generally on board.

LRT electrical power is usually collected from an overhead catenary by pantograph or trolley pole. A wayside power rail may be used on grade-separated installations. The same vehicle may operate in power rail and catenary territory when equipped for dual power pickup.

Light rail typically represents a service application, when traffic density per mile ranges from 3,000 to 18,000 persons per hour in one direction. LRT offers a quality of service somewhat below the level of full rapid rail, but above that of bus on street. LRT retains the ability to be upgraded to full rapid rail over its grade-separated portions. Its principal feature remains the ability to operate on non-exclusive, at-grade right-of-way, with attendant savings in construction costs.

Rail Rapid Transit (RRT), also known as rapid rail, rapid transit, subway, or elevated, may be defined as a high-frequency, high capacity rail system operating on exclusive, grade-separated right-of-way, whether at grade, in subway, or on an elevated structure.

The rapid transit vehicles (RTV) are electrically powered and may operate in trains of up to eleven cars. High level platforms and multiple doors on each vehicle provide for rapid loading and unloading at stations. Fare collection is handled through turnstyles at stations or on board vehicles. The vehicles receive electric power from a wayside power rail or from an overhead catenary.

Rail rapid transit passenger volumes usually range between 10,000 and 50,000 per hour in each direction during peak periods. Maximum operating speeds range between 45 and 80 miles per hour.

Commuter Rail is defined as an urban rail passenger service, typically operated by intercity railroads within thirty to sixty miles of central cities.

Equipment may be diesel or electric locomotives hauling passenger coaches, self-propelled rail diesel cars (RDC), or electric self-propelled multiple-unit vehicles. Where the equipment is electrically powered, current is collected from a wayside power rail or an overhead catenary.

The right-of-way is exclusive, but not necessarily grade-separated. Commuter service usually shares the same facilities with intercity freight and passenger service. Operations are governed by normal railroad procedures and work rules.

Maximum operating speeds range up to 80 miles per hour. Passenger volume may vary from under 1,000 to 20,000 per hour, per track.

Table 1-1 summarizes the characteristics of light rail, rail rapid transit, and commuter rail with respect to physical plant, equipment, and operations.

The cost estimates projected in this report are in 1974 dollars. Capital costs were converted to July 1, 1974 dollars, by applying the Engineering News Record (ENR) Construction Cost Indices prior to 1969 and the Washington Metropolitan Transit Authority's after 1969.

The Association of American Railroads Indices of Material Prices and Wage Rates were utilized to project 1974 operating costs. A graphic presentation shows these indices. (See Figure 1-1.)

Cost data were collected on all types of pertinent construction, including subway, elevated, and at-grade route construction, stations, signals and communications, power, utilities, and tracks. Actual contract bid documents, including unit price bids, plans, and specifications, were obtained for selected projects. Property acquisition costs and conditions imposed were obtained and analyzed.

Types of vehicles utilized and acquisition costs were reviewed for light rail, rapid rail, and commuter rail systems. Engineering

TABLE 1-1. CHARACTERISTICS OF URBAN RAIL SYSTEMS

Characteristics	Light Rail	Rapid Rail	Commuter Rail
PHYSICAL PLANT			
Exclusive Right of Way	Possible	Yes	Yes
Grade Crossings	Possible	No	Yes
High Platforms	Possible	Yes	Possible
Low Platforms	Yes	No	Yes
Route Construction - At Grade	Yes	Yes	Yes
Route Construction - Elevated	Yes	Yes	Yes
Route Construction - Subway	Yes	Yes	Yes
Power - 3rd Rail	No	Yes	Yes
Power - Catenary	Yes	Yes	Yes
Signal System - Auto. Block Signal	Yes	Yes	Yes
Signal System - Auto. Train Control	Possible	Yes	Possible
Station Spacing	500'-2600'	1240'-2600'	1-5 miles
Capacity - Pass/Hour/Track - (Maximum)	18,000	30,000	20,000
EQUIPMENT			
Vehicle Length	46'-72'	48'-75'	85'
Vehicle Capacity - Seated	40-68	48-81	90-140
Vehicle Capacity - Seated & Standing	70-150	150-300	120-180
Powered By - Diesel - Hauled	No	No	Yes
Powered By - Diesel - Self Propelled	No	No	Yes
Powered By - Electric - Hauled	No	No	Yes
Powered By - Electric - Self Propelled	Yes	Yes	Yes
Car Weight	15-35 Tons	25-35 Tons	30-60 Tons
Normal Operating Speeds	20-50	35-80	50-80
Loadings From High Platform	Possible	Yes	Yes
Loadings From Low Platform	Yes	No	Yes
OPERATIONS			
Level Of Service - Peak (Normal Minimum Headway)	60 Sec.	90 Sec.	5 Min.
Manning Requirements	1 Operator/car	Varies	Varies
Automatic Fare Collection	Possible	Possible	Possible
On Board Fare Collection	Yes	Yes	Yes
No. Of Cars/Train	1-4	1-11	1-18

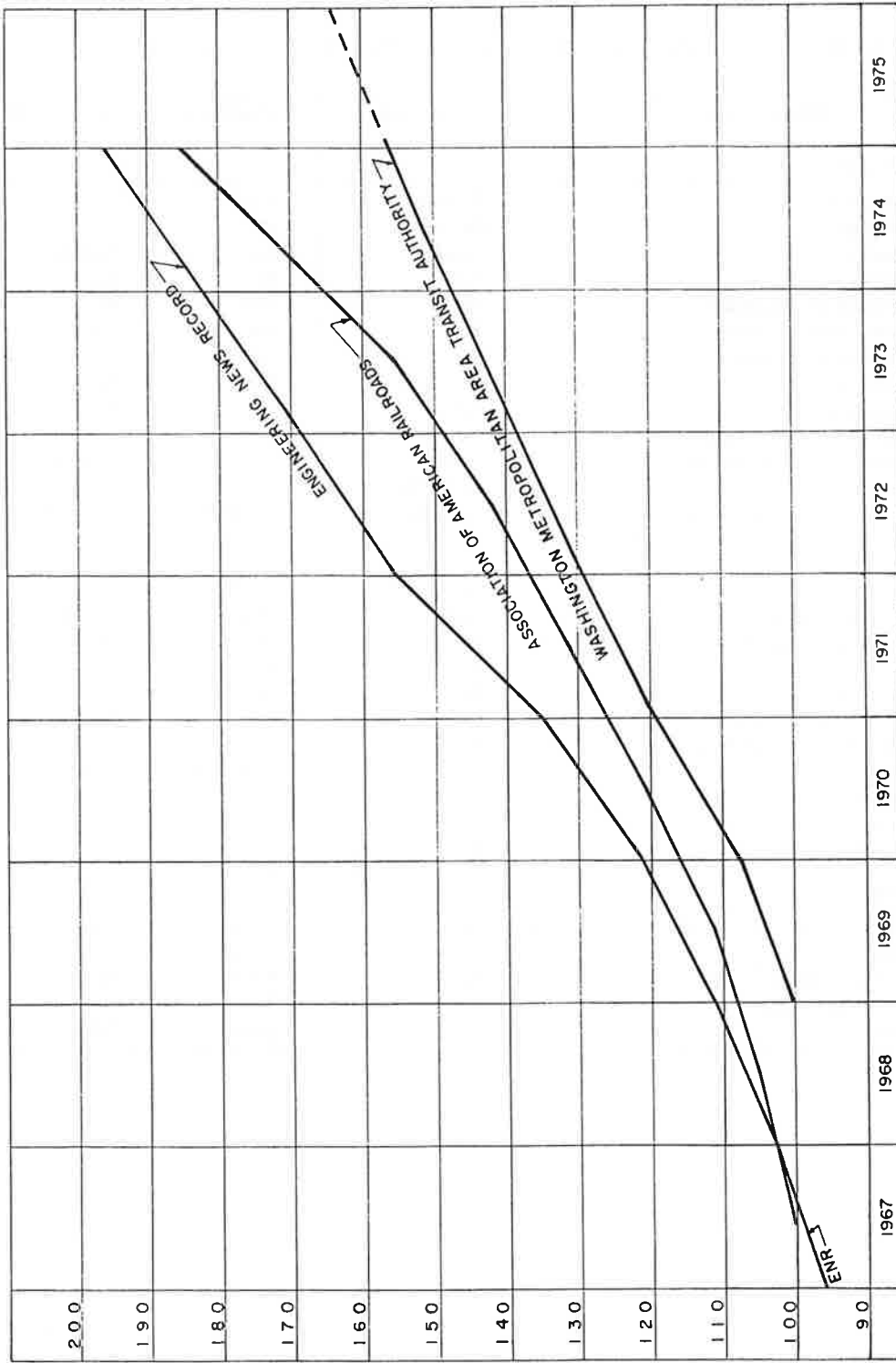


FIGURE 1.1 CONSTRUCTION COST INDEX

and contract administration costs for construction projects were obtained and are included as a percentage of overall construction costs.

1.3 CAPITAL COSTS

Table 1-2 presents a capital cost summary for double track systems. (Refer to Section 4.3 for the criteria for scaling the cost between a low and a high range of each cost element.) The cost projections reflect the normal range of the various cost elements for double track light rail, rapid rail, and commuter rail systems in suburban, city, and core areas where applicable.

Backup sheets are provided in the report, to allow choosing the range most accurately expressing the local situation.

1.4 OPERATING COSTS

Operating costs were ascertained, in terms of 1974 dollars per car mile, for light rail, rapid transit rail, and commuter rail systems.

Light rail operating costs were obtained from four systems ranging from \$1.75 to \$5.20 per car mile. The highest-cost system was an old plant with considerable tunnel and elevated construction, restrictive geometry, and very old equipment. The average car-mile cost of the other three systems was \$1.95 with revenues offsetting about 85% of the cost.

Rapid transit rail operating costs from seven systems varied from \$1.10 to \$4.35 per car mile. The highest-cost system operated four-car trains requiring three-man crews by state law and had unique equipment problems. The average car-mile cost of the other six systems was \$1.80 with revenues offsetting about 70% of the cost. If New York City were excluded, the average cost of the remaining five systems would be \$1.45 per car mile with revenues offsetting about 80% of the cost.

Commuter rail systems ranged from \$1.90 to \$4.00 per car mile in 1974 dollars based on the railroads' Annual Report to the Interstate Commerce Commission. The highest-cost system reflects the effects of short trains and short haul on commuter rail systems costs. The average of the other three systems was \$1.95 per car mile with revenues offsetting about 75% of the cost.

TABLE 1-2. CAPITAL COST SUMMARY FOR DOUBLE TRACK SYSTEMS
(COST IN MILLIONS OF 1974 DOLLARS)

	Unit	Suburban						City						Core					
		At Grade		Elevated		Depressed ¹		At Grade		Elevated		Depressed ¹		At Grade		Elevated		Depressed ¹	
		Low ²	High ²	Low ²	High ²	Low ²	High ²	Low ²	High ²	Low ²	High ²	Low ²	High ²	Low ²	High ²	Low ²	High ²	Low ²	High ²
Light Rail																			
Route Constr. ⁴	Mile	.72	2.43	2.82	8.34	4.21	12.27	.50	.86	14.55	17.15	29.13	33.73	NA ³	NA	14.55	17.15	29.13	33.73
Guideway ⁵	Mile	.75	.75	.83	.83	.83	.83	1.00	1.00	.91	.91	.91	.91	NA	NA	1.00	1.00	1.00	1.00
Signal	Mile	.21	.41	.21	.41	.21	.41	.21	.41	.21	.41	.21	.41	NA	NA	.21	.41	.21	.41
Power	Mile	1.10	1.30	1.10	1.30	1.10	1.30	1.10	1.30	1.10	1.30	1.10	1.30	NA	NA	1.10	1.30	1.10	1.30
Land	Mile	.13	.40	.13	.40	.13	.40	1.32	3.96	1.32	3.96	1.32	3.96	NA	NA	2.64	7.92	2.64	7.92
Total Per Mile		2.91	5.29	5.09	11.28	6.48	15.21	4.13	7.32	18.09	23.73	32.67	40.31	NA	NA	19.50	27.78	34.08	44.36
Stations	Each	.02	2.77	.19	3.52	.21	3.56	.02	.06	.21	.70	.44	1.00	NA	NA	1.32	4.56	1.78	7.56
Yards	Each	4.02	16.03	NA	NA	NA	NA	4.02	16.03	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shops	Each	8.04	29.39	NA	NA	NA	NA	8.04	29.39	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vehicles	Each	.32	.32	.32	.32	.32	.32	.32	.32	.32	.32	.32	.32	NA	NA	.32	.32	.32	.32
Land	Acre	.01	.03	.01	.03	.01	.03	.11	.33	.11	.33	.11	.33	NA	NA	.22	.66	.22	.66
Signal																			
Grade Crossings	Each	.05	.05	NA	NA	NA	NA	.05	.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Onboard Equipm't	Each	0	.02	0	.02	0	.02	0	.02	0	.02	0	.02	NA	NA	0	.02	0	.02
Yard Control	Each	0	1.20	NA	NA	NA	NA	0	1.20	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Rapid Rail																			
Route Constr. ⁴	Mile	1.15	3.78	2.82	8.34	4.21	12.27	NA	NA	14.55	17.15	29.13	33.73	NA	NA	14.55	17.15	29.13	33.73
Guideway ⁵	Mile	.75	.75	.83	.83	.83	.83	NA	NA	.91	.91	.91	.91	NA	NA	1.00	1.00	1.00	1.00
Signal	Mile	.69	2.65	.69	2.65	.69	2.65	NA	NA	.69	2.65	.69	2.65	NA	NA	.69	2.65	.69	2.65
Power	Mile	.70	.85	.70	.85	.70	.85	NA	NA	.70	.85	.70	.85	NA	NA	.70	.85	.70	.85
Land	Mile	.13	.40	.13	.40	.13	.40	NA	NA	1.32	3.96	1.32	3.96	NA	NA	2.64	7.92	2.64	7.92
Total Per Mile		3.42	8.43	5.17	13.07	6.56	17.00	NA	NA	18.17	25.52	32.75	42.10	NA	NA	19.58	29.57	34.16	46.15
Stations	Each	.35	4.15	.70	5.16	.87	5.53	NA	NA	.95	2.85	4.0	10.0	NA	NA	1.39	4.65	5.0	12.0
Yards	Each	3.41	12.97	NA	NA	NA	NA	3.41	12.97	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shops	Each	7.71	27.73	NA	NA	NA	NA	7.71	27.73	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vehicles	Each	.35	.55	.35	.55	.35	.55	NA	NA	.35	.55	.35	.55	NA	NA	.35	.55	.35	.55
Land	Acre	.01	.03	.01	.03	.01	.03	NA	NA	.11	.33	.11	.33	NA	NA	.22	.66	.22	.66
Signal																			
Onboard Equipm't	Each	.02	.02	.02	.02	.02	.02	NA	NA	.02	.02	.02	.02	NA	NA	.02	.02	.02	.02
Yard Control	Each	1.20	10.50	NA	NA	NA	NA	1.20	10.50	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Commuter Rail																			
Route, Upgrade ⁴	Mile	.33	3.10	NA	NA	NA	NA	.33	3.10	NA	NA	NA	NA	.33	3.10	NA	NA	NA	NA
Guideway, Upgrade ⁵	Mile	.56	.67	NA	NA	NA	NA	.64	.73	NA	NA	NA	NA	.70	.81	NA	NA	NA	NA
Signal	Mile	.08	.27	NA	NA	NA	NA	.08	.27	NA	NA	NA	NA	.08	.27	NA	NA	NA	NA
Power	Mile	.23	.35	NA	NA	NA	NA	.23	.35	NA	NA	NA	NA	.23	.35	NA	NA	NA	NA
Land	Mile	.13	.40	NA	NA	NA	NA	1.32	3.96	NA	NA	NA	NA	2.64	7.92	NA	NA	NA	NA
Total Per Mile		1.40	4.09	NA	NA	NA	NA	2.65	7.71	NA	NA	NA	NA	4.03	11.75	NA	NA	NA	NA
Stations, Upgrade	Each	.12	.62	NA	NA	NA	NA	.10	.48	NA	NA	NA	NA	.17	.85	NA	NA	NA	NA
Yards, Upgrade	Each	.30	2.59	NA	NA	NA	NA	.30	2.59	NA	NA	NA	NA	.30	2.59	NA	NA	NA	NA
Shops, Upgrade	Each	.89	4.36	NA	NA	NA	NA	.89	4.36	NA	NA	NA	NA	.89	4.36	NA	NA	NA	NA
Vehicles																			
Coach	Each	.25	.25	NA	NA	NA	NA	.25	.25	NA	NA	NA	NA	.25	.25	NA	NA	NA	NA
Diesel, Locom.	Each	.40	.40	NA	NA	NA	NA	.40	.40	NA	NA	NA	NA	.40	.40	NA	NA	NA	NA
Electric, Locom.	Each	.75	.75	NA	NA	NA	NA	.75	.75	NA	NA	NA	NA	.75	.75	NA	NA	NA	NA
Diesel, Self Propel.	Each	.65	.65	NA	NA	NA	NA	.65	.65	NA	NA	NA	NA	.65	.65	NA	NA	NA	NA
Electric, Self Propel.	Each	.70	.70	NA	NA	NA	NA	.70	.70	NA	NA	NA	NA	.70	.70	NA	NA	NA	NA
Land	Acre	.01	.03	NA	NA	NA	NA	.11	.33	NA	NA	NA	NA	.22	.66	NA	NA	NA	NA
Signal																			
Grade Crossings	Each	.05	.05	NA	NA	NA	NA	.05	.05	NA	NA	NA	NA	.05	.05	NA	NA	NA	NA

¹ Depressed costs are for open, retained cut in the suburbs and cut and cover in the city and core. Costs for driven tunnels are difficult to ascertain except on a site-specific basis. Costs per mile may range from \$10-30 million.

² Low and High describe the range of cost. Backup sheets provide for scaling costs to particular requirements.

³ NA = not applicable.

⁴ Includes grading, drainage, structures, and sub-ballast.

⁵ Includes ballast, ties, rails, and fastenings.

2 SYSTEM CAPITAL COSTS

2.1 GENERAL

The construction of an urban rail transit system involves a multitude of choices as to route location, size of the system, capacity requirements, quality of service, and degree of sophistication of the mode.

To plan and estimate the construction cost of a system, considerable detailed information must be assembled, such as traffic projections, land surveys, earth borings, and location of utilities.

The factors and cost guidelines identified in this report are not designed to replace the detailed analysis required for a system, but are meant to assist in the preliminary planning stage of a project.

The cost experiences of the transit properties visited served as the basis for the cost projections made in this study. A wide variation was found in the cost of projects, due to differences in standards, local conditions, and contract terms.

For instance, included in the contract for electrical power facilities for the South Shore Rapid Transit Extension in Boston, Massachusetts, were new sub-station installations at Kendall Square and Central Square. Both are several miles removed from the South Shore Extension. If these costs were excluded, the costs of the power facilities on the Extension would be less.

The same holds true for two track contracts (in Boston and Chicago) where the running rail and cross ties in one contract, and the rail in the other, were furnished by the transit authority. Unit costs in each contract would have to be adjusted to reflect these situations.

Similarly, a contract for automatic train control for the Massachusetts Bay Transportation Authority on a transit line extension included considerable upgrading to an abutting, existing

signal system. Without detailed knowledge of this upgrading cost, the extension unit cost would be distorted.

Cost projections in this report are based on analysis of representative projects from several systems.

All construction cost projections include a contingency amount of 10 percent and an engineering and administration amount of 15 percent. Costs were based on current construction standards for transit and railroad properties.

2.2 ROUTE CONSTRUCTION

The cost of constructing a rail system at grade, elevated, or below grade varies tremendously at any particular location. The choice of each is usually dictated by requirements of non-interference with other travel modes and environmental impacts. From the economic standpoint, costs escalate sharply between construction at grade, above grade, and below grade. Additionally, within each category costs can vary materially as outlined below.

At-grade construction will vary substantially from suburban areas to the more densely occupied urban areas. The extent of grading and drainage work required, number and size of grade crossings, the need to remove rock or soils, and building or other structural obstructions, all add to the construction cost.

Elevated route construction can either be on fill with bridges over or under crossings with other streets and ways, or on a trestle structure. The latter has the advantage of utilizing the area beneath the trestle for streets and other purposes. In addition to the same elements affecting at-grade construction costs, elevated fill construction increases materially if fill must be retained in restricted areas. Trestle construction varies between open and solid decks, and whether it is for ballasted track or direct fixation.

Below-grade route construction varies considerably between cut-and-cover, tunnelling in rock or earth, and sunken tube methods. Additionally, such factors as maintaining vehicular traffic during

construction, underpinning requirements, dewatering or other hydraulic concerns, depth of cover, and need for pressurized work areas vary costs substantially.

2.3 GUIDEWAYS

Recent track construction in the United States and European transit systems has followed conventional system patterns, namely:

- 1) tee rail* on wood or concrete cross ties, stone ballast, sub-ballast, and compacted gravel subgrade, at grade, or concrete base in tunnels or aerial section;
- 2) tee rail directly fixed to concrete in tunnels or elevated structures; and
- 3) girder rail** attached to cross ties or a concrete base in street sections.

Standard track gage is 4'-8½". However, there are systems or lines which vary from standard up to 5'-6".

Most transit properties in the United States have set a standard of 115 lbs (per yard) tee-rail section for new construction (although some continue to use 100 lbs), and it is usually welded in lengths greater than 1,000 feet. Girder rail, utilized in streets and paved areas, usually varies in section between 128 and 149 lbs per yard.

Wood cross ties are 6" x 8" or 7" x 9" by 8'-0" or 8'-6", treated with pressurized preservatives.

The cost of track construction varies with such factors as: track standards; availability of the work site; adequacy of the right-of-way for material storage, material distribution, and utilization of work equipment; and the amount of special track work such as switches, restraining rails, crossing diamonds, etc.

* Typical rail cross section shaped like letter "T".

* Girder rail is used for track embedded in pavement and provides cast wheel flangeway.

2.4 TRAIN CONTROL SYSTEMS

Three basic systems of wayside signal control apparatus are generally used in commuter rail and/or suburban and rapid transit rail operation. Each of these primary systems can be further divided into a variety of sub-systems designed for increased safety, reliability, traffic density, dispatching requirements, and other degrees of automation.

Automatic Block Signaling (ABS). This system is used on most commuter rail and a few light rail suburban operations consists of fixed wayside signals which convey information to the motorman as to track conditions ahead. With this type of system, safety is dependent upon the motorman's compliance with wayside signal indications and block signal rules.

Automatic Train Stop (ATS). This system is similar in operation to the system described above, but with the addition of automatic train stop devices. With this system, an electromechanical train stop or trip will force compliance with a stop signal. Should a train pass a stop signal, a brake-line trip cock on the train is mechanically activated by the wayside trip arm, thereby effecting an emergency stop.

Automatic Train Control (ATC). With this system, fixed wayside signals are not required. In addition, the basic speed control system is expandable to full automatic train operation (ATO).

In the basic ATC system, often referred to as a continuous cab-signal system, allowable speed information is displayed directly and continuously within the motorman's cab. An on-board over speed (or speed regulation) feature forces compliance with reduced, restrictive, or stop speed commands. This is the primary type of wayside control system being installed by the majority of transit and rail systems for either suburban or rapid transit operation.

The addition of supervisory control (most recently computer-directed) is that portion of the ATC system that enforces schedules and routing of individual trains and is analogous to a high-speed automatic or programmed, centralized traffic control system. With the exception of the Chicago Transit Authority, all new ATC systems being installed have centralized-command supervisory control in various degrees of sophistication. Toronto has recently included supervisory control of its ATS system.

A further refinement (and added cost) of the ATC consists of the next logical step: Fully Automatic Train Operation (ATO). With such a system, the train control system substitutes for the normal duties of the motorman and automatically produces the traction and braking responses in the train. Refinements of ATO can be carried to the opening and closing of doors, automatic station stops, automatic station announcements, program dispatching, etc.

The majority of train control systems presently being installed stop short of a fully automatic train operation, normally containing continuous overspeed control and automatic, centralized line-supervisory control.

Automatic supervisory train control requires a vastly expanded communications network to transmit intelligence and feedback, as well as to provide backup systems for successful operation.

It should be noted that most of the safety requirements commonly specified are obtained with an automatic train stop system. The necessity for more sophisticated systems is dependent on the present or future considerations of reduced operating costs that may be obtained by partial or fully automated train operation, and also upon the necessity for high-speed close headway operation, particularly if two or more lines combine into one. The more complicated the system, the greater is the need for more information systems and computer aid in operations.

Design Headways and Speeds. The scheduled peak headways desired and the free-running operating speed are of initial concern in the choice and resulting construction, and maintenance cost of

any train control system. The proper design headway must be considerably shorter than the proposed scheduled operating headway, in order to obtain adequate compensation for the variations in schedule operations. The primary limiting parameter of a minimum free-running headway is the amount of station dwell time required to unload and load passengers. To a lesser degree, rates of acceleration and deceleration influence minimum headway.

In general, the cost of train control and attainable minimum headway is proportional to the maximum operating speed. The faster the trains are operated, the greater becomes the spacing required; and the train control system becomes accordingly more costly, in order to obtain close headways.

Nearly all new rapid rail systems are designed for minimum 90-second headway, with scheduled peak operating headways of 3 to 5 minutes. New system operating speeds range from 55 to 80 miles per hour.

Most light rail systems are not signaled except at junctions, or in grade-separated locations.

Commuter and light rail systems may be designed for 3 to 5 minutes minimum headways with peak scheduled headways of 5 to 10 minutes. In general, commuter rail lines can take advantage of higher operating speeds due to longer spacing between stations and use either skip-stop or express-type operation.

Interlockings. The second major cost element in a train control system is the number of interlockings (controlled switches) required. As a minimum, interlockings are required at line terminals, intermediate turnbacks, junction points, entrances to storage yards, and lay-up points. If the line segment is lengthy, certain intermediate emergency cross-over or turnback interlockings are usually added for operating reasons.

Storage and Repair Yards. For any new line and, in many cases, extensions to existing lines, local switching and signal control of yard operation is required. When completed, the new Washington Metropolitan Area Transit Authority (WMATA) system will contain seven interlocked yards. The new Bay Area Rapid Transit (BART)

system in San Francisco contains three controlled yards. Both the new South Shore and Haymarket North extensions in Boston contain one new yard each.

Supervisory Control. With the single exception of Chicago, all new rapid transit lines or extensions include a centralized supervisory control command center.

Grade Crossing Protection. On most commuter rail, light rail, and a few rail rapid transit lines, highway grade crossings exist. In some cases, these crossings are subject to extremely heavy density peak-hour vehicular and train traffic.

In order to effect a safe and reliable protective system for the traveling public and to avoid traffic tie-ups, it is generally recognized that automatic crossing protection circuits must be interconnected with the train control system in such a manner that speed commands (or wayside signal indications) will cause trains approaching these congested crossings to reduce to a low speed before the crossing protection device, e.g., flashing lights, automatic gates, etc., are operated. The train then may receive a speed command or signal to proceed over the crossing. In this manner, the minimum time of crossing protection device operation and vehicular delay can be held to approximately 30 to 40 seconds. These systems are often interconnected with pre-emption circuits for street traffic lights to aid in clearing the crossing.

Communications. Communication systems are of increasing importance in the design of new rail systems or extensions to existing lines. More sophisticated systems may contain all or parts of the following components:

1. Truck Line Cable Plant
 - Signal Telemetry
 - Voice and Carrier
 - Fire and Intrusion Alarms

2. Radio Systems

- Train
- Police
- Maintenance

3. Telephone Systems

- Train
- Dispatch
- Emergency
- General
- Maintenance

4. Closed Circuit Television

5. Automatic Vehicle Identification

- Automatic Routing
- Automatic Recording of Car Mileage

6. Supervisory Controls and Systems Monitoring

7. Central Computer Traffic and Schedule Regulation.

The cost elements included under communications are listed above. If supervisory train control is required, an inherent communication cost results from the on-line heavy cable plant required to convey information to and from all points on the line.

If central computer traffic and schedule regulations, together with automatic traffic management and information, are desired, the communication cost will increase appreciably. Such latter type systems are used in San Francisco.

A variety of additional subsystems to aid in operation and management information are often added once central supervisory control and an adequate communication plant exists. Items within this category consist of such elements as headway recorders, automatic dispatchers, automatic vehicle identification and routing, third-rail indicators, centralized station paging, etc.

2.5 ELECTRIFICATION

Rail rapid transit, light rail, and some commuter operations place demands of service frequency, operating flexibility and reliability on the operating plants, that best can be met by electrification.

The advantages of rapid acceleration and high speed attainable through electrification provide better utilization of system capacity during peak hours. Factors concerning smoke abatement, noise, fuel efficiency, and operating cost savings also favor electrification for most metropolitan areas.

Alternating Current. This type of system utilizes an overhead catenary with a contact wire that usually (in the U.S.) carries single phase voltages of 11,000 to 25,000 volts. Commercial 60-Hz frequency distribution appears to be the preference for all future AC electrifications.

The light, single-phase AC contact system represents the lowest-cost, fixed-plant electrified installation. Increased vehicle costs result from the need to convert to direct current on-board. Transformers supplied by a power utility company and cost-covered in the rate structure can be fed from the same central power stations that serve residential and commercial properties.

Direct Current. These systems consist of traction power distribution by means of either overhead catenary or third rail, depending upon the operating voltage and physical parameters of the line. The nominal voltage is range 600-750 VDC, with the exception of BART which uses 1000 volts.

AC/DC. Commercial frequency AC electrification systems may be considered for any new proposed major suburban or commuter rail extensions. Modern electronic techniques applied to on-board switching now make dual-voltage motive power practical, as it can operate over routes where power must be collected from different voltages, or where it could be advantageous to collect from either AC or DC on the same train run. New equipment developed for New York City suburban service provides an example of the applications of such technology.

In single-phase AC electrification, substations simply consist of transformer stations with circuit breakers to control the trolley and feeder circuits. Usually this apparatus is located out-of-doors. Circuit breakers may be unattended with automatic transfer or may be supervisory controlled by a central power dispatcher.

In DC electrification, substations consist of incoming 3-phase AC feeders, high-tension circuit breakers, step-down transformers, switchboards for the control of incoming AC and outgoing DC feeders, conversion apparatus to change AC to DC, and outgoing feeders and switches.

DC substations may be automatic with relay apparatus to control the various operations in relation to the load or system voltage, but in most newer systems will be supervisory controlled from a central power dispatcher console.

2.6 LAND ACQUISITION

Local land values usually determine the cost of right-of-way acquisition. In addition to the price of property, substantial legal, engineering, and brokerage costs are incurred in the acquisition of right-of-way.

2.7 STATIONS

Station construction is normally included as part of the route construction for elevated, and underground sections of a system. Length of platforms, number and size of escalators and/or elevators, the need for waiting room, rest rooms, and other ancillary areas, parking lot capacity, and whether the station is elevated, or depressed all have direct influence on construction costs as well as the number per mile or total number per system.

2.8 YARD, REPAIR AND MAINTENANCE FACILITIES

Yards. Yard requirements are a function of fleet size and equipment utilization on a given transit system. They must satisfy two basic functions, i.e., (1) storage of cars for current

operations, and (2) storage of cars in support of repair and maintenance shops.

Normally, storage yards are provided at each line terminus for storage of revenue equipment, reduction of non-revenue mileage, and to facilitate changes in train consist during operating periods. Support yards are provided for major repair shops and service and inspection facilities.

Repair and Maintenance Facilities. Every transit property requires at least one major repair facility that is able to overhaul vehicles, make repairs, change trucks, turn wheels, and make extensive modifications. Service, inspection, and running repair shops are also provided at terminals.

The size and degree of sophistication of each shop is considered as a function of fleet size and physical characteristics of the property.

Vehicles. The major factors that appear to influence vehicle costs consist of the vehicle's specific or typical characteristics, length, weight, passenger capacity; type of propulsion; type of vehicle, as to being either self-powered or non-powered; size of the purchase order; and the degree of sophistication of on-board train control and communications equipment.

Catenary power distribution systems are generally more costly to maintain than power rail distribution systems.

Maintenance of Equipment (M/E). These costs include expenses associated with the maintenance and repair of the vehicle fleet. It includes the labor, materials, supervision, and shop expense necessary to inspect, service, maintain, repair, and rebuild the vehicles and component parts.

Factors which affect the cost of maintaining equipment include the size of the fleet, type of equipment, age of equipment, the miles operated annually, hours of operation, permissible out-of-service ratio, and the shop facilities available.

Power. Within this category are all the costs associated with the purchase or production of electrical energy to the vehicle.

Power costs vary with such factors as the cost to purchase or produce power, load factors, type of equipment, train length, train frequency, and system design.

Transportation. Within this category are all of the costs of conducting transportation. It includes train personnel, station personnel, switchmen and yard crews, towermen, supervision, and other labor directly related to the movement of trains. Factors which affect transportation efficiency and expense include hours of service, train manning requirement, number of cars per train, train frequency, train turn-around time relative to the duration of the peak period, method of fare collection, and number and type of stations.

General and Administrative. The salaries and expense of general officers are the main cost in this category and normally vary in proportion to the size of the system. Pensions, insurance, taxes, and claims are also significant costs.

3 SYSTEM OPERATING COSTS

3.1 OPERATING COSTS

Operating costs on transit and railroad systems consist of items of expense covering day-to-day operations, including labor, material, supplies to operate the trains, supplies to maintain and service the equipment; maintenance of the fixed plant, the cost of electric power produced or purchased, general and administrative expense, injuries and damages, employee benefits, and taxes.

3.2 MAJOR FACTORS INFLUENCING OPERATING COSTS

There are many factors which influence operating costs on a given system. Some of the major factors are as follows:

Maintenance-of-Way (M/W). The costs associated with the maintenance of the fixed plant and facilities, including tracks, tunnels, bridges, buildings, signals, communications, and power distribution are all within this category.

The cost to maintain the fixed plant varies substantially with the type of construction, elevated and subway structures requiring larger annual expense than at-grade construction.

Maintenance costs increase if service levels provide minimum on-track time for track maintenance equipment or require work to be done at night.

Costs affected by wear, such as the track and overhead wire or power rail, vary with the amount of traffic.

Type of track, number of switches, grade crossings, track bridges, drainage structures, retaining walls, and other components of the fixed plant bear directly on maintenance costs.

Sophisticated signal and communication systems, such as automatic train control, are more complicated and, therefore, more costly to maintain than are automatic block systems or sections with interlocking protection only.

ROUTE CONSTRUCTION COSTS PER ROUTE MILE OF DOUBLE TRACK
LIGHT RAIL MODE
CITY AND CORE AREAS
DEPRESSED CUT AND COVER TUNNEL

<u>Item</u>	(1974 Dollars)	
	<u>Low</u>	<u>High</u>
¹ Utilities 1	\$ 600,000	\$ 1,200,000
² Utilities 2	3,000,000	3,000,000
¹ Traffic Handling 1	2,200,000	4,400,000
² Traffic Handling 2	2,700,000	5,400,000
¹ Demolition 1	1,000,000	2,500,000
² Demolition 2	0	0
Grading	11,630,000	11,630,000
Drainage	500,000	500,000
Concrete Box Structure	<u>13,200,000</u>	<u>13,200,000</u>
¹ Total 1	\$29,130,000	\$33,430,000
² Total 2	\$31,030,000	\$33,730,000

CRITERIA FOR SCALING COSTS

By visual observation count the Highways, Railroads and Existing Buildings for each mile of the proposed route and proportion these quantities to the Low and High costs and quantities shown.

<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Utilities	10 Hwy or RR Crossings	20 Hwy or RR Crossings
¹ Traffic Handling 1	10 Hwy or RR Crossings	20 Hwy or RR Crossings
¹ Traffic Handling 2	10 Hwy or RR Crossings	20 Hwy or RR Crossings
¹ Demolition 1	³ 100 Single Dwellings	³ 250 Single Dwellings

¹Use Utilities 1, Traffic Handling 1 and Demolition 1 when the proposed route is not located in a street right-of-way.

²Use Utilities 2, Traffic Handling 2 and Demolition 2 when the proposed route is located in a street right-of-way.

³Convert multiple dwelling, commercial and industrial buildings into equivalent single dwellings by area up to three floors in height, then multiply accordingly for additional floors.

ROUTE CONSTRUCTION COSTS PER ROUTE MILE OF DOUBLE TRACK
LIGHT RAIL MODE
CITY AND CORE AREAS
ELEVATED

(1974 Dollars)

<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Utilities 1	\$ 200,000	\$ 400,000
² Utilities 2	500,000	500,000
¹ Traffic Handling 1	500,000	1,000,000
² Traffic Handling 2	800,000	800,000
¹ Demolition 1	1,000,000	2,500,000
² Demolition 2	0	0
Grading	750,000	750,000
Elevated Structure	<u>12,500,000</u>	<u>12,500,000</u>
¹ Total 1	\$14,950,000	\$17,150,000
² Total 2	\$14,550,000	\$14,550,000

CRITERIA FOR SCALING COSTS

By visual observation, count the Highways, Railroads and Existing Buildings for each mile of the proposed route, and proportion these quantities to the Low and High costs and ²quantities shown.

<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Utilities 1	10 Hwy or RR Crossings	20 Hwy or RR Crossings
³ Traffic Handling 1	10 Hwy or RR Crossings	20 Hwy or RR Crossings
¹ Demolition 1	³ 100 Single Dwellings	³ 250 Single Dwellings

¹Use Utilities 1, Traffic Handling 1 and Demolition 1 when the proposed route is not located in a street right-of-way.

²Use Utilities 2, Traffic Handling 2 and Demolition 2 when the proposed route is located in a street right-of-way.

³Convert multiple dwelling, commercial and industrial buildings into equivalent single dwellings by area up to three floors in height, then multiply accordingly for additional floors.

ROUTE CONSTRUCTION COSTS PER ROUTE MILE OF DOUBLE TRACK
LIGHT RAIL MODE
CITY AREAS
AT GRADE

Route construction in city, at grade, is applicable to median construction in divided highways.

<u>Item</u>	(1974 Dollars)	
	<u>Low</u>	<u>High</u>
Grading	\$150,000	\$150,000
Drainage	140,000	140,000
Utilities	40,000	100,000
Traffic Handling	60,000	150,000
Fences	<u>110,000</u>	<u>110,000</u>
Total	\$500,000	\$650,000

CRITERIA FOR SCALING COSTS

By visual observation, count the Highway Crossings for each mile of the proposed route, and proportion these quantities to the Low and High costs and quantities shown.

<u>Item</u>	<u>Low</u>	<u>High</u>
Utilities	4 Highway Crossings	10 Highway Crossings
Traffic Handling	4 Highway Crossings	10 Highway Crossings

ROUTE CONSTRUCTION COSTS PER ROUTE MILE OF DOUBLE TRACK
LIGHT RAIL MODE
SUBURBAN AREAS
DEPRESSED-OPEN RETAINED CUT

<u>Item</u>	(1974 Dollars)	
	<u>Low</u>	<u>High</u>
¹ Grading 1	\$ 925,000	\$ 1,900,000
² Grading 2	1,400,000	2,750,000
Drainage	100,000	300,000
Utilities	120,000	300,000
Concrete Box	2,500,000	7,500,000
Other Structures	300,000	900,000
Traffic Handling	80,000	200,000
Demolition	70,000	210,000
Fences	110,000	110,000
	¹ Title 1	\$4,205,000
	² Title 2	\$11,420,000
		\$4,680,000
		\$12,270,000

CRITERIA FOR SCALING COSTS

By visual observation, determine the percent of Concrete Box Structure, Dry Earth, Wetland and Exposed Rock and count the Highways, Railroads, Rivers and Existing Buildings for each mile of the proposed route and proportion these quantities to the Low and High costs and quantities shown.

<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Grading 1	100% Dry Earth	10% Rock
² Grading 2	100% Dry Earth	20% Rock
Drainage	1000 Feet per Mile	3000 Feet per Mile
Utilities	2 Highway Crossings	5 Highway Crossings
Concrete Box	1000 Feet per Mile	3000 Feet per Mile
Other Structures	1 Hwy, RR or River	3 Hwy, RR or Rivers
Traffic Handling	2 Hwy or RR Crossings	5 Hwy or RR Crossings
Demolition	³ 10 Single Dwellings	³ 30 Single Dwellings

¹Use Grading 1 for level to rolling terrain.

²Use Grading 2 for rolling to rough terrain.

³Convert multiple dwelling, commercial and industrial building into equivalent single dwellings by area up to three floors in height, then multiply accordingly for additional floors.

ROUTE CONSTRUCTION COSTS PER ROUTE MILE OF DOUBLE TRACK
RAPID TRANSIT MODE
SUBURBAN AREAS
ELEVATED

(1974 Dollars)

<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Grading 1	\$ 200,000	\$ 450,000
² Grading 2	400,000	700,000
¹ Drainage 1	20,000	75,000
² Drainage 2	30,000	120,000
Utilities	40,000	100,000
Elevated Structure	2,000,000	6,000,000
Other Structures	300,000	900,000
Traffic Handling	80,000	200,000
Demolition	70,000	210,000
Fences	110,000	110,000
	¹ Total 1 \$2,820,000	\$8,045,000
	² Total 2 \$3,030,000	\$8,340,000

CRITERIA FOR SCALING COSTS

By visual observation, determine the percent of Elevated Structure, Dry Earth, Wetland and Exposed Rock and count the Highways, Railroads, Rivers, Small Streams and Existing Buildings for each mile of the proposed route, and proportion these quantities to the Low and High costs and quantities shown.

<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Grading 1	100% Dry Earth	10% Rock
² Grading 2	100% Dry Earth	20% Rock
¹ Drainage 1	1 Stream Crossing	3 Stream Crossings
² Drainage 2	1 Stream Crossing	3 Stream Crossings
Utilities	2 Highway Crossings	5 Highway Crossings
Elevated Structure	1000 LF Per Mile	3000 LF Per Mile
Other Structures	1 Hwy, RR or River	3 Hwy, RR or Rivers
Traffic Handling	2 Hwy or RR Crossings	5 Hwy or RR Crossings
Demolition	³ 10 Single Dwellings	³ 30 Single Dwellings

¹Use Grading 1 and Drainage 1 for level to rolling terrain.

²Use Grading 2 and Drainage 2 for rolling to rough terrain.

³Convert multiple dwelling, commercial and industrial buildings into equivalent single dwellings by area up to three floors in height, then multiply accordingly for additional floors.

ROUTE CONSTRUCTION COSTS PER ROUTE MILE OF DOUBLE TRACK

LIGHT RAIL MODE

SUBURBAN AREAS

AT GRADE

<u>Item</u>	(1974 Dollars)	
	<u>Low</u>	<u>High</u>
¹ Grading 1	\$200,000	\$ 400,000
² Grading 2	400,000	1,000,000
¹ Drainage 1	20,000	90,000
² Drainage 2	40,000	160,000
Utilities	10,000	25,000
Structures	300,000	900,000
Traffic Handling	10,000	25,000
Demolition	70,000	210,000
Fences	<u>110,000</u>	<u>110,000</u>
	¹ Total 1	\$720,000
	² Total 2	\$1,760,000
		\$2,430,000

CRITERIA FOR SCALING COSTS

By visual observation, determine the percent of Dry Earth, Wetland, and Exposed Rock and count the Highways, Railroads, Rivers, Small Streams and Existing Buildings for each mile of the proposed route, and proportion these quantities to the Low and High costs and quantities shown.

<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Grading 1	100% Dry Earth	20% Rock or Wetland
² Grading 2	100% Dry Earth	30% Rock or Wetland
¹ Drainage 1	2 Stream Crossings	6 Stream Crossings
² Drainage 2	2 Stream Crossings	6 Stream Crossings
Utilities	2 Hwy Crossings	5 Hwy Crossings
Structures	1 RR or Rivers	3 RR or Rivers
Traffic Handling	2 Hwy or RR Cross.	5 Hwy or RR Cross.
Demolition	³ 10 Single Dwellings	³ 30 Single Dwellings

¹Use Grading 1 and Drainage 1 for level to rolling terrain.

²Use Grading 2 and Drainage 2 for rolling to rough terrain.

³Convert multiple dwelling, commercial and industrial buildings into equivalent single dwellings by area up to three floors in height, then multiply accordingly for additional floors.

Stations - the entire, completed station complex, including the buildings, platforms, access and parking areas, where applicable.

Yards - to store equipment when not in use. This includes grading, drainage, trackwork, power, buildings, light, and fencing.

Shops - to handle the running and major maintenance for the total fleet of cars from one operating line. Included are the shop tracks, supporting yard tracks, power, access, light, and fencing. Power is transmitted through an overhead catenary system.

Vehicles - light rail car.

4.3 LIGHT RAIL COST PROJECTIONS

The following portion of this section contains the cost projections which make up a total light rail system including purchase of vehicles. Actual costs of recently purchased light rail vehicles are shown in Table 4-1. Table 4-2 shows light rail operating costs, and Table 4-3 lists expense comparisons. The cost projections give a "low" estimate and a "high" estimate, where applicable, and criteria for scaling costs between the two extremes.

Core Area - a small area located within the principal part of the city. That portion of the total community which bears the city name. It contains the most dense business area and usually resorts to high-rise construction to provide adequate space.

At Grade - construction on the existing ground, graded as necessary to provide a uniform alignment and profile. It is bridged over waterways and railroads and may or may not be grade-separated at highways.

Elevated - a continuous above-ground supporting structure. It can be built of sloped earth, retained earth, concrete or steel structure or a combination of each. It provides for continuous grade separation.

Depressed - a continuous way constructed below the existing ground. It can be sloped or retained cut, or cut and cover tunnel built of concrete or steel or both. It provides continuous grade-separation.

Tunnel (bored or tube) - an underground way bored through earth or rock, usually at considerable depths below the surface. It may also be sunken tube placed in a trench and backfilled for harbor and river crossings.

Route Construction - the grading, drainage, utilities, and structures required to provide the supporting structure or sub-grade for the guideway.

Guideway - the track structure in its final position, including ballast, ties, and rail, but not the power third rail or catenary. The estimate provides for a small percentage of direct fixation to bridge structures.

Signal - the Train Control System of electrically operated trackside equipment, controlled switches (interlocks), on-board apparatus to control train operations, and signaling to protect highway crossings.

Power - the traction power provided through electrification. It includes substation construction and the distribution system to vehicles along the right-of-way. Distribution may be by power rail or overhead catenary.

recent cost data were available for the construction of new light rail lines, that would be applicable in the United States. Similarly, Boston and San Francisco are the only United States cities that have recently purchased new light rail vehicles.

4.2 LIGHT RAIL CAPITAL COSTS

Based on the construction cost experiences of the rail systems studied, capital cost projections have been made to assist in estimating the capital cost to acquire right-of-way, construct the fixed plant and purchase vehicles for a new light rail system. The costs developed are for preliminary planning purposes.

To utilize the cost projections, the following minimum information is necessary:

1. The approximate delineation of a projected route on a United States Department of Interior 1:24000 Geological Survey map or its equivalent.
2. Field inspection of the route and inventory of principal physical features.
3. Traffic forecasts for the proposed system.
4. Preliminary transportation analysis to determine:
 - a. Train frequency and number of cars per train.
 - b. Total cars required.
 - c. Number of stations, approximate parking requirements, type of station facilities.

The terms used in preparing the light rail system estimates are as follows:

Suburban Area - the separate, smaller communities that usually surround a city. They are of 20,000 to 50,000 population and are located just inside or just outside of the metropolitan area.

City Area - A city may be defined as a spacially large, residentially dense and permanent settlement of socially heterogeneous individual. Cities contain a central area where major governmental, retail or commercial activities predominate.

4 LIGHT RAIL CAPITAL AND OPERATING COSTS

4.1 GENERAL

Light Rail Transit (LRT) also known as street railway, city rail, tram, or pre-metro may be defined as a rail guideway system wherein the route configuration may include non-grade separated portions. As an outgrowth of streetcar systems, light rail may operate in city streets with vehicular traffic or in reserved or median strips with vehicular crossings at intersections. In dense traffic areas, light rail may operate on grade-separated right-of-way in the same manner as does rail rapid transit.

Light Rail Vehicles (LRV) are electrically powered, capable of operating singly or in trains, and can be constructed to accommodate loading from either high or low platforms, which is important for mixed high platform and street level operation. In at-grade service, stations may be identical to bus facilities, i.e., as little as a sign. Fare collection may be at stations in grade-separated rights of the way, but is generally on-board.

LRT electrical power is usually collected from an overhead catenary by pantograph or trolley pole. A wayside power rail may be used on grade-separated installations. The same vehicle may operate in power rail and catenary territory when equipped for dual power pick-up.

Light rail typically represents a service application when traffic density per mile ranges from 3,000 to 18,000 persons per hour in one direction. LRT offers a quality service somewhat below the level of full rapid rail, but above that of a bus on the street. LRT retains the ability to be upgraded to full rapid rail transit over its grade-separated portions. Its principal feature remains the ability to operate on non-exclusive, at-grade right of way, with attendant savings in construction costs.

Light rail systems were inspected in Boston, Cleveland, Philadelphia, Toronto, and six European cities, to observe operations, inspect facilities, and gather cost information. Very little

ROUTE CONSTRUCTION COSTS PER ROUTE MILE OF DOUBLE TRACK
LIGHT RAIL MODE
SUBURBAN, CITY AND CORE AREAS
TUNNEL (OTHER THAN CUT AND COVER)

<u>Type</u>	<u>(1974 Dollars)</u> <u>Cost Per Mile</u>
Rock Tunnel	\$10,000,000 - \$20,000,000
Earth Tunnel	\$15,000,000 - \$30,000,000
Sunken Tube	c. \$50,000,000

There is substantial variance in the cost of non-cut and cover tunneling, which cannot be quantified without a detailed investigation of conditions, not normally available in preliminary planning stages. A major factor in tunneling costs is the length of the tunnel, as the cost of establishing the tunnel face is substantial and must be apportioned over the length. For these reasons, if tunnel construction is a major factor in system cost, a detailed investigation is necessary.

GUIDEWAY CONSTRUCTION COSTS PER ROUTE MILE OF DOUBLE TRACK
LIGHT RAIL MODE
SUBURBAN, CITY AND CORE AREAS
AT GRADE AND GRADE-SEPARATED

(1974 Dollars)

<u>Item</u>	<u>Suburban</u>	<u>City</u>	<u>Core</u>
¹ Track Structure 1	\$675,000	\$ 883,000	\$ 970,000
² Track Structure 2	742,500	819,000	900,000
¹ Special Trackwork 1	75,000	117,000	130,000
² Special Trackwork 2	<u>82,500</u>	<u>91,000</u>	<u>100,000</u>
¹ Total 1	\$750,000	\$1,000,000	\$1,100,000
² Total 2	\$825,000	910,000	\$1,000,000

¹Use Total 1 costs for At-Grade Construction. City and Core costs include continuous Girder Rail and Ballast fill.
²Use Total 2 costs for Grade-Separated Construction.

SIGNAL AND COMMUNICATION CONSTRUCTION COSTS PER ROUTE
MILE OR DOUBLE TRACK
LIGHT RAIL MODE
SUBURBAN, CITY AND CORE AREAS
AT GRADE & GRADE-SEPARATED

(1974 Dollars)

<u>Item</u>	<u>Unit</u>	<u>Low</u>	<u>High</u>
Wayside Signaling	Route Mile	\$150,000	\$285,000
Supervisory Control	Route Mile	50,000	100,000
Communications	Route Mile	10,000	25,000
		<u>\$210,000</u>	<u>\$410,000</u>
Grade Crossing Protection	Each Xing	45,000	45,000
On-Board Equipment	Each Car	0	20,000
Storage Yard Control	Each Yard	0	1,200,000

CRITERIA FOR SCALING COSTS

	<u>Low</u>	<u>High</u>
Wayside Signaling	6 Trains/Hr.	15 Trains/Hr.
Supervisory Control	6 Trains/Hr.	15 Trains/Hr.
Communications	6 Trains/Hr.	15 Trains/Hr.
Interlockings	6 Trains/Hr.	15 Trains/Hr.
On-Board Equipment	-	15 Trains/Hr.
Storage Yard Control	-	15 Trains/Hr.

ELECTRIFICATION CONSTRUCTION COSTS PER ROUTE MILE OF DOUBLE TRACK
LIGHT RAIL MODE
SUBURBAN, CITY AND CORE AREAS
AT GRADE & GRADE-SEPARATED

(1974 Dollars)

<u>Item</u>	<u>Low</u>	<u>High</u>
Overhead Catenary, 600 VDC including Substations	1,000,000	\$1,300,000

CRITERIA FOR SCALING COSTS

<u>Item</u>	<u>Low</u>	<u>High</u>
1. Operating Headways	12 Trains/Hr.	20 Trains/Hr.
2. Number of Cars/Train	1	4

LAND ACQUISITION COST⁽¹⁾ PER ROUTE MILE OF DOUBLE TRACK
LIGHT RAIL MODE
SUBURBAN, CITY AND CORE AREAS
AT GRADE AND GRADE-SEPARATED

(1974 Dollars)

<u>Area</u>	<u>Low</u>	<u>High</u>
Suburban	\$ 130,000	\$ 400,000
City	\$1,300,000	\$4,000,000
Core	\$2,600,000	\$8,000,000

1. Actual Values Are Highly Site-Specific

CRITERIA FOR SCALING COSTS

Storage Yard areas range from 3 to 10 acres. Shop areas range from 4 to 12 acres. Parking lots range from 1 to 3 acres for small parking facilities, to 5 to 15 acres for major parking facilities.

<u>Area</u>	<u>Low</u>	<u>High</u>
Suburban	\$0.25/SF	\$0.75/SF
City	2.50/SF	7.50/SF
Core	5.00/SF	15.00/SF

STATION CONSTRUCTION COST-EACH
LIGHT RAIL MODE
SUBURBAN AREA
AT GRADE

(1974 Dollars)

<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Awning 1	-0-	-0-
² Awning 2	\$ 80,000	\$ 160,000
¹ Parking 1	-0-	-0-
² Parking 2	115,000	575,000
³ Parking 3	230,000	1,150,000
<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Access 1	-0-	-0-
² Access 2	\$144,000	\$ 720,000
³ Access 3	288,000	1,400,000
Platform	15,000	30,000
Passenger Shelters	<u>5,000</u>	<u>25,000</u>
¹ Total 1	\$ 20,000	\$ 55,000
² Total 2	359,000	1,510,000
³ Total 3	618,000	2,765,000

CRITERIA FOR SCALING COSTS

<u>Item</u>	<u>Low</u>	<u>High</u>
² Awning 2	2 Car Train	4 Car Train
² Parking 2	75 Automobiles	375 Automobiles
³ Parking 3	150 Automobiles	750 Automobiles
² Access 2	75 Automobiles	375 Automobiles
³ Access 3	150 Automobiles	750 Automobiles
Platform	2 Car Train	4 Car Train
Passenger Shelter	360 People	1800 People

- ¹Use Awning 1, Parking 1 and Access 1 for no Awnings or Parking.
²Use Awning 2, Parking 2 and Access 2 for Awnings and Limited Parking.
³Use Awning 2, Parking 3 and Access 3 for Awnings and Major Parking.

STATION CONSTRUCTION COSTS-EACH
LIGHT RAIL MODE
SUBURBAN AREA
ELEVATED

(1974 Dollars)

<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Awning 1	\$ - 0-	\$ - 0-
² Awning 2	80,000	160,000
¹ Parking 1	- 0-	- 0-
² Parking 2	115,000	575,000
³ Parking 3	230,000	1,150,000
<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Access 1	50,000	150,000
² Access 2	350,000	1,120,000
³ Access 3	490,000	1,900,000
Platform	128,000	256,000
Passenger Shelters	<u>10,000</u>	<u>50,000</u>
¹ Total 1	\$188,000	\$ 456,000
² Total 2	683,000	\$2,161,000
³ Total 3	938,000	\$3,516,000

CRITERIA FOR SCALING COST

<u>Item</u>	<u>Low</u>	<u>High</u>
² Awning 2	2 Car Train	4 Car Train
² Parking 2	75 Automobiles	375 Automobiles
³ Parking 3	150 Automobiles	750 Automobiles
¹ Access 1	360 People	1800 People
² Access 2	75 Automobiles	375 Automobiles
³ Access 3	150 Automobiles	750 Automobiles
Platform	2 Car Train	4 Car Train
Passenger Shelters	360 People	1800 People

- ¹Use Awning 1, Parking 1 and Access 1 for no Awnings or Parking.
²Use Awning 2, Parking 2 and Access 2 for Awnings and Limited Parking.
³Use Awning 2, Parking 3 and Access 3 for Awnings and Major Parking.

STATION CONSTRUCTION COSTS - EACH
LIGHT RAIL MODE
SUBURBAN AREA
DEPRESSED-OPEN RETAINED CUT

(1974 Dollars)

<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Awning 1	-0-	-0-
² Awning 2	80,000	160,000
¹ Parking 1	-0-	-0-
² Parking 2	115,000	575,000
³ Parking 3	230,000	1,150,000
<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Access 1	50,000	150,000
² Access 2	350,000	1,120,000
³ Access 3	490,000	1,900,000
Platform	150,000	300,000
Passenger Shelters	<u>10,000</u>	<u>50,000</u>
¹ Total 1	\$210,000	\$ 500,000
² Total 2	\$705,000	\$ 2,205,000
³ Total 3	\$960,000	\$ 3,560,000

CRITERIA FOR SCALING COSTS

<u>Item</u>	<u>Low</u>	<u>High</u>
² Awning 2	2 Car Train	4 Car Train
² Parking 2	75 Automobiles	375 Automobiles
³ Parking 3	150 Automobiles	750 Automobiles
¹ Access 1	360 People	1800 People
² Access 2	75 Automobiles	375 Automobiles
³ Access 3	150 Automobiles	750 Automobiles
Platform	2 Car Train	4 Car Train
Passenger Shelters	360 People	1800 People

- ¹Use Awning 1, Parking 1 and Access 1 for no Awnings or Parking.
²Use Awning 2, Parking 2 and Access 2 for Awnings and Limited Parking.
³Use Awning 2, Parking 3 and Access 3 for Awnings and Major Parking.

STATION CONSTRUCTION COSTS - EACH
LIGHT RAIL MODE
CITY AREA
AT GRADE

Station construction in city, at grade consists of paved, lighted platforms with passenger shelters.

<u>Item</u>	(1974 Dollars)	
	<u>Low</u>	<u>High</u>
Platform	\$15,000	\$30,000
Passenger Shelter	<u>5,000</u>	<u>25,000</u>
Total	\$20,000	\$55,000

CRITERIA FOR SCALING COSTS

<u>Item</u>	<u>Low</u>	<u>High</u>
Platform	2 Car Train	4 Car Train
Passenger Shelters	360 People	1800 People

STATION CONSTRUCTION COST-EACH
LIGHT RAIL MODE
CITY AREA
ELEVATED

(1974 Dollars)

<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Awning 1	\$ -0-	\$ -0-
² Awning 2	80,000	160,000
Platform	128,000	256,000
Access	60,000	180,000
Passenger Shelters	<u>20,000</u>	<u>100,000</u>
	¹ Total 1	¹ Total 1
	\$208,000	\$536,000
	² Total 2	² Total 2
	\$288,000	\$696,000

CRITERIA FOR SCALING COSTS

<u>Item</u>	<u>Low</u>	<u>High</u>
² Awning 2	2 Car Train	4 Car Train
Platform	2 Car Train	4 Car Train
Access	600 People	3000 People
Passenger Shelters	600 People	3000 People

¹Use Awning 1 for No Awnings.

²Use Awning 2 for Awnings.

STATION CONSTRUCTION COSTS-EACH
LIGHT RAIL MODE
CITY AREA (1)
DEPRESSED CUT & COVER TUNNEL

(1974 Dollars)

<u>Item</u>	<u>Low</u>	<u>High</u>
Platform	\$320,000	\$ 640,000
Access	<u>120,000</u>	<u>360,000</u>
	\$440,000	\$1,000,000
1. Station Facility Not Included		

CRITERIA FOR SCALING COSTS

<u>Item</u>	<u>Low</u>	<u>High</u>
Platform	2 Car Train	4 Car Train
access	600 People	3000 People

STATION CONSTRUCTION COSTS-EACH
LIGHT RAIL MODE
CORE AREA
ELEVATED

(1974 Dollars)

<u>Item</u>	<u>Low</u>	<u>High</u>
Awning	\$ 80,000	\$ 400,000
Platform	128,000	640,000
Access	750,000	1,720,000
Station Facility	<u>360,000</u>	<u>1,300,000</u>
Total	\$1,318,000	\$4,560,000

CRITERIA FOR SCALING COSTS

<u>Item</u>	<u>Low</u>	<u>High</u>
Awning	2 Car Train	2 Trains of 4 Cars Ea.
Platform	2 Car Train	2 Trains of 4 Cars Ea.
Access	1800 People	9000 People
Station Facility	1800 People	9000 People

STATION CONSTRUCTED COSTS - EACH
LIGHT RAIL MODE
CORE AREA
DEPRESSED CUT AND COVER TUNNEL

(1974 Dollars)

<u>Item</u>	<u>Low</u>	<u>High</u>
Platform	\$ 352,000	\$1,760,000
Access	605,000	1,672,000
Station Facility	<u>825,000</u>	<u>4,125,000</u>
Total	\$1,782,000	\$7,557,000

CRITERIA FOR SCALING COSTS

<u>Item</u>	<u>Low</u>	<u>High</u>
Platform	2 Car Train	2 Trains of 4 Cars Ea.
Access	1800 People	9000 People
Station Facility	1800 People	9000 People

STORAGE YARD CONSTRUCTION-EACH
LIGHT RAIL MODE
SUBURBAN OR CITY AREAS
AT GRADE

(1974 Dollars)

<u>Item</u>	<u>Low</u>	<u>High</u>
Grading	\$ 340,000	\$ 1,120,000
Drainage	70,000	350,000
Utilities	80,000	400,000
Track	1,760,000	5,000,000
Power	1,670,000	8,864,000
Fence	30,000	100,000
Buildings	<u>70,000</u>	<u>200,000</u>
Total	\$4,020,000	\$16,034,000

CRITERIA FOR SCALING COSTS

<u>Item</u>	<u>Low</u>	<u>High</u>
Fleet	60 Cars	300 Cars

SHOP CONSTRUCTION COSTS-EACH
LIGHT RAIL MODE
SUBURBAN & CITY AREAS
AT GRADE

(1974 Dollars)

<u>Item</u>	<u>Low</u>	<u>High</u>
Grading	\$ 250,000	\$ 1,250,000
Drainage	150,000	750,000
Utilities	200,000	1,000,000
Shop Building	5,400,000	16,200,000
Shop Track	720,000	3,600,000
Support Yard Track	370,000	1,850,000
Power	917,000	4,585,000
Fence	<u>30,000</u>	<u>150,000</u>
Total	\$8,037,000	\$29,385,000

CRITERIA FOR SCALING COST

<u>Item</u>	<u>Low</u>	<u>High</u>
Fleet	60 Cars	300 Cars

VEHICLE ACQUISITION COST-EACH
LIGHT RAIL MODE
SUBURBAN, CITY AND CORE AREAS
AT GRADE & GRADE-SEPARATED

(1974 Dollars)

Cost per vehicle (if ordered 1974) \$300,000 - \$450,000

TABLE 4-1. LIGHT RAIL VEHICLE COSTS

Operating Agency	Passenger Capacity		Cars Per Train Min-Max	Car Dimensions			Car Light Weight (lbs)	Max. Speed (mph)	Initial Accel. Rate (mph/s)	On-Brd. Cab-Sign. Or Speed Control	Power	Year Built	Cost Per Car
	No. of Seats	Max. Crush		Schedule Peak	Length	Height							
Boston	52	219	150	1-4	73'-0"	11'-4"	8'-10 1/4"	69,000	50	2.8	No	1975-76	\$300,000
San Francisco	68	193	88	1-4	73'-0"	11'-4"	8'-10 1/4"	69,000	50	2.8	Yes	1975-76	315,000

TABLE 4-2. LIGHT RAIL OPERATING COST COMPARISONS FOR 1973

Operating Agency	Route Miles	Main Track Miles	No. of Vehicles	Car Miles	Revenues	Revenue Per Car Mile	Operating Expenses					Cost Per Car Mile	
							M/W	M/E	Power	Transp.	Other		Total
Bern, Switzerland	11.03	22.06	84	1,837,876	\$ 2,632,201	\$1.43	\$ 205,128	\$ 586,666	\$ 136,752	\$ 1,330,120	\$ 767,656	\$ 3,026,322	\$1.65
Boston	43.35	86.7	295	6,314,000	11,930,490	1.89	4,994,288	5,446,495	2,831,681	10,117,731	7,469,064	30,859,259	4.89
Cleveland Shaker Heights	10.5	21.0	55	1,042,256	1,995,619	1.91	243,732	189,057	149,864	980,185	562,077	2,124,915	2.04
Philadelphia	84.7	145.1	364	8,040,404	12,146,084	1.51	2,542,377	3,247,810	1,852,457	7,135,869		14,778,513	1.84

TRAIN MANNING REQUIREMENTS
ON SELECTED PROPERTIES
LIGHT RAIL

<u>OPERATING AGENCY</u>		<u>MANNING REQUIREMENTS</u>
Bern		1 Operator per train
Boston	MBTA	1 Operator (or Ticket Collector) per car
Cleveland	CTS	1 Operator (or Ticket Collector) per car
Philadelphia	SEPTA	1 Operator (or Ticket Collector) per car

4.4 OPERATING COSTS

Operating costs of four light rail systems were obtained. A summary of the results for 1973 (the latest year available) is presented in Tables 4-2 and 4-3. Train manning requirements for various light rail systems are shown above.

In 1974 dollars per car mile, costs are as follows:

- a. The cost range for the four systems is from \$1.75 to \$5.20 per car mile.
- b. If Boston is excluded (an old fixed plant with considerable tunnel and elevated construction, restrictive geometry, and very old equipment), the average cost is \$1.95 per car mile for the other three systems with revenue offsetting about 85 percent of the cost.

TABLE 4-3. LIGHT RAIL SYSTEMS' EXPENSE COMPARISONS
1973 MAINTENANCE OF WAY EXPENSE

Operating Agency	Route Miles	Main Track Miles	M/W Expense	Cost Per Car Mile	Cost Per Route Mile	Cost Per Main Track Mile
Bern, Switzerland	11.03	22.06	\$ 205,128	\$.11	\$ 18,597	\$ 9,299
Boston MBTA	43.35	86.7	4,994,288	.79	115,208	57,604
Cleveland Shaker Heights SHRT	10.5	21.0	243,732	.23	23,213	11,606
Philadelphia SEPTA	84.7	145.1	2,542,377	.32	30,016	17,522

1973 MAINTENANCE OF EQUIPMENT EXPENSE

Operating Agency	Vehicles	M/E Expense	Cost Per Vehicle	Average Miles/Vehicle	M/E Cost Per Mile ¹
Bern, Switzerland	84	\$ 586,666	\$ 6,984	21,879	\$.32
Boston MBTA	295	5,446,495	18,463	21,403	.86
Cleveland Shaker Heights SHRT	55	189,057	3,437	18,950	.18
Philadelphia SEPTA	364	3,247,810	8,923	22,089	.40

¹Vehicle mile

1973 POWER EXPENSE

Operating Agency	Car Miles	Power Expense	Power Cost Per Car Mile
Bern, Switzerland	1,837,876	\$ 136,752	\$.074
Boston MBTA	6,314,000	2,891,681	.458
Cleveland Shaker Heights SHRT	1,042,256	149,864	.144
Philadelphia SEPTA	8,040,404	1,852,457	.23

1973 TRANSPORTATION EXPENSE

Operating Agency	Transportation Cost	Car Miles	Transportation Cost/Car Mile
Bern, Switzerland	\$ 1,330,120	1,837,876	\$.72
Boston MBTA	10,117,731	6,314,000	1.60
Cleveland Shaker Heights SHRT	980,185	1,042,256	.94
Philadelphia SEPTA	7,135,869	8,040,404	.89

5 RAIL RAPID TRANSIT CAPITAL AND OPERATING COSTS

5.1 GENERAL

Rail rapid transit (RRT), also known as rapid rail, subway, or elevated may be defined as a high-frequency, high-capacity rail system operating on exclusive, grade-separated right-of-way, whether at grade, in subway, or on elevated structure.

Rapid transit vehicles (RTV) are electrically powered and may operate in trains of up to eleven cars. High level platforms and multiple doors on each vehicle provide for rapid loading and unloading at stations. Fare collection is handled through turnstyles at stations.

Electric power is provided to the vehicle via a wayside power rail or from overhead catenary.

Rapid rail passenger volumes usually range between 10,000 and 30,000 per hour in each direction in peak periods. Maximum operating speeds range between 45 and 80 MPH.

Rapid rail systems were visited in Boston, Chicago, Cleveland, Philadelphia, San Francisco, Toronto, and Washington, D.C., to observe operations, inspect facilities, and gather cost information. Considerable recent cost information was available on many types of construction and several rail rapid vehicles.

A wide variance was noted in the costs of comparable projects, due to differences in construction standards, local conditions, cost format, and contract terms. Tables A-1 through A-9 in Appendix A show recent cost experience for new construction of major North American rapid transit systems. This information is the basis for the cost projections in the report.

5.2 RAIL RAPID TRANSIT CAPITAL COSTS

Based on the construction cost experiences of the rail systems studied, capital cost projections have been made to assist in estimating the capital cost to acquire right-of-way, construct

the fixed plant, and purchase vehicles for a new rapid transit system. The costs developed are for preliminary planning purposes.

To utilize the cost projections, the following minimum information is necessary:

1. The approximate delineation of projected route on a United States Department of Interior 1:24000 Geological Survey map, or its equivalent.
2. Field inspection of the route and inventory of principal physical features.
3. Traffic forecasts for the proposed system.
4. Preliminary transportation analysis to determine:
 - a. Train frequency and number of cars per train.
 - b. Total cars required.
 - c. Number of stations, approximate parking requirements, type of station facilities.

The terms used in preparing rail rapid system estimates are as follows:

Suburban Area - the separate, smaller communities that usually surround a city. They are of 20,000 to 50,000 population and are located just inside or just outside of the metropolitan area.

City Area - a city may defined as a spacially large, residentially dense and permanent settlement of socially heterogeneous individual. Cities contain a central area where major governmental, retail or commercial activities predominate.

Core Area - a small area located within the principal part of the city. That portion of the total community which bears the city name. It contains the most dense business area and usually resorts to high-rise construction to provide adequate space.

At Grade - construction on the existing ground, graded as necessary to provide a uniform alignment and profile. It is bridged over waterways, railroads, and highways.

Elevated - a continuous above-ground supporting structure. It can be built of sloped earth, retained earth, concrete or steel structure or a combination of each. It provides for continuous grade separation.

Depressed - a continuous way constructed below the existing ground. It can be sloped or retained-cut, cut-and-cover tunnel built of concrete or steel or both. It provides continuous grade separation.

Tunnel - (bored or tube) an underground way bored through earth or rock, usually at considerable depths below the surface. It may also be sunken tube placed in a trench and backfilled for harbor and river crossings.

Route Construction - the grading, drainage, utilities and structures required to provide the supporting structure or subgrade for the guideway.

Guideway - the track structure in its final position, including ballast, ties, and rail, but not the power third rail or catenary. The estimate provides for a small percentage of direct fixation to bridge structures.

Signal - the train control system of electrical, trackside, controlled switches (interlocks) and on-board apparatus to control train operations.

Power - the traction power provided through electrification. It includes substation construction and the distribution system to vehicles along the right-of-way. Distribution may be by power rail or overhead catenary.

Stations - the entire, completed station complex, including the buildings, platforms, access, and parking areas, where applicable.

Yards - to store equipment when not in use. It includes grading, drainage, trackwork, power, buildings, light and fencing. Power is transmitted through a wayside power rail or overhead catenary.

Shops - to handle the running and major maintenances for the total fleet of cars from one operating line. Included are the shop tracks, supporting yard tracks, power, access, light, and fencing. Power for movement within the shop is provided by an

isolated power rail, a portable feeder cable or an auxiliary mechanical means.

Vehicles - rail rapid transit vehicle

5.3 RAIL RAPID TRANSIT COST PROJECTIONS

The following portion of this section contains the cost projections which make up a total rapid rail system, including purchase of vehicles. The cost projections give a "low" estimate and a "high" estimate, where applicable, and a criteria for scaling costs between the two extremes. Tables 5-1 through 5-3 list cost comparisons, and Table 5-4 shows train manning requirements.

ROUTE CONSTRUCTION COSTS PER ROUTE MILE OF DOUBLE TRACK
RAPID RAIL MODE
SUBURBAN AREAS
AT GRADE

<u>Item</u>	(1974 Dollars)	
	<u>Low</u>	<u>High</u>
¹ Grading 1	\$ 250,000	\$ 500,000
² Grading 2	500,000	1,250,000
¹ Drainage 1	20,000	90,000
² Drainage 2	40,000	160,000
Utilities	40,000	100,000
Structures	600,000	1,800,000
Traffic Handling	60,000	150,000
Demolition	70,000	210,000
Fences	<u>110,000</u>	<u>110,000</u>
¹ Total 1	\$1,150,000	\$2,960,000
² Total 2	\$1,420,000	\$3,780,000

CRITERIA FOR SCALING COSTS

By visual observation, determine the percent of Dry Earth, Wetland and Exposed Rock and count the Highways, Railroads, Rivers, Small Streams and Existing Buildings for each mile of the proposed route, and proportion these quantities to the Low and High costs and quantities shown.

<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Grading 1	100% Dry Earth	20% Rock or Wetland
² Grading 2	100% Dry Earth	30% Rock or Wetland
¹ Drainage 1	2 Stream Crossings	6 Stream Crossings
² Drainage 2	2 Stream Crossings	6 Stream Crossings
Utilities	2 Highway Crossings	5 Highway Crossings
Structures	2 Hwy, RR or Rivers	6 Hwy, RR or Rivers
Traffic Handling	2 Hwy or RR Crossings	5 Hwy or RR Crossings
Demolition	³ 10 Single Dwellings	³ 30 Single Dwellings

¹Use Grading 1 and Drainage 1 for level to rolling terrain.

²Use Grading 2 and Drainage 2 for rolling to rough terrain.

³Convert multiple dwelling, commercial and industrial buildings into equivalent single dwellings by area up to three floors in height, then multiply accordingly for additional floors.

ROUTE CONSTRUCTION COSTS PER ROUTE MILE OF DOUBLE TRACK
RAPID RAIL MODE
SUBURBAN AREAS
ELEVATED

(1974 Dollars)

<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Grading 1	\$ 200,000	\$ 450,000
² Grading 2	400,000	700,000
¹ Drainage 1	20,000	75,000
² Drainage 2	30,000	120,000
Utilities	40,000	100,000
Elevated Structure	2,000,000	6,000,000
Other Structures	300,000	900,000
Traffic Handling	80,000	200,000
Demolition	70,000	210,000
Fences	110,000	110,000
	<u>1Total 1</u>	<u>\$8,045,000</u>
	<u>2Total 2</u>	<u>\$8,340,000</u>

CRITERIA FOR SCALING COSTS

By visual observation, determine the percent of Elevated Structure, Dry Earth, Wetland and Exposed Rock and count the Highways, Railroads, Rivers, Small Streams and Existing Buildings for each mile of the proposed route, and proportion these quantities to the Low and High costs and quantities shown.

<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Grading 1	100% Dry Earth	10% Rock
² Grading 2	100% Dry Earth	20% Rock
¹ Drainage 1	1 Stream Crossing	3 Stream Crossings
² Drainage 2	1 Stream Crossing	3 Stream Crossings
Utilities	2 Highway Crossings	5 Highway Crossings
Elevated Structure	1000 LF Per Mile	3000 LF Per Mile
Other Structures	1 Hwy, RR or River	3 Hwy, RR or Rivers
Traffic Handling	2 Hwy or RR Crossings	5 Hwy or RR Crossings
Demolition	³ 10 Single Dwellings	³ 30 Single Dwellings

¹Use Grading 1 and Drainage 1 for level to rolling terrain.

²Use Grading 2 and Drainage 2 for rolling to rough terrain.

³Convert multiple dwelling, commercial and industrial buildings into equivalent single dwellings by area up to three floors in height, then multiply accordingly for additional floors.

ROUTE CONSTRUCTION COSTS PER ROUTE MILE OF DOUBLE TRACK

RAPID RAIL MODE

SUBURBAN AREAS

DEPRESSED OPEN RETAINED CUT

(1974 Dollars)

<u>Item</u>	\$	<u>Low</u>	<u>High</u>
¹ Grading 1		925,000	\$ 1,900,000
² Grading 2		1,400,000	2,750,000
Drainage		100,000	300,000
Utilities		120,000	300,000
Concrete Box		2,500,000	7,500,000
Other Structures		300,000	900,000
Traffic Handling		80,000	200,000
Demolition		70,000	210,000
Fences		110,000	110,000
	¹ Total 1	\$4,205,000	\$11,420,000
	² Total 2	\$4,680,000	\$12,270,000

CRITERIA FOR SCALING COST

By visual observation, determine the percent of Concrete Box, Structure, Dry Earth, Wetland and Exposed Rock and count the Highways, Railroads, Rivers and Existing Buildings for each mile of the proposed route and proportion these quantities to the Low and High costs and quantities shown

<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Grading 1	100% Dry Earth	10% Rock
² Grading 2	100% Dry Earth	20% Rock
Drainage	1000 Feet Per Mile	3000 Feet Per Mile
Utilities	2 Highway Crossings	5 Highway Crossings
Concrete Box	1000 Feet Per Mile	3000 Feet Per Mile
Other Structures	1 Hwy, RR or River	3 Hwy, RR or Rivers
Traffic Handling	2 Hwy or RR Crossings	5 Hwy or RR Crossings
Demolition	³ 10 Single Dwellings	³ 30 Single Dwellings

¹Use Grading 1 for level to rolling terrain.

²Use Grading 2 for rolling to rough terrain.

³Convert multiple dwelling, commercial and industrial buildings into equivalent single dwellings by area up to three floors in height, then multiply accordingly for additional floors.

ROUTE CONSTRUCTION COSTS PER ROUTE MILE OF DOUBLE TRACK
RAPID RAIL MODE
CITY AND CORE AREAS
ELEVATED

(1974 Dollars)

<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Utilities 1	\$ 200,000	\$ 400,000
² Utilities 2	500,000	500,000
¹ Traffic Handling 1	500,000	1,000,000
² Traffic Handling 2	800,000	800,000
¹ Demolition 1	1,000,000	2,500,000
² Demolition 2	0	0
Grading	750,000	750,000
Elevated Structure	<u>12,500,000</u>	<u>12,500,000</u>
¹ Total 1	\$14,950,000	\$17,150,000
² Total 2	\$14,550,000	\$14,550,000

CRITERIA FOR SCALING COSTS

By visual observation, count the Highways, Railroads and Existing Buildings for each mile of the proposed route, and proportion these quantities to the Low and High costs and quantities shown.

<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Utilities 1	10 Hwy or RR Crossings	20 Hwy or RR Crossings
¹ Traffic Handling 1	10 Hwy or RR Crossings	20 Hwy or RR Crossings
¹ Demolition 1	³ 100 Single Dwellings	³ 250 Single Dwellings
¹ Use Utilities 1, Traffic Handling 1 and Demolition 1 when the proposed route is located between parallel streets.		
² Use Utilities 2, Traffic Handling 2 and Demolition 2 when the proposed route is located in a street right-of-way.		
³ Convert multiple dwelling, commercial and industrial buildings into equivalent single dwellings by area up to three floors in height, then multiply accordingly for additional floors.		

ROUTE CONSTRUCTION COSTS PER ROUTE MILE OF DOUBLE TRACK
RAPID RAIL MODE
CITY AND CORE AREAS
DEPRESSED-CUT AND COVER TUNNEL
(1974 Dollars)

<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Utilities 1	\$ 600,000	\$ 1,200,000
² Utilities 2	3,000,000	3,000,000
¹ Traffic Handling 1	2,200,000	4,400,000
² Traffic Handling 2	2,700,000	5,400,000
¹ Demolition 1	1,000,000	2,500,000
² Demolition 2	0	0
Grading	11,630,000	11,630,000
Drainage	500,000	500,000
Concrete Box Structure	13,200,000	13,200,000
¹ Total 1	\$29,130,000	\$33,430,000
² Total 2	\$31,030,000	\$33,730,000

CRITERIA FOR SCALING COSTS

By visual observation count the Highways, Railroads and Existing Buildings for each mile of the proposed route and proportion these quantities to the Low and High costs and quantities shown.

<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Utilities 1	10 Hwy or RR Crossings	20 Hwy or RR Crossings
¹ Traffic Handling 1	10 Hwy or RR Crossings	20 Hwy or RR Crossings
¹ Traffic Handling 2	10 Hwy or RR Crossings	20 Hwy or RR Crossings
¹ Demolition 1	³ 100 Single Dwellings	³ 250 Single Dwellings

¹Use Utilities 1, Traffic Handling 1 and Demolition 1 when the proposed route is located between parallel streets.

²Use Utilities 2, Traffic Handling 2 and Demolition 2 when the proposed route is located in a street right-of-way.

³Convert multiple dwelling, commercial and industrial buildings, into equivalent single dwellings by area up to three floors in height, then multiply accordingly for additional floors.

ROUTE CONSTRUCTION COSTS PER ROUTE MILE OF DOUBLE TRACK
RAPID RAIL MODE
SUBURBAN, CITY AND CORE AREAS
TUNNEL OTHER THAN CUT & COVER

(1974 Dollars)

<u>Type</u>	<u>Cost Per Mile</u>
Rock Tunnel	\$10,000,000 - \$20,000,000
Earth Tunnel	\$15,000,000 - \$30,000,000
Sunken Tube	c. \$50,000,000

There is substantial variance in the cost of non-cut and cover tunneling which cannot be quantified without detailed investigation of conditions, not normally available in preliminary planning stages. A major factor in tunneling costs is the length of the tunnel as the cost of establishing the tunnel face is substantial and must be apportioned over the length. For these reasons, if tunnel construction is a major factor in system cost, a detailed investigation is necessary.

GUIDEWAY CONSTRUCTION COSTS PER ROUTE MILE OF DOUBLE TRACK
RAPID RAIL MODE
SUBURBAN, CITY AND CORE AREAS
AT GRADE AND GRADE-SEPARATED

<u>Item</u>	(1974 Dollars)		
	<u>Suburban</u>	<u>City</u>	<u>Core</u>
¹ Track Structure 1	\$675,000	\$ 883,000	\$ 970,000
² Track Structure 2	742,500	819,000	900,000
¹ Special Trackwork 1	75,000	117,000	130,000
² Special Trackwork 2	<u>82,500</u>	<u>91,000</u>	<u>100,000</u>
¹ Total 1	\$750,000	\$1,000,000	\$1,100,000
² Total 2	\$825,000	\$ 910,000	\$1,000,000

¹Use Total 1 Costs for At-Grade Construction. City and Core Costs include continuous Girder Rail and Ballast Fill.

²Use Total 2 Costs for Grade-Separated Construction.

SIGNAL AND COMMUNICATION CONSTRUCTION COSTS PER ROUTE MILE OF
DOUBLE TRACK
RAPID RAIL MODE
SUBURBAN, CITY AND CORE AREAS
AT GRADE & GRADE-SEPARATED

<u>Item</u>	<u>Unit</u>	(1974 Dollars)	
		<u>Low</u>	<u>High</u>
Wayside ATC 1	Route Mile	\$ 450,000	\$ 650,000
Wayside ATC 2	Route Mile	800,000	1,100,000
Supervisory Control 1	Route Mile	200,000	250,000
Supervisory Control 2	Route Mile	1,200,000	1,500,000
Communications	Route Mile	<u>35,000</u>	<u>45,000</u>
Total 1		\$ 685,000	\$ 945,000
Total 2		\$ 2,035,000	\$ 2,645,000
On-Board Equipment	Each Car	\$ 20,000	20,000
Storage Yard Control 1	Each Yard (100-150 Cars)	\$ 1,200,000	\$ 1,200,000
Storage Yard Control 2	Each Yard (100-150 Cars)	\$ 2,800,000	\$ 2,800,000
Storage Yard Control 3	Each Yard (100-150 Cars)	\$ 3,600,000	\$ 3,600,000
Storage Yard Control 4	Each Yard (100-150 Cars)	\$10,500,000	\$10,500,000

CRITERIA FOR SCALING COSTS

<u>Item</u>	<u>Low</u>	<u>High</u>
Wayside ATC 1 (without Speed Regulation)	15 Trains/Hr.	20 Trains/Hr.
Wayside ATC 2 (with Speed Regulation)	20 Trains/Hr.	30 Trains/Hr.
Supervisory Control 1 (manual Override) ¹	15 Trains/Hr.	20 Trains/Hr.
Supervisory Control 2 (Computer Override) ²	20 Trains/Hr.	30 Trains/Hr.
Communications	15 Trains/Hr.	30 Trains/Hr.
On-Board Equipment (Wayside ATC 2, only)	20 Trains/Hr.	30 Trains/Hr.
Storage Yard Control 1 (Push Button Control)		
Storage Yard Control 2 (Controlled Trailable Switches)		
Storage Yard Control 3 (Controlled Fully Interlocked)		
Storage Yard Control 4 (Controlled Fully ATC)		

ELECTRIFICATION CONSTRUCTION COSTS PER ROUTE MILE OF DOUBLE TRACK
RAPID RAIL MODE
SUBURBAN, CITY AND CORE AREAS
GRADE-SEPARATED

<u>Item</u>	(1974 Dollars)	
	<u>Low</u>	<u>High</u>
Third Rail 600 VDC, including substations	\$700,000	\$850,000

CRITERIA FOR SCALING COSTS

<u>Item</u>	<u>Low</u>	<u>High</u>
1. Operating Headway	15 Trains/Hr.	30 Trains/Hr.
2. Number of Cars/Train	4	10

LAND ACQUISITION COST PER ROUTE MILE OF DOUBLE TRACK
RAPID RAIL MODE
SUBURBAN, CITY AND CORE AREAS
AT GRADE AND GRADE-SEPARATED

(1974 Dollars)

<u>Area</u>	<u>Low</u>	<u>High</u>
Suburban	\$ 132,000	\$ 396,000
City	1,320,000	3,960,000
Core	2,640,00	7,920,000

CRITERIA FOR SCALING COSTS

Storage Yard areas range from 3 acres to 10 acres. Shop areas range from 4 acres to 12 acres. Parking lots range from 1 to 3 acres for small parking facilities to 5 to 15 acres for major parking facilities.

<u>Area</u>	<u>Low</u>	<u>High</u>
Suburban	\$0.25/SF	\$0.75/SF
City	2.50/SF	7.50/SF
Core	5.00/SF	15.00/SF

STATION CONSTRUCTION COST
RAPID RAIL MODE
SUBURBAN AREA
AT GRADE

<u>Item</u>	(1974 Dollars)	
	<u>Low</u>	<u>High</u>
¹ Parking 1	\$ -0-	\$ -0-
² Parking 2	115,000	575,000
³ Parking 3	230,000	1,150,000
¹ Access 1	100,000	500,000
² Access 2	244,000	1,220,000
³ Access 3	388,000	1,940,000
Platform	120,000	300,000
Station Facility	72,000	360,000
Awning	<u>160,000</u>	<u>400,000</u>
¹ Total 1	\$ 352,000	\$1,560,000
² Total 2	\$ 711,000	\$2,855,000
³ Total 3	\$ 970,000	\$4,150,000

CRITERIA FOR SCALING COST

<u>Item</u>	<u>Low</u>	<u>High</u>
² Parking 2	75 Automobiles	375 Automobiles
³ Parking 3	150 Automobiles	750 Automobiles
¹ Access 1	360 People	1800 People
² Access 2	75 Automobiles	375 Automobiles
³ Access 3	150 Automobiles	750 Automobiles
Platform	4-Car Train	10-Car Train
Station Facilities	360 People	1800 People
Awning	4-Car Train	10-Car Train

¹Use Parking 1 and Access 1 for No Parking.

²Use Parking 2 and Access 2 for Limited Parking.

³Use Parking 3 and Access 3 for Major Parking.

STATION CONSTRUCTION COST
RAPID RAIL MODE
SUBURBAN AREA
ELEVATED

<u>Item</u>	(1974 Dollars)	
	<u>Low</u>	<u>High</u>
¹ Parking 1	-0-	-0-
² Parking 2	\$ 115,000	\$ 575,000
³ Parking 3	230,000	1,150,000
¹ Access 1	150,000	750,000
² Access 2	350,000	1,120,000
³ Access 3	490,000	2,450,000
Platform	320,000	800,000
Station Facility	72,000	360,000
Awning	<u>160,000</u>	<u>400,000</u>
¹ Total 1	\$ 702,000	\$2,310,000
² Total 2	\$1,017,000	\$3,255,000
³ Total 3	\$1,272,000	\$5,160,000

CRITERIA FOR SCALING COSTS

<u>Item</u>	<u>Low</u>	<u>High</u>
² Parking 2	75 Automobiles	375 Automobiles
³ Parking 3	150 Automobiles	750 Automobiles
¹ Access 1	360 People	1800 People
² Access 2	75 Automobiles	375 Automobiles
³ Access 3	150 Automobiles	750 Automobiles
Platform	4-Car Train	10-Car Train
Station Facility	360 People	1800 People
Awning	4-Car Train	10-Car Train

¹Use Parking 1 and Access 1 for No Parking

²Use Parking 2 and Access 2 for Limited Parking.

³Use Parking 3 and Access 3 for Major Parking.

STATION CONSTRUCTION COST
RAPID RAIL MODE
SUBURBAN AREA
DEPRESSED-OPEN RETAINED CUT

<u>Item</u>	(1974 Dollars)	
	<u>Low</u>	<u>High</u>
¹ Parking 1	-0-	-0-
² Parking 2	\$ 115,000	\$ 575,000
³ Parking 3	230,000	1,150,000
¹ Access 1	200,000	1,000,000
² Access 2	350,000	1,120,000
³ Access 3	490,000	2,450,000
Platform	400,000	1,000,000
Station Facility	105,000	525,000
Awning	<u>160,000</u>	<u>400,000</u>
¹ Total 1	\$ 865,000	\$2,925,000
² Total 2	\$1,130,000	\$3,620,000
³ Total 3	\$1,385,000	\$5,525,000

CRITERIA FOR SCALING COSTS

<u>Item</u>	<u>Low</u>	<u>High</u>
² Parking 2	75 Automobiles	375 Automobiles
³ Parking 3	150 Automobiles	750 Automobiles
¹ Access 1	360 People	1800 People
² Access 2	75 Automobiles	375 Automobiles
³ Access 3	150 Automobiles	750 Automobiles
Platform	4-Car Train	10-Car Train
Station Facility	360 People	1800 People
Awning	4-Car Train	10-Car Train

¹Use Parking 1 and Access 1 for No Parking.

²Use Parking 2 and Access 2 for Limited Parking.

³Use Parking 3 and Access 3 for Major Parking.

STATION CONSTRUCTION COSTS
RAPID RAIL MODE
CITY AREAS
ELEVATED

<u>Item</u>	(1974 Dollars)	
	<u>Low</u>	<u>High</u>
Platform	\$ 320,000	\$ 800,000
Station Facility	120,000	600,000
Access	350,000	1,050,000
Awning	<u>160,000</u>	<u>400,000</u>
Total	\$ 950,000	\$2,850,000

CRITERIA FOR SCALING COSTS

<u>Item</u>	<u>Low</u>	<u>High</u>
Platform	4-Car Train	10-Car Train
Station Facility	600 People	3000 People
Access	600 People	3000 People
Awning	4-Car Train	10-Car Train

STATION CONSTRUCTION COSTS
RAPID RAIL MODE
CITY AREA
DEPRESSED-CUT AND COVER TUNNEL

<u>Item</u>	<u>Low</u>	<u>High</u>
Platform	\$ 704,000	\$1,760,000
Station Facility	250,000	1,250,000
Access	<u>400,000</u>	<u>1,200,000</u>
Total	\$1,354,000	\$4,210,000

CRITERIA FOR SCALING COSTS

<u>Item</u>	<u>Low</u>	<u>High</u>
Platform	4 Car Train	10 Car Train
Station Facility	600 People	3000 People
Access	600 People	3000 People

STATION CONSTRUCTION COSTS
RAPID RAIL MODE
CORE AREAS
ELEVATED

(1974 Dollars)

<u>Item</u>	<u>Low</u>	<u>High</u>
Platform	\$ 320,000	\$ 800,000
Station Facility	360,000	1,800,000
Access	550,000	1,650,000
Awning	<u>160,000</u>	<u>400,000</u>
Total	\$1,390,000	\$4,650,000

CRITERIA FOR SCALING COSTS

<u>Item</u>	<u>Low</u>	<u>High</u>
Platform	4-Car Train	10-Car Train
Station Facility	1800 People	9000 People
Access	1800 People	9000 People
Awning	4-Car Train	10-Car Train

STATION CONSTRUCTION COSTS
RAPID RAIL MODE
CORE AREAS
DEPRESSED-CUT AND COVER TUNNEL

(1974 Dollars)

<u>Item</u>	<u>Low</u>	<u>High</u>
Platform	\$ 800,000	\$ 2,000,000
Station Facility	3,200,000	7,000,000
Access	<u>1,000,000</u>	<u>3,000,000</u>
Total	\$5,000,000	\$12,000,000

1. Does not include costs associated with the construction of the tunnel.

CRITERIA FOR SCALING COSTS

<u>Item</u>	<u>Low</u>	<u>High</u>
Platform	4-Car Train	10-Car Train
Station Facility	1800 People	9000 People
Access	1800 People	9000 People

STORAGE YARD CONSTRUCTION COSTS
RAPID RAIL MODE
SUBURBAN OR CITY AREAS
AT GRADE

(1974 Dollars)

<u>Item</u>	<u>Low</u>	<u>High</u>
Grading	\$ 340,000	\$ 1,120,000
Drainage	70,000	350,000
Utilities	80,000	400,000
Track	1,760,000	5,000,000
Power	1,060,000	5,800,000
Fence	30,000	100,000
Buildings	<u>70,000</u>	<u>200,000</u>
Total	\$3,410,000	\$12,970,000

CRITERIA FOR SCALING COSTS

<u>Item</u>	<u>Low</u>	<u>High</u>
Fleet	60 Cars	300 Cars

SHOP CONSTRUCTION COSTS
RAPID RAIL MODE
SUBURBAN AND CITY AREAS
AT GRADE

<u>Item</u>	(1974 Dollars)	
	<u>Low</u>	<u>High</u>
Grading	\$ 250,000	\$ 1,250,000
Drainage	150,000	750,000
Utilities	200,000	1,000,000
Shop Building	5,400,000	16,200,000
Shop Track	720,000	3,600,000
Support Yard Track	370,000	1,850,000
Power	585,000	2,925,000
Fence	<u>30,000</u>	<u>150,000</u>
Total	\$7,705,000	\$27,725,000

CRITERIA FOR SCALING COSTS

<u>Item</u>	<u>Low</u>	<u>High</u>
Fleet	60 Cars	300 Cars

VEHICLE ACQUISITION COST
RAPID RAIL MODE
SUBURBAN, CITY AND CORE AREAS
AT GRADE AND GRADE-SEPARATED

(1974 Dollars)

Cost per vehicle (if ordered 1974) \$350,000 - \$550,000

5.4 OPERATING COSTS

Operating costs of seven rapid rail systems were obtained. Tables 5-1 through 5-3 show a summary of the results for 1973 (the latest year available). Table 5-4 lists the train manning requirements for the various rapid transit systems.

In 1974 dollars per car mile costs are as follows:

- a. The cost range for the seven systems is from \$1.10 to \$4.35 per car mile.
- b. If Boston is excluded (four-car trains with three-man crews by state law and unique equipment problems), the average cost is \$1.80 per car mile for the other six systems with revenue offsetting about 70% of the cost.
- c. If New York City is eliminated, the average cost of the remaining five systems is \$1.45 per car mile with revenues offsetting about 80% of the cost.

TABLE 5-1. RAIL RAPID TRANSIT 1973 OPERATING COST COMPARISONS

Operating Agency	Route Miles	Main Track Miles	No. of Vehicles	Car Miles	Revenues	Revenue Per Car Mile	Operating Expenses						Cost Per Car Mile
							M/W	M/E	Power	Transp.	Other	Total	
Boston MBTA	38.65	77.3	343	10,325,344	\$17,128,291	\$1.66	\$9,088,996	\$4,598,013	\$3,492,716	\$14,317,218	\$10,820,324	\$42,237,267	\$4.09
Chicago CTA	90.0	205.0	1094	48,726,796	47,628,334	0.98	8,027,923	9,539,719	5,095,795	29,721,570	18,575,111	70,960,118	1.46
Cleveland CTS	19.04	38.08	116	3,689,924	4,650,000	1.26	443,744	605,902	692,480	1,716,439	331,074	3,789,639	1.03
New York NYCTA ¹	231.7	709.6	6704	158,735,896	191,379,124	1.21	46,878,380	48,859,184	30,702,232	123,798,264	40,732,385	290,970,443	1.83
Philadelphia PATCO	14.50	29.0	75	4,084,498	5,797,089	1.42	895,571	1,258,338	794,458	1,769,047	882,062	5,590,476	1.37
Philadelphia SEPTA Market-Frankford	12.80	25.6	266	9,075,176	20,139,690	1.41	2,076,699	1,156,704	1,260,326	4,718,051		9,211,780	1.02
Philadelphia SEPTA Broad-Ridge	11.50	23.0	223	5,249,144			1,677,668	1,242,111	897,734	4,025,711		7,843,224	1.49

¹Last 6 months of 1973

TABLE 5-2. RAIL RAPID TRANSIT POWER AND TRANSPORTATION EXPENSE COMPARISONS

1973 POWER EXPENSE

Operating Agency	Car Miles	Power Expense	Cost Per Car Mile
Boston MBTA	10,325,344	\$ 3,492,716	\$0.338
Chicago CTA	48,726,796	5,095,795	0.105
Cleveland CTS	3,689,924	692,480	0.188
New York NYCTA ¹	158,735,896	30,702,232	0.193
Philadelphia PATCO	4,084,498	795,458	0.195
Philadelphia SEPTA Market-Frankford	9,075,176	1,260,326	0.139
Philadelphia SEPTA Broad-Ridge	5,249,144	897,734	0.171

¹Last 6 months of 1973 used to project entire year

1973 TRANSPORTATION EXPENSE

Operating Agency	Transportation Cost	Car Miles	Transportation Cost/Car Mile
Boston MBTA	\$14,317,218	\$10,325,413	\$1.39
Chicago CTA	29,721,570	48,726,796	0.61
Cleveland CTS	1,716,439	3,689,847	0.47
New York NYCTA ¹	247,596,530	317,471,792	0.78
Philadelphia PATCO	1,759,047	4,084,498	0.43
Philadelphia SEPTA Market-Frankford	4,718,051	9,075,176	0.52
Philadelphia SEPTA Broad-Ridge	4,025,711	5,249,144	0.77

¹Last 6 months of 1973 used to project entire year

TABLE 5-3. RAIL RAPID TRANSIT MAINTENANCE EXPENSE COMPARISONS

1973 MAINTENANCE OF WAY EXPENSE

Operating Agency		Route Miles	Main Track Miles	M/W Expense	Cost Per Car Mile	Cost Per Route Mile	Cost Per Main Track Mile
Boston	MBTA	38.65	77.3	\$ 9,008,996	\$0.87	\$233,092	\$116,546
Chicago	CTA	90.0	205.0	8,027,923	0.17	89,199	39,160
Cleveland	CTS	19.04	38.08	443,744	0.12	23,306	11,653
New York	NYCTA ¹	231.7	709.6	93,756,760	0.30	404,647	132,126
Philadelphia	PATCO	14.5	29.0	895,571	0.22	61,764	30,882
Philadelphia Market-Frankford	SEPTA	11.5	23.0	1,677,668	0.32	145,884	72,942
Philadelphia Broad-Ridge	SEPTA	12.8	25.6	2,076,699	0.23	162,242	81,121

¹ Last 6 months of 1973 used to project entire year.

1973 MAINTENANCE OF EQUIPMENT EXPENSE

Operating Agency		Cars	M/E Expense	Cost Per Car	Average Miles/Car	Cost Per Car Mile
Boston	MBTA	343	\$ 4,598,013	\$13,405	\$30,104	\$0.45
Chicago	CTA	1094	9,539,719	8,720	44,540	0.20
Cleveland	CTS	116	605,902	5,223	31,810	0.16
New York	NYCTA ¹	6704	97,718,368	14,576	47,356	0.31
Philadelphia	PATCO	75	1,258,338	16,778	54,460	0.31
Philadelphia Market-Frankford	SEPTA	266	1,156,704	4,349	34,117	0.13
Philadelphia Broad-Ridge	SEPTA	223	1,242,111	5,570	23,539	0.24

¹ Last 6 months of 1973 used to project entire year.

TABLE 5-4. TRAIN MANNING REQUIREMENT COMPARISONS

OPERATING AGENCY		MANNING REQUIREMENTS
Boston	MBTA	1 Operator plus 1 Guard for every two cars in train
Chicago	CTA	1 Operator plus 1 Conductor per train
New York	NYCTA	1 Operator plus 1 Conductor per train
Philadelphia	PATCO	1 Operator per train
Philadelphia	SEPTA	1 Operator plus 1 Conductor per train
San Francisco	BART	1 Attendant per train

6 COMMUTER RAIL REHABILITATION AND OPERATING COSTS

6.1 GENERAL

A commuter rail system is defined as an urban rail passenger service, typically operated by intercity railroads within 10 to 60 miles of central cities.

Equipment may be diesel or electric locomotives, hauling passenger coaches, self-propelled rail diesel cars (RDC), or electric self-propelled multiple unit vehicles. Where the equipment is electrically powered, current is collected from wayside power rail or overhead catenary.

The right-of-way is exclusive, but not necessarily grade-separated. Commuter service usually shares the same facilities with intercity freight and passenger service. Operations are governed by normal railroad procedures and work rules.

Maximum operating speeds range up to 80 mph. Passenger volumes usually vary from under 1,000 to 20,000 passengers per hour, per track.

6.2 COMMUTER RAIL CAPITAL COSTS (REHABILITATION ONLY)

Cost projections have been prepared for upgrading and/or double tracking existing rail lines for commuter service. The costs developed are for preliminary planning purposes. The following is a brief description of terms used in the commuter rail cost projection estimates:

Route Construction - clearing and reshaping the existing right-of-way, rebuilding, but not eliminating, grade crossings; and repairing, but not rebuilding, existing culverts, overhead bridges, and track bridges, in the case of an existing double track railroad. Rebuilding overhead bridges, repairing, but not rebuilding, the existing track span, and adding a track span in the case of an existing single track railroad.

Estimates are based on all work being related to the existing railroad grade with no differential between suburban, city, or

core areas, because in early railroad construction, grade separation was achieved through embankment construction in heavily congested areas and retained embankment, or cut in the more confining areas.

Major structures that have deteriorated beyond repair or major structures that need major repairs to restore normal operation require individual analysis and are not included in this report.

Guideway - upgrading existing track provides for new, welded rail and fastenings. New turnouts and 50-percent new, treated timber ties, with two-thirds the stone ballast, used in estimating new track. The estimate provides for upgrading two tracks, or upgrading one track and building a second track new.

Signal - new signal system estimate is provided in the cost projection estimate. If a signal system exists, no cost should be included for this item.

Power - new overhead catenary, high-voltage, AC system for electric propulsion equipment only. No power costs should be used for self-propelled or conventional, engine-hauled coaches.

Station - provides for a new enclosed, heated, lighted space with awnings, or renovations to existing structures, with signs, area lighting, and communications. It also provides for curbing and resurfacing existing and for extending or building new platforms, as required, to serve longer trains and double track, where one track currently exists. All station facilities are assumed to be at grade. Improved drainage, lighting and surfacing of existing parking area is applicable to suburban areas only. No provision is made for controlled parking.

Yards - estimated costs provide for replacement of 20 percent of the rail, 50 percent of the ties, 33 percent of the turnout materials, and for new gravel ballast. It also provides for modifying, but not rebuilding, the drainage; and for new fencing and new crew quarters.

Shop - the shop upgrading costs provide for extensive renovation to an existing railroad shop, including floor and track work,

replacement of machinery and equipment, repairs to doors, windows, and roofing; painting and improved lighting, heating, and workmen's facilities. It does not include replacement of any of the building shell or its foundation, or any major partitioning costs.

The commuter rail shop estimate also provides for upgrading fueling facilities. It does not provide for building or relocating major fuel handling and storage facilities.

6.3 COMMUTER RAIL UPGRADING COST PROJECTIONS

The following portion of this section contains the cost projections for upgrading the existing railroad system, including purchase of vehicles. The last of the projected listings gives actual costs of recently purchased commuter cars. The cost projections give a "low" estimate and a "high" estimate, where applicable, and a criteria for scaling costs between the two extremes. Table 6-1 shows vehicle cost comparisons, Table 6-2 gives operating cost comparisons, and Table 6-3 lists the transportation and maintenance expense comparisons.

6.4 OPERATING COSTS

Due to the lack of uniformity of the public subsidy agreements with railroads, comparative commuter operating costs based on contract agreements with public agencies are not relevant. The Annual Report of Class I Railroads to the Interstate Commerce Commission apportions costs on a uniform basis between freight and passenger service. Operating and maintenance costs from the Annual Report to the Interstate Commerce Commission for four commuter rail systems are shown in Tables 6-2 and 6-3. It should be noted that the maintenance-of-way expense is apportioned between freight and passenger service and varies substantially with the amount of freight service sharing common costs. Table 6-4 lists the train manning requirements for selected commuter rail systems.

In 1974 dollars per car mile, costs are as follows:

- a. The cost range for the four systems is from \$1.90 to \$4.00 per car mile.
- b. If the Boston and Maine is excluded (short trains and short haul), the average cost is \$1.95 per car mile for the other three systems, with revenue offsetting about 75 percent of the cost.

EXISTING ROUTE UPGRADING COSTS PER ROUTE MILE OF DOUBLE TRACK
COMMUTER RAIL MODE
SUBURBAN, CITY & CORE AREAS
AT GRADE

(1974 Dollars)

<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Grading 1	\$ 170,000	\$ 270,000
² Grading 2	325,000	425,000
¹ Drainage 1	42,000	46,000
² Drainage 2	50,000	70,000
¹ Overhead Bridges 1	-0-	-0-
² Overhead Bridges 2	200,000	1,000,000
¹ Track Bridges 1	-0-	-0-
² Track Bridges 2	250,000	1,250,000
¹ Highway Traffic Handling 1	-0-	-0-
² Highway Traffic Handling 2	10,000	30,000
¹ Railroad Traffic Handling 1	10,000	10,000
² Railroad Traffic Handling 2	45,000	117,000
¹ Utilities 1	-0-	-0-
² Utilities 2	40,000	100,000
Fences	<u>110,000</u>	<u>110,000</u>
¹ Total 1	\$ 332,000	\$ 436,000
² Total 2	\$1,030,000	\$3,102,000

CRITERIA FOR SCALING COSTS

By visual observations, count the number of Highway Grade Crossings, Existing Cross Drains, Overhead Bridges and Track Bridges for each mile of the existing railroad route, and proportion these quantities to the Low and High costs and quantities shown.

<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Grading 1	0 Hwy Grade Cross.	4 Hwy Grade Cross.
² Grading 2	0 Hwy Grade Cross.	4 Hwy Grade Cross.
¹ Drainage 1	2 Extg. Cross Drains	6 Extg. Cross Drains
² Drainage 2	2 Extg. Cross Drains	6 Extg. Cross Drains
² Overhead Bridge 2	1 Bridge Over RR	5 Bridges Over RR
² Track Bridges 2	1 Brdg. Supporting RR	5 Brdgs. Supporting RR
² Hwy Traffic Handling 2	2 Hwy Brdgs. or Grade Cross.	6 Hwy Brdgs. or Grade Cross.
² RR Traffic Handling 2	2 Hwy or Track Brdgs.	6 Hwy or Track Brdgs.
² Utilities 2	2 Hwy Over or Under RR	5 Hwy Over or Under RR

¹Use Grading 1, Drainage 1 for existing two-track roadbed.

²Use Grading 2, Drainage 2 Overhead Bridges 2, Track Bridges 2, Highway Traffic Handling 2, Railroad Traffic Handling 2, and Utilities 2 for double tracking existing one-track roadbed.

EXISTING GUIDEWAY UPGRADING COSTS PER ROUTE MILE OF DOUBLE TRACK
COMMUTER RAIL MODE
SUBURBAN, CITY AND CORE AREAS
AT GRADE

(1974 Dollars)

<u>Item</u>	<u>Suburban</u>	<u>City</u>	<u>Core</u>
¹ Track Structure 1	\$505,000	\$555,500	\$612,000
² Track Structure 2	590,000	650,000	714,000
¹ Special Trackwork 1	75,000	82,500	91,000
² Special Trackwork 2	<u>75,000</u>	<u>82,500</u>	<u>91,000</u>
¹ Total 1	\$580,000	\$638,000	\$703,000
² Total 2	\$665,000	\$732,500	\$805,000

¹Use Total 1 Costs to upgrade two existing tracks.

²Use Total 2 Costs to upgrade one existing track and build one new track.

SIGNAL AND COMMUNICATION UPGRADING COSTS PER
ROUTE MILE OF DOUBLE TRACK
COMMUTER RAIL MODE
SUBURBAN, CITY AND CORE AREAS
AT GRADE

<u>Item</u>	<u>Unit</u>	(1974 Dollars)	
		<u>Low</u>	<u>High</u>
Wayside Signal Apparatus 1	Route Mile	\$ 40,000	\$ 60,000
Wayside Signal Apparatus 2	Route Mile	150,000	200,000
Centralized Interlocking Control	Route Mile	25,000	40,000
Communications	Route Mile	<u>10,000</u>	<u>25,000</u>
Total 1		\$ 75,000	\$125,000
Total 2		\$185,000	\$265,000
Grade Crossing Protection	Ea. Xing	\$ 45,000	\$ 45,000

CRITERIA FOR SCALING COSTS

<u>Item</u>	<u>Low</u>	<u>High</u>
Wayside Signal Apparatus 1 (Non-Electrified)	2 Trains/Hr.	20 Trains/Hr.
Wayside Signal Apparatus 2 (AC-Electrified)	2 Trains/Hr.	20 Trains/Hr.
Centralized Interlocking Control	2 Trains/Hr.	20 Trains/Hr.
Communications	2 Trains/Hr.	20 Trains/Hr.

ELECTRIFICATION UPGRADING COSTS PER ROUTE MILE OF DOUBLE TRACK
COMMUTER RAIL MODE
SUBURBAN, CITY AND CORE AREAS
AT GRADE

(1974 Dollars)

<u>Item</u>	<u>Low</u>	<u>High</u>
O.H. Catenary - High-Voltage AC (incl. sub-stations)	\$225,000	\$350,000

CRITERIA FOR SCALING COSTS

<u>Item</u>	<u>Low</u>	<u>High</u>
1. Operating Headways	4 Trains/Hr.	20 Trains/Hr.
2. No. of Cars (if not Self-Propelled)	4	12

LAND ACQUISITION COST PER ROUTE MILE OF DOUBLE TRACK
COMMUTER RAIL MODE
SUBURBAN, CITY AND CORE AREAS
AT GRADE AND GRADE-SEPARATED

(1974 Dollars)

<u>Area</u>	<u>Low</u>	<u>High</u>
Suburban	\$ 132,000	\$ 396,000
City	\$ 1,320,000	\$3,960,000
Core	\$2,640,000	\$7,920,000

CRITERIA FOR SCALING COSTS

Storage Yard Areas range from 3 to 10 acres. Shop areas range from 4 to 12 acres. Parking lots range from 1 to 3 acres for small parking facilities, to 5 to 15 acres for major parking facilities.

<u>Area</u>	<u>Low</u>	<u>High</u>
Suburban	\$0.25/SF	\$0.75/SF
City	2.50/SF	7.50/SF
Core	5.00/SF	15.00/SF

UPGRADE EXISTING STATION COSTS
COMMUTER RAIL MODE
SUBURBAN AREAS
AT GRADE

(1974 Dollars)

<u>Item</u>	<u>Low</u>	<u>High</u>
Platforms	\$ 8,000	\$ 40,000
Station Facility	7,500	37,500
Parking	36,000	180,000
Awning	<u>72,000</u>	<u>360,000</u>
Total	\$ 123,500	\$ 617,000

CRITERIA FOR SCALING COST

<u>Item</u>	<u>Low</u>	<u>High</u>
Platforms	2-Car Train	10-Car Train
Station Facilities	150 People	750 People
Parking	30 Automobiles	150 Automobiles
Awning	2-Car Train	10-Car Train

UPGRADE EXISTING STATION COSTS
COMMUTER RAIL MODE
CITY AREAS
AT GRADE

<u>Item</u>	(1974 Dollars)	
	<u>Low</u>	<u>High</u>
Platforms	\$ 8,000	\$ 40,000
Station Facilities	15,000	75,000
Awning	<u>72,000</u>	<u>360,000</u>
Total	\$ 95,000	475,000

CRITERIA FOR SCALING COST

<u>Item</u>	<u>Low</u>	<u>High</u>
Platforms	2-Car Train	10-Car Train
Station Facilities	300 People	1500 People
Awning	2-Car Train	10-Car Train

UPGRADE EXISTING STATION COSTS
COMMUTER RAIL MODE
CORE AREAS
AT GRADE

(1974 Dollars)

<u>Item</u>	<u>Low</u>	<u>High</u>
Platforms	\$ 8,000	\$ 40,000
Station Facility	90,000	450,000
Awning	<u>72,000</u>	<u>360,000</u>
Total	\$ 170,000	\$ 850,000

CRITERIA FOR SCALING COST

<u>Item</u>	<u>Low</u>	<u>High</u>
Platform	2-Car Train	10-Car Train
Station Facilities	1800 People	9000 People
Awning	2-Car Train	10-Car Train

EXISTING STORAGE YARD UPGRADING COSTS
COMMUTER RAIL MODE
SUBURBAN, CITY AND CORE AREAS
AT GRADE

(1974 Dollars)

<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Power 1	\$ -0-	\$ -0-
² Power 2	170,500	1,195,000
Drainage	21,600	108,000
Track	225,000	1,125,000
Fence	15,000	50,000
Buildings	<u>36,000</u>	<u>110,000</u>
¹ Total 1	\$ 297,600	\$1,393,000
² Total 2	\$ 468,100	\$2,588,000

CRITERIA FOR SCALING COSTS

<u>Item</u>	<u>Low</u>	<u>High</u>
Fleet	20 Cars	100 Cars

¹Use Power 1 for yards with no existing electric propulsion service.
²Use Pow-r 2 for yards with existing electric propulsion service.

EXISTING SHOP UPGRADING COSTS
COMMUTER RAIL MODE
SUBURBAN, CITY AND CORE AREAS
AT GRADE

(1974 Dollars)

<u>Item</u>	<u>Low</u>	<u>High</u>
¹ Power 1	-0-	-0-
² Power 2	\$ 187,500	\$ 937,500
Drainage	90,000	450,000
Shop Building	495,000	1,458,000
Shop Track	180,000	900,000
Support Yard Track	92,500	462,500
Fence	<u>30,000</u>	<u>150,000</u>
¹ Total 1	\$ 887,500	\$3,420,500
² Total 2	\$1,075,000	\$4,358,000

CRITERIA FOR SCALING COST

<u>Item</u>	<u>Low</u>	<u>High</u>
Fleet	20 Cars	100 Cars

¹Use Power 1 for shops with no existing electric propulsion service.

²Use Power 2 for shops with existing electric propulsion service.

AVERAGE VEHICLE ACQUISITION COST
RAPID TRANSIT MODE
SUBURBAN, CITY AND CORE AREAS
AT GRADE AND GRADE-SEPARATED

(1974 Dollars)

Coach, Non-Powered	\$250,000
Diesel Locomotive	400,000
Electric Locomotive	750,000
Diesel, Self-Propelled	650,000
Electric, Self-Propelled	700,000

TABLE 6-1. COMMUTER RAIL VEHICLE COST COMPARISONS

Operating Agency	No. of Seats	Car Dimensions			Car Light Weight (lbs)	Max. Speed (mph)	Initial Accel. Rate (mph/s)	On-Brd. Cab-Sign. Or Speed Control	Type Propulsion	Year	Cost Per Car
		Length	Height	Width							
New York Long Island Railroad	— 120	85'-0"	12'-10½"	10'-6"	90,000	—	—	Yes	600V-DC	1967	M1—\$199,800
						100	2.1		Self-Propelled Cam Control	1968	M1— 206,470
						—	—			1971	M1— 299,950
New York PC—Harlem and Hudson	— 120	85'-0"	12'-10½"	10'-6"	90,000	—	—	No	600V-DC	1970	M1A—287,743
						100	2.1		Self-Propelled Cam Control	1971	M1A—295,650
						—	—			1972	M1A—312,080
New York PC—New Haven	118	85'-0"	14'-9"	10'-6"	M-2 130,000 M-2 cafe 132,000	—	—	Yes	600V-DC	1970	M2 —398,185
						(DC) 80	(DC) 1.6		11,000V-AC	1970	M2 cafe—417,168
						(AC) 100	(AC) 2.2		Self-Propelled Cam Control	1974	M2 —639,000
Philadelphia Reading	129	85'-0"	12'-8"	10'-6"	122,000	85	2.2	Yes	11,000V-AC Self-Propelled Cam Control	1974	394,930
Philadelphia Penn Central	129	85'-0"	12'-8"	10'-6"	119,000	85	2.2	Yes	11,000V-AC Self-Propelled Cam Control	1974	372,948
Toronto Canadian National	94	84'-10½"	12'-11"	10'-0"	RTC 85 67,600 RTC85SP 96,000	80	— 2.8	Yes	Diesel-Electric Locomotive Push, Pull or Self-Propelled	1975 ¹	RTC 85-245,000

¹ Date represents delivery (purchase year was 1974).

TABLE 6-2. COMMUTER RAIL 1973-1974 COST COMPARISONS

Operating Agency	Year	Route Miles	Main Track Miles	No. of Vehicles	Car Miles	Revenues	Revenue Per Car Mile	Operating Expenses				Cost Per Car Mile	
								M/W	M/E	Transp.	Other		Total
Boston and Maine Corp.	1974	158	262	84	2,955,000	\$ 5,411,000	\$1.83	\$ 611,000	\$2,963,000	\$ 7,518,000	\$ 631,000	\$11,723,000	\$3.97
The Central R.R. Co. of N.J.	1973	115	206	125	5,992,000	4,731,000	.79	1,224,000	2,129,000	6,369,000	1,289,000	11,011,000	1.84
Chicago and North Western Transportation Co.	1974	176	389	296	11,334,000	26,718,000	2.36	1,652,000	6,220,000	13,209,000	1,429,000	22,510,000	1.99
Erie Lackawanna Ry. Co.	1974	300	473	410	13,463,000	13,919,000	1.03	2,492,000	5,612,000	15,380,000	1,839,000	25,323,000	1.88

TABLE 6-3. COMMUTER RAIL TRANSPORTATION AND MAINTENANCE EXPENSE COMPARISONS

MAINTENANCE OF WAY EXPENSE

Operating Agency	Route Miles	Main Track Miles	M/W Expense	Cost Per Car Mile	Cost Per Route Mile	Cost Per Main Track Mile
Boston and Maine Corp.	158	262	\$ 611,000	\$.21	\$ 3,867	\$2,332
The Central R.R. Co. of N.J.	115	206	1,224,000	.20	10,643	5,942
Chicago and NorthWestern Transportation Co.	176	389	1,652,000	.15	9,386	4,247
Erie Lackawanna Ry. Co.	300	473	2,492,000	.19	8,306	5,268

MAINTENANCE OF EQUIPMENT EXPENSE

Operating Agency	No. of Cars	M/E Expense	Cost Per Car	Average Miles/Car	M/E Cost Per Car Mile
Boston and Maine Corp.	84	\$2,963,000	\$35,274	35,179	\$1.00
The Central R.R. Co. of N.J.	125	2,129,000	17,032	47,936	.36
Chicago and North Western Transportation Co.	296	6,220,000	21,014	38,291	.55
Erie Lackawanna Ry. Co.	410	5,612,000	13,688	32,837	.42

TRANSPORTATION EXPENSE

Operating Agency	Transportation Cost	Car Miles	Transportation Cost/Car Mile
Boston and Maine Corp.	\$ 7,518,000	2,955,000	\$2.54
The Central R.R. Co. of N.J.	6,369,000	5,992,000	1.06
Chicago and North Western Transportation Co.	13,209,000	11,334,000	1.17
Erie Lackawanna Ry. Co.	15,380,000	13,463,000	1.14

TABLE 6-4. TRAIN MANNING REQUIREMENT COMPARISONS

OPERATING AGENCY	MANNING REQUIREMENTS
Boston & Maine Corp.	1 Engineer, 1 Conductor and 1 Trainman for 4-car train. Additional trainman for each two cars.
The Central Railroad Co. of N.J.	1 Engineer, 1 Conductor and 1 Trainman per train. Additional Ticket Collectors as required to collect revenues.
Chicago and North Western Transportation Co.	1 Engineer, 1 Fireman, 1 Conductor and 1 Trainman per train. Additional Ticket Collectors as required to collect revenues.
Erie Lackawana Railway Co.	1 Engineer, 1 Fireman, 1 Conductor and 2 Trainmen per train.

APPENDIX A
NORTH AMERICAN RAIL RAPID TRANSIT SYSTEMS
RECENT CAPITAL COST EXPERIENCE

CONTENTS

TABLE A-1	SUMMARY OF CONSTRUCTION COSTS
TABLE A-2	ROUTE CONSTRUCTION AT GRADE
TABLE A-3	ROUTE CONSTRUCTION BELOW GRADE
TABLE A-4	GUIDEWAY CONSTRUCTION - DOUBLE TRACK
TABLE A-5	SIGNAL, COMMUNICATIONS, AND WAYSIDE CONTROL
TABLE A-6	POWER AND ELECTRIC TRACTION
TABLE A-7	LAND ACQUISITIONS BY RAPID TRANSIT PROPERTIES
TABLE A-8	RAPID RAIL SYSTEMS STATION CONSTRUCTION
TABLE A-9	RAPID RAIL VEHICLES

TABLE A-1. SUMMARY OF CONSTRUCTION COSTS
(RAIL RAPID TRANSIT)

TOTAL SYSTEM COSTS¹

Operating Agency	Route Miles	Years Constructed	1974 Total Cost (000,000)	Approx. Cost/Mile 1974 Dollars (000,000)
Atlanta MARTA	60.90	1975-80	2,100 ³	34.5
San Francisco BART	75.00	1964-75	1,600	32.1
Washington, D.C. WMATA	98.00	1969-78	4,500 ³	45.9

LINE EXTENSION CONSTRUCTION COSTS²

Operating Agency	Route Miles	Years Constructed	1974 Total Cost (000,000)	Approx. Cost/Mile 1974 Dollars (000,000)
Boston MBTA So. Shore Line	6.25	1966-71	48.5	12.9
Boston MBTA Haymarket No.	5.90	1967-75	126.1	27.7
Chicago CTA Kennedy Line	5.20	1968-72	48.2	14.0
Chicago CTA Dan Ryan	10.50	1968-72	42.6	6.1
Cleveland CTS Airport Extension	4.00	1966-68	15.2	6.4
Toronto TTC Yonge Line	5.50	1968-73	140	35.8
Toronto TTC Spadina Line	6.25	1974-77	155 ³	24.8

- ¹ Includes land and vehicles
- ² Excludes vehicles
- ³ Estimated costs

TABLE A-2. ROUTE CONSTRUCTION AT GRADE

Operating Agency	Year	Route Miles Double Track	Total Cost (000)	Total Cost in 1974 dollars (000)	Cost Per Mile in 1974 dollars (000)
Boston South Shore MBTA	1966-71	6.25	\$18,100	\$25,992	\$4,159
Chicago Dan Ryan ¹ CTA	1968-72	10.50	13,061	18,756	1,786
Chicago Kennedy ¹ CTA	1968-72	5.20	22,716	32,620	6,273
Cleveland Airport CTS	1966-69	4.00	3,894	6,706	1,676

¹Routes contain areas of elevated structure.

TABLE A-3. ROUTE CONSTRUCTION BELOW GRADE

Operating Agency	Year	Route Miles Double Track	Type	Cost in Thousands of Dollars							Total Cost (000)	Cost per Mile in 1974 Dollars ² (000)	
				Utilities	Deck & Traffic Cont.	Underpin	Excavate	Concrete	Backfill	Restore			Misc.
Boston So. Cove ¹	1968	0.28	Cut & Cover	785	315	NA	5,062	3,237	266	20	3,736	13,400	74,226
Boston Haymarket No. 1	1966-71	0.75	Cut & Cover w/Sunken Tube	660	237	2,190	6,406	5403	Incd. in Excavation	9,550		24,446	50,522
New York E110th-E120th	1973	0.48	Cut & Cover	2,452	3,766	2,719	19,616	4,223	901	1,773		35,450	81,388
Philadelphia So. Broad St.	1969	1.378	Cut & Cover	5,305	1,273	-	8,110	10,783	472	660	7,895	34,498	37,602
San Francisco Trans Bay	1969-71	3.6	Sunken Tube	NA	NA	NA	NA	NA	NA	NA		180,000	67,222
San Francisco Muni Line	1971-72	0.576	Cut & Cover	3,775	236		3,171	3,004	237	564	44	11,032	21,163
San Francisco Oakland	1971-73	0.04	Free Air Tunnel Line	446	111	32	628	470	35	47	97	1,866	62,700
Washington, D.C. Farragut	1971-73	0.45	Cut & Cover	1,565	1,676	2,748	6,506	4,923	734	473	778	19,403	43,118
Washington, D.C. Archives-Union Station	1970	0.45	Cut & Cover	1,412	1,315	947	1,190	1,752	667	997	4,050	12,330	36,826
Washington, D.C. DuPont Circle-Zoo/Logical Park	1970	0.76	Rock	77	NA	120	5,725	301	NA	NA	700	6,923	12,243

¹Construction included stations.

²Costs per mile are extrapolated from site-specific construction and may not represent efficiencies anticipated for longer sections. NA - Not Applicable

Operating Agency	Year	Route Miles Double Track	Type	Cost in Thousands of Dollars					Total Cost (000)	Cost per Mile (000)
				Tunnel Constr., Erection Grouting, Caulking, Clean Up	Tunnel Liners	Tunnel Concrete	Work & Vent Shafts	Underpin		
San Francisco Market St.	1970	1.94	Compressed Air	22,384	4,127	1,178	3,233	-	30,922	15,939

TABLE A-4. GUIDEWAY CONSTRUCTION - DOUBLE TRACK

Operating Agency	Length and Type Constr.		Cost Per Foot			Year	Cost of Special Trackwork				
	Welded Rail Wood Ties	Welded Rail Conc. Ties	Direct Fixation	At Grade	Elevated		Below Grade	Small Turnouts	Large Turnouts	Small Crossover	Large Crossover
Boston ¹ Haymarket No.	13,200'					113.67 (151.41)		187,000 ⁸ (249,084)			
Boston South Bay	10,000'			70.00 (81.76)			150' - 15,000 (17,520) #6 - 12,500 (14,600)	# 8 - 15,000 (17,520)	#6 - 28,000 (32,700)	#6 - Diam. Xover 63,000 (73,584)	
Boston South Shore		33,000		69.70 ³ (103.78)							
Chicago Kennedy/Dan Ryan					99.00 ² (147.41)		#5 - 8,225 (12,247) #7 - 9,250 (13,773)	// 9 - 15,550 (23,154) #12 - 14,400 (21,442)	#5 - 49,330 (73,452) #7 - 50,200 (74,748)		
Cleveland Airport	21,120'			94.65 (140.93)				128,000 ⁶ (190,600)			
New York E. 63rd St. - 41st Av.			3,005'			557.40 ² (608.12)					
Philadelphia South Broad St.			7,275'			181.58 ^{2,7} (255.85)					
Washington Phase 1			21,750'		90.00 ⁴ (112.23)	90.00 ⁴ (112.23)	#6 - 12,000 (14,964)	#8 - 20,000 - B. (24,940) #8 - 25,000 - D.F. (31,175)	#8 - 28,000 (34,916)	#8 - 65,000 - D.F. (81,055) #8 - 70,000 - B. (87,290)	
Boston Green Line	46,250'			90.00 ⁵ (98.19)					#6 - 50,000 (54,550)		

1 - Light Rail - Rehabilitation

2 - Includes Furnishing And Installing Power Rail

3 - Includes Installing Power Rail

4 - Does Not Include Furnishing Materials

5 - Does Not Include Furnishing Rail and Ties

6 - Approximately 32,000.00 was expended per double track mile (1974 cost = 47,650).

7 - Includes (2) Crossovers and (2) Turnouts.

8 - Includes (1) #6 Double Crossover and (3) Turnouts.

() = 1974 cost.

TABLE A-5. SIGNAL, COMMUNICATIONS, AND WAYSIDE CONTROL

Operating Agency	Cost Year	Road Miles	Design Speed (mph)	Design Headway (sec)	No. of Interlockings	No. Yards	Cost Per Mile, Basic Two-Track Territory, in Thousands of Dollars								
							Basic Signaling	Supervisory Control	Third Rail Indicators	Communications	Headway Recorders	Automatic Dispatchers	Automatic Vehicle Identification	Project Cost for Route Mile Installed	1974
Boston MBTA Haymarket North	1973	5.9	65	90	4	1	1,359.8 (1,489.0)	169.5 (185.6)	37.4 (41.0)	329.4 (360.7)	2.4 (2.6)	2.4 (2.6)	23.2 (25.4)	1,924.1	2,106.9
Boston MBTA South Shore	1967	6.5	70	90	4	0	538.5 (868.3)	Yes	No	21.4 (34.5)	Yes	Yes	Yes	559.9	902.7
Boston MBTA Cambridge Derchester	1967	9.0	70	90	1	0	520.7 (839.5)	Yes	No	31.9 (56.5)	Yes	Yes	Yes	552.6	890.8
Chicago North South	Under Constr. 1974	15.5	55	90	2	0	605.9	No	No	No	(existing)	No	No	605.9	605.9
Chicago Kennedy	1968	5.2	55	90	1	0	290.6 (429.8)	No	No	1.4 (2.1)	(existing)	(existing)	No	292.0	431.9
Chicago Dan Ryan	1968	10.5	55	90	1	0	311.1 (460.1)	No	No	0.8 (1.2)	(existing)	(existing)	No	311.9	461.3
Chicago Evanston Skokie-Swift Ravenswood	Under Constr. 1974	4.0 5.0 10.0	55	90	2	0	637.4	No	No	No	(existing)	(existing)	No	637.4	637.4
Cleveland Airport	1966	4.9	55	90			247.7 (436.0)	Yes	No	No	No	No	No	247.7	436.0
Philadelphia So. Broad St. Ext.	1969	1.4	-	-	-	-	1,323.0 (1,957.0)	-	No	Yes	-	-	-	1,323.0	1,957.0
Philadelphia Harbor-Warminster	1972	1.8	-	-	-	-	392.9 (470.3)	-	No	No	No	No	No	392.9	470.3
San Francisco All Routes	1963	71.59	80	90	28	3	977.8 (1,778.8)	Computer	No	19.5 (35.5)	Computer	Computer	Computer	997.3	1,814.3
Toronto Yonge Extension	1971	5.5	55	120	2	0	353.3 (463.5)	(existing)	No	Yes	Yes	Yes	Yes	353.3	463.5
Washington, D.C. Phase I	Under Constr. 1974	3.9	75	90	3	1	1,921.9	234.3	No	3,378.2 (Computer)	Computer	Computer	Computer	5,552.0	5,552.0

¹ Reading R.R. Commuter Rail. | 1 - Adjusted to 1974 Costs.

TABLE A-6. POWER AND ELECTRIC TRACTION

Operating Agency	Cost Year	Route Miles	Design Speed (mph)	Design Headway (sec)	Power	No. of Sub Stations	Cost Per Mile, Basic Two-Track Territory, in Thousands of Dollars							
							Sub-Station Equipment	Install Cable	Supervisory Control	Primary Hi-Volt Line	Catenary and Messenger	Catenary Structures	Project Cost Per Route Mile Installed	1974
Boston Haymarket North	Under Constr. 1974	5.9	65	90	3rd Rail 600V-DC	4	339.0	Yes	Yes	No	None	None	984.0	984.0
Chicago Kennedy	1968	5.2	55	90	3rd Rail 600V-DC	4	199.2 (338.6)	33.2	8.2	179.8	None	None	420.4	714.7
Chicago Dan Ryan	1968	10.5	55	90	3rd Rail 600V-DC	4	67.4 (114.6)	30.0	3.12	105.3	None	None	208.0	355
Cleveland Airport	1966	4.9	55	90	O.H. Cat. 600V-DC	-	187.0 (353.4)	Incl. in Cat. Cost	Yes	No	857.1	-	213.1	402.8
Philadelphia So. Broad St. Ext.	1969	1.4	-	-	3rd Rail 600V-DC	-	-	-	-	-	-	-	296.3	492.6
Philadelphia Hatboro-Warminster	1972	1.8	-	-	O.H. Cat 11,000V-AC	-	-	-	-	-	Yes	Yes	113.7	134.2
San Francisco System	1963	73	80	90	3rd Rail 1000V-DC	37	Included in Total Cost	-	Yes	Yes	No	No	293.6	575.5
Toronto Ont. Yonge	1971	5.5	55	120	3rd Rail 600V-DC	-	505.4 (525.6)	Yes	Yes	No	No	No	505.4	525.6
Washington D.C. Phase I	Under Constr. 1974	3.9	75	90	3rd Rail 600V-DC	6	364.6	Yes	Yes	No	No	No	364.4	386.3

¹ Reading R.R. Commuter Rail. () = 1974 Cost

TABLE A-7. LAND ACQUISITION BY RAPID TRANSIT PROPERTIES

Boston Orange Line	MBTA	16.9 miles of railroad corridor from the Boston & Maine Corp. \$18,056,896 (this figure is the result of an arbitrators award rendered in 1971)				
Boston Red Line	MBTA	7.5 miles of railroad corridor and yard areas from New Haven RR & private abutters. \$12,000,000 ± -- 1966				
Chicago Dan Ryan Kennedy Englewood	CTA	<table> <tr> <td>10.5 miles \$971,724</td> <td rowspan="3">} Constructed in medians previously acquired by the Highway Dept.</td> </tr> <tr> <td>5.2 miles \$2,024,975</td> </tr> <tr> <td>0.63 miles \$1,157,400</td> </tr> </table>	10.5 miles \$971,724	} Constructed in medians previously acquired by the Highway Dept.	5.2 miles \$2,024,975	0.63 miles \$1,157,400
10.5 miles \$971,724	} Constructed in medians previously acquired by the Highway Dept.					
5.2 miles \$2,024,975						
0.63 miles \$1,157,400						
Philadelphia	PATCO	10.5 miles of primarily railroad corridor, \$6,150,000 -- 1964				
San Francisco	BART	75.0 miles of right-of-way, stations, parking, yards, etc. \$94,979,174 through March 31, 1974				
Washington, D.C.	WMATA	98.0 miles \$215,000,000 (an estimated expenditure for total land to include right-of-way, parking, yards, etc.)				

TABLE A-8. RAPID RAIL SYSTEMS STATION CONSTRUCTION

Operating Agency	Year	Length	Type	Total Cost (000)	Total Cost 1974 Dollars (000)	Cost Per Foot ¹ (000)	
At Grade							
Boston N. Quincy	MBTA	1971	440'	Concrete	2,556	3,468	7.9
Boston Wollaston	MBTA	1971	440'	Concrete	1,250	1,696	3.9
Boston Quincy Sta. & 5-Story Garage 850-Car Capacity	MBTA	1971	500'	Concrete	5,887	7,989	16.0
Chicago Dan Ryan 10 Stations	CTA	1967 1968	423	Concrete & Steel	9 @ 1,100± 1 @ 2,500	9 @ 1,971± 1 @ 4,480	Varies
Elevated							
Washington, D.C. 1B0041	WMATA	1972	647'	Concrete	2,820	3,017	4.7
Below Grade							
San Francisco Oakland	BART	1970	838'	Cut & Cover	13,154	17,679	21.1
Washington, D.C. Farragut	WMATA	1972	770'	Cut & Cover	15,344	16,419	21.3
Washington, D.C. Farragut W.	WMATA	1972	771'	Cut & Cover	6,892	7,375	9.6
Washington, D.C. Foggy Bottom	WMATA	1972	860'	Cut & Cover	8,303	8,884	10.3
Washington, D.C. DuPont Circle-Zoological Park	WMATA	1972	724'	Rock	5,665	6,062	8.4

¹Platform length.

TABLE A-9. RAPID RAIL VEHICLES

Operating Agency	Passenger Capacity			Car Dimensions			Car Light Weight (lbs)	Max. Speed (mph)	Initial Accel. Rate (mphps)	On-Brd. Cab-Sign. Or Speed Control	Power	Year	Actual Cost Per Car
	No. of Seats	Max. Crush	Schedule Peak	Length	Height	Width							
Boston	64	239	150	69'-10"	12'-5"	10'-0"	60,800	70	2.75	Yes	600V-DC 3rd Rail	1968	\$165,072 (52) 179,165 (24)
Chicago	47(A) 51(B)	150	100	48'-3"	12'-0"	9'-4"	44,500	70	3.2	Yes	600V-DC 3rd Rail	1967	125,000
Chicago	47(A) 51(B)	150	100	48'-3"	12'-0"	9'-4"	50,100	70	3.2	Yes	600V-DC 3rd Rail	1974	293,200
Cleveland	80	140	120	70'-3"	12'-0"	10'-5"	64,775	55	2.75	Yes	O.H. 600V Pantograph	1966	171,208
Cleveland	80	140	120	51'-3"	11'-1"	9'-3"	59,000	55	3.0	Yes	O.H. 600V Pantograph	1970	251,950
New York	46	220	140-160	60'-0"	12'-2"	10'-0"	R-40 68,200 R-40 A/C 74,200	50	2.5	No	600V-DC 3rd Rail	1966	R40 - 115,000 R40 A/C - 137,000
New York	46	220	140-160	60'-0"	12'-2"	10'-0"	R-42 74,400	50	2.5	No	600V-DC 3rd Rail	1968	R42 - 132,700
New York	72-76	280	180-210	75'-0"	12'-2"	10'-0"	R-44 82,800	70	2.5	Yes	600V-DC 3rd Rail	1970	R44 - 206,600
New York	72-76	280	180-210	75'-0"	12'-2"	10'-0"	R-46 90,000	70	2.5	Yes	600V-DC 3rd Rail	1972	R46 - 273,000
New York	41	140	140	51'-3"	11'-9"	9'-3"	A - Cars 58,000	70	3.0	No	600V-DC 3rd Rail	1966	A - Cars - 128,925
New York	33	165	139	51'-3"	11'-1"	9'-3"	C - Cars 59,000	70	3.5	No	600V-DC 3rd Rail	1970	C - Cars - 184,000

A - Car - Operating cab at one end
C - Car - No cab must be coupled with A Cars for operation (PATH)

TABLE A-9. RAPID RAIL VEHICLES (Cont.)

Operating Agency	Passenger Capacity		Car Dimensions			Car Light Weight (lbs)	Max. Speed (mph)	Initial Accel. Rate (mphps)	On-Brd. Cab-Sign. Or Speed Control	Power	Year	Actual Cost Per Car
	No. of Seats	Max. Crush	Schedule Peak	Length	Height							
San Francisco	72	216	120	75'-0"	10'-6"	10'-6"	80	3.0	Yes	1000V-DC 3rd Rail	1969 1974	A - Cars — \$233,100 A - Cars — 386,538
San Francisco	72	228	132	70'-0"	10'-6"	10'-6"	80	3.0	Yes	1000V-DC 3rd Rail	1969 1974	B - Cars — 229,000 B - Cars — 380,675
SOAC (Boeing Vertol)	62/72	240/ 300		74'-8 1/2"	12'-1 1/2"	9'-9"	80	3.96	Yes	600V-DC	1971	Est. Cost 350,000
Toronto	83	300	222	74'-10"	11'-1"	10'-4"	55	2.5	No	600V-DC 3rd Rail/ O.H. Catenary	1970	151,210
Toronto	83	300	222	74'-10"	11'-1"	10'-4"	55	2.5	No	600V-DC 3rd Rail	1976 ¹	243,333
Washington, D.C. WMATA	81	240		75'-0"	10'-10"	10'-2"	75	3.0	Yes	750V-DC	1972	300,000

¹ Date represents delivery (purchase year was 1974).

A - Car — Operating cab at one end

B - Car — No cab - hostling controls

APPENDIX B
WMATA ESCALATION FACTORS

CONTENTS

TABLE B-1	AERIAL ESCALATION FACTORS
TABLE B-2	CUT & COVER ESCALATION FACTORS
TABLE B-3	ROCK TWINBORNE TUNNEL ESCALATION FACTORS
TABLE B-4	SOFT GROUND TUNNEL ESCALATION FACTORS
TABLE B-5	TRACKWORK ESCALATION FACTORS
TABLE B-6	TRAIN CONTROL ESCALATION FACTORS
TABLE B-7	TRACTION POWER ESCALATION FACTORS

TABLE B-1. AERIAL ESCALATION FACTORS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1969	1.000	1.007	1.014	1.020	1.027	1.034	1.041	1.048	1.055	1.061	1.068	1.075
1970	1.082	1.093	1.105	1.116	1.127	1.139	1.150	1.161	1.173	1.184	1.195	1.207
1971	1.218	1.227	1.237	1.246	1.255	1.264	1.274	1.283	1.292	1.301	1.311	1.320
1972	1.329	1.337	1.346	1.354	1.363	1.371	1.380	1.388	1.396	1.405	1.413	1.422
1973	1.430	1.438	1.446	1.454	1.462	1.470	1.478	1.485	1.493	1.501	1.509	1.517
1974	1.525	1.535	1.546	1.556	1.567	1.577	1.588	1.598	1.608	1.619	1.629	1.640
1975	1.650	1.662	1.674	1.686	1.698	1.710	1.722	1.734	1.746	1.758	1.770	1.782
1976	1.794	1.806	1.817	1.829	1.840	1.852	1.863	1.875	1.886	1.898	1.909	1.921
1977	1.932	1.943	1.954	1.965	1.976	1.987	1.998	2.009	2.020	2.031	2.042	2.053
1978	2.064	2.075	2.086	2.097	2.108	2.119	2.130	2.140	2.151	2.162	2.173	2.184
1979	2.195	2.206	2.217	2.229	2.240	2.251	2.262	2.273	2.284	2.296	2.307	2.318
1980	2.329	2.341	2.353	2.364	2.376	2.388	2.400	2.411	2.423	2.435	2.447	2.458
1981	2.470											

TABLE B-2. CUT & COVER ESCALATION FACTORS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1969	1.000	1.006	1.012	1.019	1.025	1.031	1.037	1.043	1.049	1.056	1.062	1.068
1970	1.074	1.084	1.094	1.103	1.113	1.123	1.133	1.143	1.153	1.162	1.172	1.182
1971	1.192	1.201	1.210	1.218	1.227	1.236	1.245	1.253	1.262	1.271	1.280	1.288
1972	1.297	1.305	1.313	1.321	1.329	1.337	1.345	1.353	1.361	1.369	1.377	1.385
1973	1.393	1.400	1.408	1.415	1.422	1.429	1.437	1.444	1.451	1.458	1.466	1.473
1974	1.480	1.490	1.500	1.509	1.519	1.529	1.539	1.549	1.559	1.568	1.578	1.588
1975	1.598	1.609	1.621	1.632	1.643	1.655	1.666	1.677	1.689	1.700	1.711	1.723
1976	1.734	1.745	1.756	1.766	1.777	1.788	1.799	1.810	1.821	1.831	1.842	1.853
1977	1.864	1.875	1.885	1.896	1.906	1.917	1.927	1.938	1.948	1.959	1.969	1.980
1978	1.990	2.000	2.011	2.021	2.031	2.042	2.052	2.062	2.073	2.083	2.093	2.104
1979	2.114	2.125	2.135	2.146	2.156	2.167	2.177	2.188	2.199	2.209	2.220	2.230
1980	2.241	2.252	2.263	2.275	2.285	2.297	2.308	2.319	2.330	2.342	2.353	2.364
1981	2.375											

TABLE B-3. ROCK TWINBORE TUNNEL ESCALATION FACTORS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1969	1.000	1.006	1.011	1.017	1.022	1.028	1.033	1.039	1.044	1.050	1.055	1.061
1970	1.066	1.076	1.087	1.097	1.107	1.117	1.128	1.138	1.148	1.158	1.169	1.179
1971	1.189	1.199	1.209	1.219	1.230	1.240	1.250	1.260	1.270	1.280	1.291	1.301
1972	1.311	1.319	1.328	1.336	1.344	1.352	1.361	1.369	1.377	1.385	1.394	1.402
1973	1.410	1.418	1.426	1.434	1.442	1.450	1.458	1.465	1.473	1.481	1.489	1.497
1974	1.505	1.516	1.527	1.537	1.548	1.559	1.570	1.585	1.591	1.602	1.613	1.623
1975	1.634	1.646	1.658	1.670	1.682	1.694	1.706	1.719	1.731	1.743	1.755	1.767
1976	1.779	1.791	1.802	1.814	1.826	1.837	1.849	1.861	1.872	1.884	1.896	1.907
1977	1.919	1.930	1.941	1.952	1.963	1.974	1.985	1.997	2.008	2.019	2.030	2.041
1978	2.052	2.063	2.074	2.085	2.096	2.107	2.118	2.129	2.140	2.151	2.162	2.173
1979	2.184	2.195	2.207	2.218	2.229	2.241	2.252	2.263	2.275	2.286	2.297	2.309
1980	2.320	2.332	2.344	2.356	2.368	2.380	2.392	2.403	2.415	2.427	2.439	2.451
1981	2.463											

TABLE B-4. SOFT GROUND TUNNEL ESCALATION FACTORS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1969	1.000	1.006	1.012	1.018	1.026	1.030	1.036	1.041	1.047	1.053	1.059	1.065
1970	1.071	1.080	1.090	1.099	1.109	1.118	1.128	1.137	1.146	1.156	1.165	1.175
1971	1.184	1.192	1.200	1.208	1.216	1.224	1.232	1.240	1.248	1.256	1.264	1.272
1972	1.280	1.287	1.294	1.302	1.309	1.316	1.323	1.330	1.337	1.345	1.352	1.359
1973	1.366	1.373	1.380	1.387	1.394	1.401	1.408	1.416	1.423	1.430	1.437	1.444
1974	1.451	1.461	1.470	1.480	1.490	1.499	1.509	1.519	1.528	1.538	1.548	1.557
1975	1.567	1.578	1.590	1.601	1.612	1.623	1.635	1.646	1.657	1.668	1.680	1.691
1976	1.702	1.713	1.724	1.735	1.746	1.757	1.768	1.780	1.791	1.802	1.813	1.824
1977	1.835	1.846	1.857	1.868	1.879	1.890	1.901	1.912	1.923	1.934	1.945	1.956
1978	1.967	1.978	1.989	2.000	2.011	2.022	2.033	2.045	2.056	2.067	2.078	2.089
1979	2.100	2.112	2.123	2.135	2.147	2.158	2.170	2.182	2.193	2.205	2.217	2.228
1980	2.240	2.252	2.265	2.277	2.289	2.302	2.314	2.326	2.339	2.351	2.363	2.376
1981	2.388											

TABLE B-5. TRACKWORK ESCALATION FACTORS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1969	1.000	1.005	1.011	1.016	1.021	1.027	1.032	1.037	1.043	1.048	1.053	1.059
1970	1.064	1.072	1.079	1.087	1.094	1.102	1.109	1.117	1.124	1.132	1.139	1.147
1971	1.154	1.161	1.167	1.174	1.181	1.187	1.194	1.201	1.207	1.214	1.221	1.227
1972	1.234	1.241	1.247	1.254	1.260	1.267	1.273	1.280	1.286	1.293	1.299	1.306
1973	1.312	1.318	1.325	1.331	1.337	1.343	1.350	1.356	1.362	1.368	1.375	1.381
1974	1.387	1.396	1.405	1.414	1.423	1.432	1.441	1.451	1.460	1.469	1.478	1.478
1975	1.496	1.507	1.517	1.528	1.539	1.549	1.560	1.571	1.581	1.592	1.603	1.613
1976	1.624	1.635	1.645	1.656	1.666	1.677	1.687	1.698	1.708	1.719	1.729	1.740
1977	1.750	1.761	1.771	1.782	1.793	1.803	1.814	1.825	1.835	1.846	1.857	1.867
1978	1.878	1.889	1.900	1.910	1.921	1.932	1.943	1.953	1.964	1.975	1.986	1.996
1979	2.007	2.019	2.030	2.042	2.054	2.065	2.077	2.089	2.100	2.112	2.124	2.135
1980	2.147	2.159	2.171	2.184	2.196	2.208	2.220	2.232	2.244	2.257	2.269	2.281
1981	2.293											

TABLE B-6. TRAIN CONTROL ESCALATION FACTORS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1969	1.000	1.005	1.010	1.014	1.019	1.024	1.029	1.033	1.038	1.043	1.048	1.052
1970	1.057	1.066	1.075	1.085	1.094	1.103	1.112	1.121	1.130	1.140	1.149	1.158
1971	1.167	1.179	1.186	1.196	1.205	1.215	1.224	1.234	1.244	1.253	1.263	1.272
1972	1.282	1.291	1.299	1.308	1.316	1.325	1.333	1.342	1.350	1.359	1.367	1.376
1973	1.384	1.392	1.400	1.408	1.416	1.424	1.432	1.439	1.447	1.455	1.463	1.471
1974	1.479	1.490	1.501	1.511	1.522	1.533	1.544	1.554	1.565	1.576	1.587	1.597
1975	1.608	1.620	1.633	1.645	1.657	1.669	1.682	1.694	1.706	1.718	1.731	1.743
1976	1.755	1.767	1.779	1.791	1.803	1.815	1.827	1.839	1.851	1.863	1.875	1.887
1977	1.899	1.911	1.923	1.934	1.946	1.958	1.970	1.982	1.994	2.005	2.017	2.029
1978	2.041	2.053	2.065	2.076	2.088	2.100	2.112	2.124	2.136	2.147	2.159	2.171
1979	2.183	2.195	2.207	2.219	2.231	2.243	2.255	2.268	2.280	2.292	2.304	2.316
1980	2.328	2.341	2.353	2.366	2.379	2.391	2.404	2.417	2.429	2.442	2.455	2.467
1981	2.480											

TABLE B-7. TRACTION POWER ESCALATION FACTORS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1969	1.000	1.006	1.013	1.019	1.025	1.032	1.038	1.044	1.051	1.057	1.063	1.070
1970	1.076	1.088	1.101	1.113	1.126	1.138	1.151	1.163	1.175	1.188	1.200	1.213
1971	1.225	1.238	1.252	1.265	1.278	1.291	1.305	1.318	1.331	1.344	1.358	1.371
1972	1.384	1.395	1.407	1.418	1.429	1.440	1.452	1.463	1.474	1.485	1.497	1.508
1973	1.519	1.529	1.539	1.549	1.559	1.569	1.579	1.590	1.600	1.610	1.620	1.630
1974	1.640	1.653	1.666	1.679	1.692	1.705	1.718	1.730	1.743	1.756	1.769	1.782
1975	1.795	1.809	1.824	1.838	1.853	1.867	1.882	1.896	1.910	1.925	1.939	1.954
1976	1.968	1.982	1.996	2.010	2.024	2.038	2.052	2.065	2.079	2.093	2.107	2.121
1977	2.135	2.148	2.161	2.175	2.188	2.201	2.214	2.227	2.240	2.254	2.267	2.280
1978	2.293	2.306	2.319	2.331	2.344	2.357	2.370	2.382	2.395	2.408	2.421	2.433
1979	2.446	2.459	2.471	2.484	2.497	2.509	2.522	2.535	2.547	2.560	2.573	2.585
1980	2.598	2.611	2.625	2.638	2.651	2.665	2.678	2.691	2.705	2.718	2.731	2.745
1981	2.758											