Report No. UMTA-MA-06-0025-76-3

RAIL TRANSIT SYSTEM COST STUDY

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

REPRINT
JULY 1976
FINAL REPORT

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

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
URBAN MASS TRANSPORTATION ADMINISTRATION
Office of Research and Development
Washington DC 20590

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UMTA-MA-06-0025-76-3		

4. Title and Subtitle	5. Report Date
RAIL TRANSIT SYSTEM COST STUDY	Reprint July 1976
	6. Performing Organization Code
7. Author(s) T.K. Dyer, W.K. Hale, F.A. Ingalls, R.B. Whelan	8. Performing Organization Report No. DOT-TSC-UMTA-75-22
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS) UM604/R6730T
Thomas K. Dyer, Inc.* 1762 Massachusetts Avenue Lexington MA 02173	11. Contract or Grant No. DOT-TSC-808
	13. Type of Report and Period Covered Final Report May 1974-July 1975
12. Sponsoring Agency Name and Address U.S. Department of Transportation Urban Mass Transportation Administration Office of Research and Development Washington DC 20590	14. Sponsoring Agency Code

15. Supplementary Notes

*Under contract to: U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge MA 02142

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 costs 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 the 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.

17. Key Words	18. Distribution Statement
Rapid Rail Light Rail Commuter Rail	DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	120	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

PREFACE

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

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 contacted and assisted on the project.

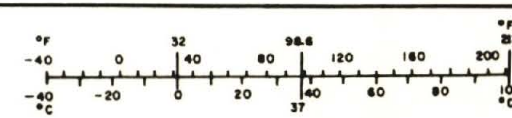
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



CONTENTS

ILLUSTRATION

Figure | | Page

TABLES

Table | | Page

TABLES (CONT'D)

Section 1
INTRODUCTION

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 is 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. The use of modern light-rail vehicle systems in the United States being rather limited, 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:

Boston, Massachusetts

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 dense traffic areas, LRT may operate on grade-separated right-of-way, in the same manner as rail rapid transit.

The 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 5,000 to 20,000 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 twelve 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. 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 capacity may vary from under 1,000 to 30,000 passengers 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	Possible	Yes	Yes
Signal System - Auto. Train Control	Possible	Possible	Possible
Station Spacing	500'-2600'	1240'-2600'	1-3 miles
Capacity - Pass/Hour/Track - (Maximum)	20,000	50,000	30,000
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	Possible
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	1-12	1-12

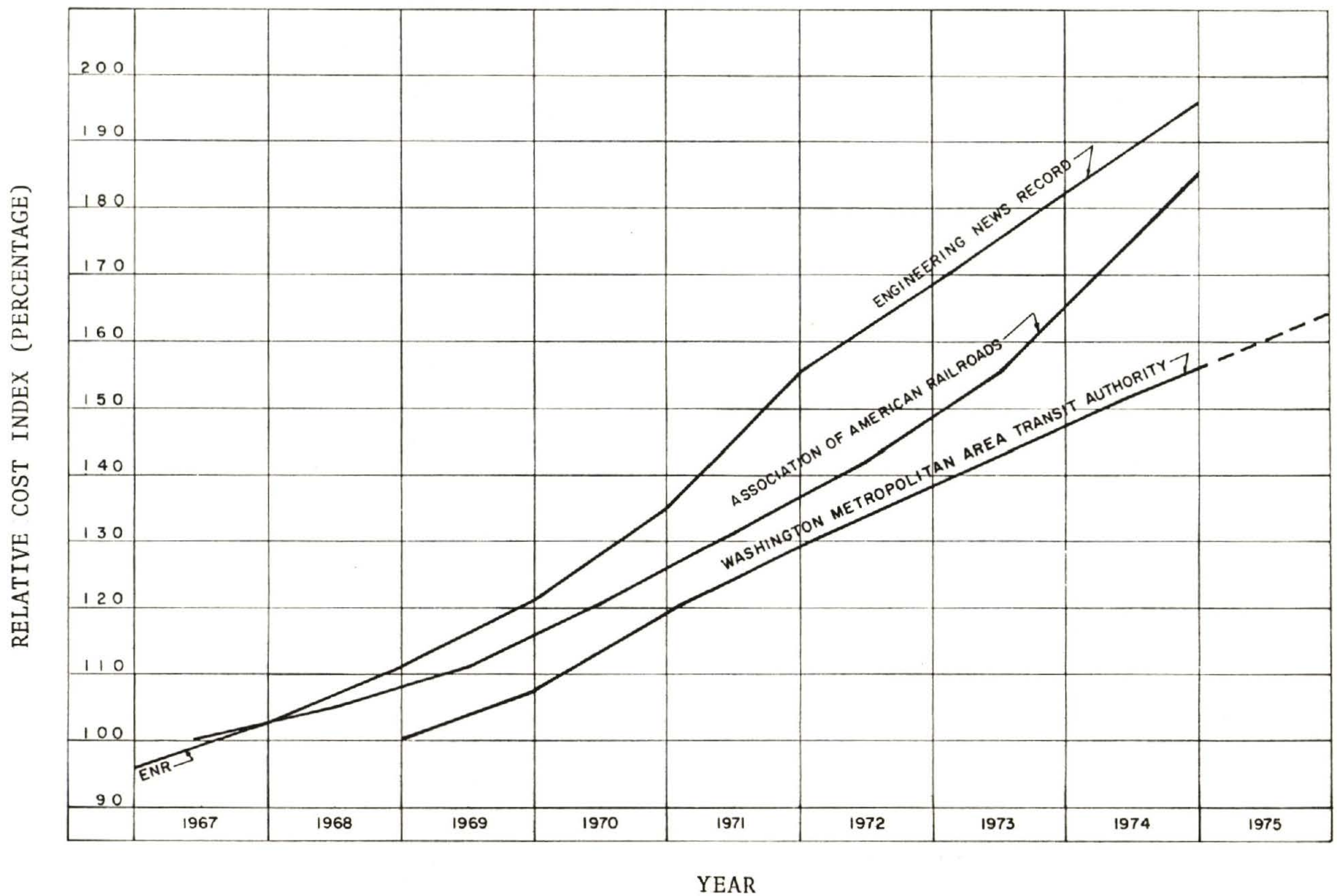


FIGURE 1.1 CONSTRUCTION COST INDEX

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 obtained from four light rail systems and ranged from $1.75 per car mile to $5.20 per car mile in 1974 dollars. The highest cost system operates four-car trains, requiring three-man crews by state law. The system has unique equipment problems. The average car mile cost of the other six systems is $1.80, with revenues offsetting about 70 percent of the cost. 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 percent of the cost.

Operating costs of four commuter rail systems examined range from $1.90 to $4.00 per car mile in 1974 dollars, the data being based on the railroads' annual report to the Interstate Commerce Commission. The highest cost system reflects the effect of short trains and short haul on commuter rail costs. The average of the other three systems is $1.95 per car mile, with revenues offsetting about 75 percent of the cost.

TABLE 1-2. CAPITAL COST SUMMARY FOR DOUBLE TRACK SYSTEMS

		Suburban						City						Core					
		At Grade		Elevated		Depressed[1]		At Grade		Elevated		Depressed[1]		At Grade		Elevated		Depressed[1]	
	Unit	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	.65	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	.58	.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.

Section 2
SYSTEM CAP COSTS

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 not excluded, the costs of the power facilities on the Extension would be distorted.

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 at grade 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 encountered 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 encountered 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 block signaling is generally found on most older commuter rail and on a few light rail systems.

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 the ATS system.

A further refinement 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 does require a vastly expanded communicating 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 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 informational 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 rail and a few light rail systems may be designed for 3 to 5 minute 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 in Washington 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, included either as a part of the original signal contract or as a separate cost item.

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 sub-systems 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

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 are cost-covered in the rate structure and 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, surface 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 on the surface, 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 must be 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.

Section 3
SYSTEM OP 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.

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.

Section 4
LIGHT RAIL CAP AND
UP[illegible]OSTS

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 5000 to 20000 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 the 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 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 - the unbroken, totally populated, block-by-block distribution usually associated with urban development over a long period of time.

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.

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. 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.

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

Item		(1974 Dollars) Low	High
[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		110,000	110,000
	[1]Total 1	$720,000	$1,760,000
	[2]Total 2	$940,000	$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.

	Low	High
[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 of 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

[1]Use Grading 1 and Drainage 1 for level to rolling terrain.
[2]Use Grading 2 and Drainage 2 for rolling to rough terrain.
[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 TRANSIT MODE
SUBURBAN AREAS
ELEVATED

(1974 Dollars)

Item		Low	High
[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.

	Low	High
[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

[1]Use Grading 1 and Drainage 1 for level to rolling terrain.
[2]Use Grading 2 and Drainage 2 for rolling to rough terrain.
[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
LIGHT RAIL MODE
SUBURBAN AREAS
DEPRESSED-OPEN RETAINED CUT

		(1974 Dollars) Low	High
[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]Table 1	$4,205,000	$11,420,000
	[2]Table 2	$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.

	Low	High
[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

[1]Use Grading 1 for level to rolling terrain.
[2]Use Grading 2 for rolling to rough terrain.
[3]Convert 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
LIGHT RAIL MODE
CITY AREAS
AT GRADE

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

Item		(1974 Dollars) Low	High
Grading		$150,000	$150,000
Drainage		140,000	140,000
Utilities		40,000	100,000
Traffic Handling		60,000	150,000
Fences		110,000	110,000
	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.

	Low	High
Utilities	4 Highway Crossings	10 Highway Crossings
Traffic Handling	4 Highway Crossings	10 Highway Crossings

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

(1974 Dollars)

Item		Low	High
[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		12,500,000	12,500,000
	[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 [2]quantities shown.

	Low	High
[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 2 when the proposed route is located in a street right-of-way.

[2]Use Utilities.

proposed route is located in a street right-of-way.

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
LIGHT RAIL MODE
CITY AND CORE AREAS
DEPRESSED CUT AND COVER TUNNEL

Item		(1974 Dollars) Low	High
[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.

	Low	High
[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	100 Single Dwellings	250 Single Dwellings

[1]Use Utilities 1, Traffic Handling 1 and Demolition 1 when the proposed route is not located in a street right-of-way.
[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
LIGHT RAIL MODE
SUBURBAN, CITY AND CORE AREAS
TUNNEL (OTHER THAN CUT AND COVER)

Type	(1974 Dollars) Cost Per Mile
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 plannig 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)

Item	Suburban	City	Core
[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	82,000	91,000	100,000
[1]Total 1	$750,000	$1,000,000	$1,100,000
[2]Total 2	$825,000	910,000	$1,000,000

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

Item	Unit	Low	High
Wayside Signaling	Route Mile	$150,000	$285,000
Supervisory Control	Route Mile	50,000	100,000
Communications	Route Mile	10,000	25,000
		$210,000	$410,000
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

	Low	High
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)

Item	Low	High
Overhead Catenary, 600 VDC including Substations	1,000,000	$1,300,000

CRITERIA FOR SCALING COSTS

	Low	High
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)

	Low	High
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.

	Low	High
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)

Item		Low	High
[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
Item		Low	High
[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		5,000	25,000
	[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

	Low	High
[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

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

STATION CONSTRUCTION COSTS-EACH
LIGHT RAIL MODE
SUBURBAN AREA
ELEVATED

(1974 Dollars)

Item	Low	High
[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

Item	Low	High
[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	10,000	50,000
[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

	Low	High
[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

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

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

(1974 Dollars)

Item		Low	High
[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
Item		Low	High
[1]Access 1		50,000	150,000
[2]Access 2		250,000	1,120,000
[3]Access 3		490,000	1,190,000
Platform		150,000	300,000
Passenger Shelters		10,000	50,000
	[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

	Low	High
[2]Awning 2	2 Car Train	4 Car Train
[2]Parking 2	75 Automobiles	375 Aubomobiles
[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

[1]Use Awning 1, Parking 1 and Access 1 for no Awnings or Parking.
[2]Use Awning 2, Parking 2 and Access 2 for Awnings and Limited Parking.
[3]Use 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.

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

CRITERIA FOR SCALING COSTS

	Low	High
Platform	2 Car Train	4 Car Train
Passenger Shelters	360 People	1800 People

STATION CONSTRUCTION COST-EACH
LIGHT RAIL MODE
CITY AREA
ELEVATED

Item	Low (1974 Dollars)	High (1974 Dollars)
[1]Awning 1	$ -0-	$ -0-
[2]Awning 2	80,000	160,000
Platform	128,000	256,000
Access	60,000	180,000
Passenger Shelters	20,000	100,000
[1]Total 1	$208,000	$536,000
[2]Total 2	$288,000	$696,000

CRITERIA FOR SCALING COSTS

	Low	High
[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

[1]Use Awning 1 for No Awnings.
[2]Use Awning 2 for Awnings.

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

Item	Low (1974 Dollars)	High (1974 Dollars)
Platform	$320,000	$ 640,000
Access	120,000	360,000
	$440,000	$1,000,000

1. Station Facility Not Included

CRITERIA FOR SCALING COSTS

	Low	High
Platform	2 Car Train	4 Car Train
acess	600 People	3000 People

STATION CONSTRUCTION COSTS-EACH
LIGHT RAIL MODE
CORE AREA
ELEVATED

(1974 Dollars)

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

CRITERIA FOR SCALING COSTS

	Low	High
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)

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

CRITERIA FOR SCALING COSTS

	Low	High
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)

Item		Low	High
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		70,000	200,000
	Total	$4,020,000	$16,034,000

CRITERIA FOR SCALING COSTS

	Low	High
Fleet	60 Cars	300 Cars

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

Item		Low (1974 Dollars)	High (1974 Dollars)
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		30,000	150,000
	Total	$8,037,000	$29,385,000

CRITERIA FOR SCALING COST

	Low	High
Fleet	60 Cars	300 Cars

AVERAGE 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 (mphps)	On-Brd. Cab-Sign. Or Speed Control	Power	Year Built	Cost Per Car
		No. of Seats	Max. Crush	Schedule Peak		Length	Height	Width							
Boston	MBTA	52	219	150	1-4	73'-0"	11'-4"	8'-10 1/4"	69,000	50	2.8	No	600V-DC Chopper Control	1975-76	$300,000
San Francisco	MUNI	60	193	88	1-4	73'-0"	11'-4"	8'-10 1/4"	69,000	50	2.8	Yes	600V-DC Chopper Control	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	MBTA	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	SHRT	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	SEPTA	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

OPERATING AGENCY		MANNING REQUIREMENTS
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

[1] Vehicle 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

Section 5
RAIL RAPID TRANSIT
CAP AND OP COSTS

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 (RTC) are electrically powered and may operate in trains of up to ten 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 rapid transit 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 - the unbroken, totally populated, block-by-block distribution usually associated with urban development over a long period of time.

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 apparata 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 - 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 TRANSIT MODE
SUBURBAN AREAS
AT GRADE

Item		Low (1974 Dollars)	High (1974 Dollars)
[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		110,000	110,000
	[1]Total	$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.

	Low	High
[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

[1]Use Grading 1 and Drainage 1 for level to rolling terrain.
[2]Use Grading 2 and Drainage 2 for rolling to rough terrain.
[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 TRANSIT MODE
SUBURBAN AREAS
ELEVATED

(1974 Dollars)

Item		Low	High
[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.

	Low	High
[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

[1]Use Grading 1 and Drainage 1 for level to rolling terrain.
[2]Use Grading 2 and Drainage 2 for rolling to rough terrain.
[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 TRANSIT MODE
SUBURBAN AREAS
DEPRESSED OPEN RETAINED CUT

(1974 Dollars)

Item		$ Low	High
[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

	Low	High
[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

[1]Use Grading 1 for level to rolling terrain.
[2]Use Grading 2 for rolling to rough terrain.
[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 TRANSIT MODE
CITY AND CORE AREAS
ELEVATED

(1974 Dollars)

Item		Low	High
[1]Utilities		$ 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		12,500,000	12,500,000
	[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.

[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 TRANSIT MODE
CITY AND CORE AREAS
DEPRESSED-CUT AND COVER TUNNEL
(1974 Dollars)

Item	Low	High
[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.

	Low	High
[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

[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 TRANSIT MODE
SUBURBAN, CITY AND CORE AREAS
TUNNEL OTHER THAN CUT & COVER

Type	Cost Per Mile (1974 Dollars)
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 TRANSIT MODE
SUBURBAN, CITY AND CORE AREAS
AT GRADE AND GRADE-SEPARATED

(1974 Dollars)

Item	Suburban	City	Core
[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	82,500	91,000	100,000
[1]Total 1	\$750,000	\$1,000,000	\$1,100,000
[2]Total 2	\$825,000	\$ 910,000	\$1,000,000

[1]Use Total 1 Costs for At-Grade Construction. City and Core Costs include continuous Girder Rail and Ballast Fill.
[2]Use Total 2 Costs for Grade-Separated Construction.

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

Item	Unit	(1974 Dollars) Low	High
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	35,000	45,000
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

	Low	High
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 TRANSIT MODE
SUBURBAN, CITY AND CORE AREAS
GRADE-SEPARATED

Item	(1974 Dollars) Low	High
Third Rail 600 VDC, including substations	$700,000	$850,000

CRITERIA FOR SCALING COSTS

	Low	High
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 TRANSIT MODE
SUBURBAN, CITY AND CORE AREAS
AT GRADE AND GRADE-SEPARATED

	(1974 Dollars) Low	High
Suburban	$ 132,000	$ 496,000
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.

	Low	High
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 TRANSIT MODE
SUBURBAN AREA
AT GRADE

Item	Low (1974 Dollars)	High (1974 Dollars)
[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	160,000	400,000
[1]Total 1	$ 4~~3~~52,000	$1,560,000
[2]Total 2	$ 711,000	$2,855,000
[3]Total 3	$ 970,000	$4,150,000

CRITERIA FOR SCALING COST

	Low	High
[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	4-Car Train

[1]Use Parking 1 and Access 1 for No Parking.

[2]Use Parking 2 and Access 2 for Limited Parking.

[3]Use Parking 3 and Access 3 for Major Parking.

STATION CONSTRUCTION COST
RAPID TRANSIT MODE
SUBURBAN AREA
ELEVATED

Item	Low (1974 Dollars)	High (1974 Dollars)
[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	160,000	400,000
[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

	Low	High
[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

[1]Use Parking 1 and Access 1 for No Parking

[2]Use Parking 2 and Access 2 for Limited Parking.

[3]Use Parking 3 and Access 3 for Major Parking.

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

Item	Low (1974 Dollars)	High (1974 Dollars)
[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	160,000	400,000
[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

	Low	High
[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

[1]Use Parking 1 and Access 1 for No Parking.

[2]Use Parking 2 and Access 2 for Limited Parking.

[3]Use Parking 3 and Access 3 for Major Parking.

STATION CONSTRUCTION COSTS
RAPID TRANSIT MODE
CITY AREAS
ELEVATED

(1974 Dollars)

Item	Low	High
Platform	$ 320,000	$ 800,000
Station Facility	120,000	600,000
Access	350,000	1,050,000
Awning	160,000	400,000
Total	$ 950,000	$2,850,000

CRITERIA FOR SCALING COSTS

	Low	High
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 TRANSIT MODE
CORE AREAS
DEPRESSED-CUT AND COVER TUNNEL

(1974 Dollars)

Item		Low	High
Platform		$ 800,000	$ 2,000,000
Station Facility		3,200,000	700,000
Access		1,000,000	3,000,000
	Total	$5,000,000	$12,000,000

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

CRITERIA FOR SCALING COSTS

	Low	High
Platform	4-Car Train	10-Car Train
Station Facility	1800 People	9000 People
Access	1800 People	9000 People

STATION CONSTRUCTION COSTS
RAPID TRANSIT MODE
CORE AREAS
ELEVATED

(1974 Dollars)

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

CRITERIA FOR SCALING COSTS

	Low	High
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

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

(1974 Dollars)

Item		Low	High
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		70,000	200,000
	Total	$3,410,000	$12,970,000

CRITERIA FOR SCALING COSTS

	Low	High
Fleet	60 Cars	300 Cars

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

Item	(1974 Dollars) Low	High
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	30,000	150,000
Total	$7,705,000	$27,725,000

CRITERIA FOR SCALING COSTS

	Low	High
Fleet	60 Cars	300 Cars

AVERAGE VEHICLE ACQUISITION COST
RAPID TRANSIT 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	1,759,047	882,062	5,590,476	1.37
Philadelphia SEPTA Market-Frankford	12.80	25.6	266	9,075,176	20,139,590 (combined)	1.41 (combined)	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	20,139,590 (combined)	1.41 (combined)	1,677,668	1,242,111	897,734	4,025,711		7,843,224	1.49

[1] Last 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 Market-Frankford	SEPTA	9,075,176	1,260,326	0.139
Philadelphia Broad-Ridge	SEPTA	5,249,144	897,734	0.171

[1] Last 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 Market-Frankford	SEPTA	4,718,051	9,075,176	0.52
Philadelphia Broad-Ridge	SEPTA	4,025,711	5,249,144	0.77

[1] Last 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

Section 6
COMMUTER RAIL REHAB
AND OP COSTS

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 30 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 30,000 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.

Signals - 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 or 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)

Item	Low	High
[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	110,000	110,000
[1]Total 1	$ 332,000	$ 436,000
[2]Total 2	$1,030,000	$3,102,000

Item	Low	High
[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 of Track Brdgs.	6 Hwy or Track Brdgs.
[2]Utilities 2	2 Hwy Over of Under RR	5 Hwy Over or Under RR

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

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.

Item	Low	High
[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

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

(1974 Dollars)

Item	Suburban	City	Core
[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	75,000	82,500	91,000
[1]Total 1	$580,000	$638,000	$703,000
[2]Total 2	$665,000	$732,500	$805,000

[1]Use Total 1 Costs to upgrade two existing tracks.
[2]Use 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

Item	Unit	(1974 Dollars) Low	High
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	10,000	25,000
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

	Low	High
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)

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

CRITERIA FOR SCALING COSTS

	Low	High
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

	Low	High
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.

	Low	High
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)

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

CRITERIA FOR SCALING COST

	Low	High
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

Item		Low	High
Platforms		$ 8,000	$ 40,000
Station Facilities		15,000	75,000
Awning		72,000	360,000
	Total	$ 95,000	475,000

CRITERIA FOR SCALING COST

	Low	High
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)

Item		Low	High
Platforms		$ 8,000	$ 40,000
Station Facility		90,000	450,000
Awning		72,000	360,000
	Total	$ 170,000	$ 850,000

CRITERIA FOR SCALING COST

	Low	High
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)

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

CRITERIA FOR SCALING COSTS

	Low	High
Fleet	20 Cars	100 Cars

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

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

Item		Low	High
[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		30,000	150,000
	[1]Total 1	$ 887,500	$3,420,500
	[2]Total 2	$1,075,000	$4,358,000

CRITERIA FOR SCALING COST

	Low	High
Fleet	20 Cars	100 Cars

[1]Use Power 1 for shops with no existing electric propulsion service.
[2]Use 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 (mphps)	On-Brd. Cab-Sign. Or Speed Control	Type Propulsion	Year	Cost Per Car
		Length	Height	Width							
New York MTA Long Island Railroad	– 120	85'-0"	12'-10½"	10'-6"	90,000	– 100	– 2.1	Yes	600V-DC Self-Propelled Cam Control	1967 1968 1971	M1–$199,800 M1– 206,470 M1– 299,950
New York MTA PC–Harlem and Hudson	– 120	85'-0"	12'-10½"	10'-6"	90,000	– 100	– 2.1	No	600V-DC Self-Propelled Cam Control	1970 1971 1972	M1A–287,743 M1A–295,650 M1A–312,080
New York MTA PC–New Haven	118	85'-0"	14'-9"	10'-6"	M-2 130,000 M-2 cafe 132,000	– (DC) 80 (AC)100	– (DC)1.6 (AC)2.2	Yes	600V-DC 11,000V-AC Self-Propelled Cam Control	1970 1970 1974	M2 –398,185 M2 cafe–417,168 M2 –639,000
Philadelphia SEPTA 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 SEPTA 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 GO 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
NA RRTS REC
CAP COST EXP

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

CONTENTS

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

TOTAL SYSTEM COSTS[1]

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 COSTS[2]

Operating Agency		Route Miles	Years Constructed	1974 Total Cost (000,000)	Approx. Cost/Mile 1974 Dollars (000,000)
Boston So. Shore Line	MBTA	6.25	1966-71	48.5	12.9
Boston Haymarket No.	MBTA	5.90	1967-75	126.1	27.7
Chicago Kennedy Line	CTA	5.20	1968-72	48.2	14.0
Chicago Dan Ryan	CTA	10.50	1968-72	42.6	6.1
Cleveland Airport Extension	CTS	4.00	1966–68	15.2	6.4
Toronto Yonge Line	TTC	5.50	1968-73	140	35.8
Toronto Spadina Line	TTC	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	S18,100	$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

[1]Routes 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: Utilities	Deck & Traffic Cont.	Under-pin	Excavate	Con-crete	Back-fill	Restore	Misc.	Total Cost (000)	Cost per Mile in 1974 Dollars[2] (000)
Boston So. Cove[1]	MBTA	1968	0.28	Cut & Cover	785	315	NA	5,062	3,237	266	20	3,736	13,400	74,226
Boston Haymarket No.[1]	MBTA	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	NYCTA	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.	SEPTA	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	BART	1969-71	3.6	Sunken Tube	NA	NA	NA	NA	NA	NA			180,000	67,222
San Francisco Muni Line	BART	1971-72	0.576	Cut & Cover	3,775	236		3,171	3,004	237	564	44	11,032	21,163
San Francisco Oakland	BART	1971-73	0.04	Free Air Tunnel Line	446	111	32	628	470	35	47	97	1,866	62,700
Washington, D.C. Farragut	WMATA	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. 1B0021	WMATA	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. 1A0043	WMATA	1970	0.76	Rock	77	NA	120	5,725	301	NA	NA	700	6,923	12,243

[1] Construction included stations.

[2] Costs per mile are extrapolated from site-specific construction and may not represent efficiences anticipated for longer sections.

NA - Not Applicable

Operating Agency		Year	Route Miles Double Track	Type	Cost in Thousands of Dollars: Tunnel Constr., Excavation, Erection Grouting, Caulking, Clean Up	Tunnel Liners	Tunnel Concrete	Work & Vent Shafts	Under-pin	Total Cost (000)	Cost per Mile (000)
San Francisco Market St.	BART	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] MBTA Haymarket No.	13,200'					113.67 (151.41)	1970		187,000[8] (249,084)		
Boston MBTA South Bay	10,000'			70.00 (81.76)			1972	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 MBTA South Shore		33,000		69.70[3] (103.78)			1968				
Chicago CTA Kennedy/Dan Ryan					99.00[2] (147.41)		1968	#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 CTS Airport	21,120'			94.65 (140.93)			1968		128,000[6] (190,600)		
New York NYCTA E.63rd St. - 41st Av.			3,005'			557.40[2] (608.12)	1973				
Philadelphia SEPTA South Broad St.			7,275'			181.58[2,7] (255.85)	1969				
Washington WMATA Phase 1			21,750'		90.00[4] (112.23)	90.00[4] (112.23)	1971	#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 MBTA[1] Green Line	46,250'			90.00[5] (98.19)			1973			#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 Head-way (sec)	No. of Inter-lockings	No. Yards	Cost Per Mile, Basic Two-Track Territory, in Thousands of Dollars: Basic Signal-ing	Super-visory Control	Third Rail Indi-cators	Communi-cations	Headway Recorders	Auto-matic Dis-patchers	Auto-matic Vehicle Identi-fication	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 Dorchester	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 CTA North South	Under Constr. 1974	15.5	55	90	2	0	605.9	No	No	No	(existing)	No	No	605.9	605.9
Chicago CTA Kennedy	1968	5.2	55	90	1	0	290.6 (429.8)	No	No	1.4 (2.1)	(existing)	No	No	292.0	431.9
Chicago CTA Dan Ryan	1968	10.5	55	90	1	0	311.1 (460.1)	No	No	0.8 (1.2)	(existing)	No	No	311.9	461.3
Chicago CTA Evanston Skokie-Swift Ravenswood	Under Constr. 1974	4.0 5.0 10.0	55	90	2	0	} 637.4	No	No	No	(existing)	No	No	637.4	637.4
Cleveland CTS Airport	1966	4.9	55	90			247.7 (436.0)	Yes	No	No	No	No	No	247.7	436.0
Philadelphia SEPTA So. Broad St. Ext.	1969	1.4	–	–	–	–	1,323.0 (1,957.0)	–	No	Yes	–	–	–	1,323.0	1,957.0
Philadelphia SEPTA[1] Hatboro- Warminster	1972	1.8	–	–	–	–	392.9 (470.3)	–	No	No	No	No	No	392.9	470.3
San Francisco BART 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 TTC 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. WMATA Phase I	Under Constr. 1974	3.9	75	90	3	1	1,921.9	234.3	No	3,378.2 (Computer)	Computer	Computer	17.6	5,552.0	5,552.0

[1]Reading R.R. Commuter Rail.

( ) = Adjusted to 1974 Costs.

TABLE A-6. POWER AND ELECTRIC TRACTION

Operating Agency		Cost Year	Route Miles	Design Speed (mph)	Design Head-way (sec)	Power	No. of Sub Sta-tions	Cost Per Mile, Basic Two-Track Territory, in Thousands of Dollars							
								Sub - Sta Equipment	Install Cable	Super-visory Control	Pri-mary Hi-Volt Line	Cate-nary and Messen-ger	Cate-nary Struc-tures	Project Cost Per Route Mile	
														Installed	1974
Boston Haymarket North	MBTA	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	CTA	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	CTA	1968	10.5	55	90	3rd Rail 600V-DC	4	67.4 (114.6)	30.0	3.12	108.3	None	None	208.0	355
Cleveland Airport	CTS	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.	SEPTA	1969	1.4	–	–	3rd Rail 600V-DC	–	–	–	–	–	–	–	296.3	492.6
Philadelphia Hatboro-Warminster	SEPTA[1]	1972	1.8	–	–	O.H. Cat 11,000V-AC	–	–	–	–	–	Yes	Yes	113.7	134.2
San Francisco System	BART	1963	73	80	90	3rd Rail 1000V-DC	37	Included in Total Cost	–	Yes	Yes	No	No	293.6	575.5
Toronto Ont. Yonge	TTC	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	WMATA	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	**CTA**	
Dan Ryan		10.5 miles $971,724 } Constructed in medians previously acquired by the Highway Dept.
Kennedy		5.2 miles $2,024,975 } Constructed in medians previously acquired by the Highway Dept.
Englewood		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 TRANSIT 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. 1C0021	WMATA	1972	771′	Cut & Cover	6,892	7,375	9.6
Washington, D.C. 1C0030	WMATA	1972	860′	Cut & Cover	8,303	8,884	10.3
Washington, D.C. 1A0044	WMATA	1972	724′	Rock	5,665	6,062	8.4

[1]Platform length.

TABLE A-9. RAPID TRANSIT 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 MBTA	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 CTA	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 CTA	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 CTS	80	140	120	70'-3"	12'-0"	10'-5"	64,775	55	2.75	Yes	O.H. 600V Pantograph	1966	171,208
Cleveland CTS	80	140	120	51'-3"	11'-1"	9'-3"	59,000	55	3.0	Yes	O.H. 600V Pantograph	1970	251,950
New York NYCTA	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 NYCTA	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 NYCTA	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 NYCTA	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 PATH	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 PATH	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 TRANSIT 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	Width							
San Francisco BART	72	216	120	75'-0"	10'-6"	10'-6"	A - Cars 56,500	80	3.0	Yes	1000V-DC 3rd Rail	1969 1974	A - Cars – $233,100 A - Cars – 386,538
San Francisco BART	72	228	132	70'-0"	10'-6"	10'-6"	B - Cars 55,000	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"	90,000	80	3.96	Yes	600V-DC	1971	Est. Cost 350,000
Toronto TTC	83	300	222	74'-10"	11'-1"	10'-4"	55,000	55	2.5	No	600V-DC 3rd Rail/ O.H. Catenary	1970	151,210
Toronto TTC	83	300	222	74'-10"	11'-1"	10'-4"	55,000	55	2.5	No	600V-DC 3rd Rail	1976[1]	243,333
Washington, D.C. WMATA	81	240		75'-0"	10'-10"	10'-2"	72,000	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 ESC
FACTORS

APPENDIX B
WMATA ESCALATION FACTORS

CONTENTS

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 TWINBORNE 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											

10-37