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PORT ON SUBWAY TUNNELING NEEDS 13 SELECTED U.S. CITIES, 1971-75

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16. Abstract

This report establishes proposed subway tunneling construction needs for thirteen selected U.S. cities during 1971-75 as given by the transit authorities. This information will be used to estimate the demand for subway tunnel construction. This demand estimate is an important criterion in the generation of an UMTA R&D program in tunneling. With the knowledge of the estimated demand in dollars as a function of the various types of construction, e.g., hard rock, soft ground, cut and cover, (including a breakdown of cost by function, i.e. excavation, mucking, etc.) research requirements will be established.

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INTRODUCTION

This report reflects the current (1971) subway tunneling requirements of 13 selected U.S. cities that are either planning a completely new rail rapid transit system or extensions to an existing system. The 13 cities have performed, as a minimum, preliminary investigations or feasibility studies on rail rapid transit systems. The data on subway tunneling demand presented here represents the instantaneous demand in 1971 and in that sense does not provide information to predict the total future demand. For instance, Detroit and Baltimore are each planning one branch of a system composed of four or five branch lines that will constitute their total integrated plan. Consequently, their future requirements for subway tunnel are not completely shown. Also, this analysis does not take into account other cities that may initiate subway construction within the next 5-15 years.

The thirteen U.S. cities surveyed for this report were:

Atlanta
Baltimore
Boston
Buffalo
Cleveland
Detroit
Los Angeles
New York
Philadelphia
St. Louis
San Francisco
Seattle
Washington

The data was obtained from personal contacts with the transit planners in each city and from the individual engineering reports prepared for each system. The transit plans are at different stages of completion for each city. Washington and San Francisco are well into the construction phase. Los Angeles, Baltimore and Atlanta are set to begin final engineering so that they can begin construction in 1973 or 1974. St. Louis has completed the feasability study on its proposed system, and Detroit has only completed the project definition report for a single line of subway.

The cost estimate for each system is expressed in 1970 dollars using the Engineering News Record Construction Cost Index (Tables 12 and 13). The three sources for unit cost prices are estimates by the transit planners, low bid price data from BART (Table 14) and the Washington METRO (Tables 15-19), and bid price data from tunnel construction with geological conditions similar to those found in several of the cities. The tunneling costs only include heavy construction costs, not including such items as track, electrification, train control, right of way, engineering financing and administrative costs. Likewise, the station costs include only the cost of "shell" construction and exclude architectural finish, most electrical and mechanical installations and operating equipment.

As of this time, no information has been received from New York City, so that the final results do not reflect New York's proposed subway construction.

SUMMARY OF RESULTS

Table 1 shows a tabulation of the planned rail rapid transit construction in the 13 cities surveyed. The locations of rapid transit and tunnel construction for each city are:

Atlanta: The 56 mile transit plan, with 3.6 miles of tunnel construction along Peachtree Street in downtown Atlanta, includes four main lines extending radially from the central business district with three branch lines (Fig. 1). For additional information see Reference 1.

Baltimore: The initial plans are for two lines serving the northwest and the southern corridors of the city. The Northwest Line begins in central Baltimore and terminates at Owings Mills. The Southern Line extends from downtown to Marley with a short extension serving Friendship Airport. The 9.6 miles of tunnel run from the proposed Leadenhal Station to a point beyond Mondawmin Station. For additional information see Reference 2.

Boston: The two mile tunnel for Boston represents the contemplated extension from Harvard Square to Route 2 at Alewife Parkway.

Buffalo: The initial phase of the transit will extend northwest along the Buffalo-Amherst Corridor from downtown Buffalo to the campus of Erie Community College. The 3.9 mile tunnel segment will be constructed along Main Street in the central city. For additional information see Reference 3.

Detroit: The route will follow Woodward Avenue from downtown Detroit to the northern side of Pontiac. The tunnel portion of the route will extend from downtown Detroit, to the Eleven Mile Road Station. For additional information see Reference 4.

Los Angeles: Plans prepared by the Southern California Rapid Transit District include construction along four main corridors. The Wilshire Corridor extends from Union Station westward to MacArthur Park then along Wilshire Boulevard to its western terminus just east of the San Diego Freeway. The line will be entirely subway construction.

The San Gabriel Valley Corridor begins at the eastern terminus of the Wilshire Corridor and extends eastward in

the median of the San Bernadino Freeway to Baldwin Avenue where it leaves the expressway and continues to El Monte. The subway portion of the line is about 3/4 mile from the junction with the Wilshire Corridor to the Macy Street Yard.

The San Fernando Valley Corridor extends northeastward from its connection with the Wilshire Corridor at Wilton Place through the Santa Monica Mountains to its terminus at Tampa Avenue. The tunnel portion of this corridor consists of a 3/4 mile segment of tunnel from the intersection with the Wilshire Corridor, almost 2 miles of subway along Selma Avenue in Hollywood, and a 3 mile tunnel through the Santa Monica Mountains.

The Long Beach Corridor extends from Ninth and Broadway in Los Angeles south to its terminus in Long Beach near Long Beach Avenue. The tunnel portion consists of a 14 mile subway along Broadway and a 1 mile subway along Ocean Boulevard to the terminus in Long Beach.

For additional information see References 8, 9, and 10.

Philadelphia: The tunnel extensions to Philadelphia's subway system consist of a short extension to the South Broad Street Subway to Snyder Street and a 6.5 mile Northeast extension to the Broad Street Subway.

St. Louis: The plan has five radial lines extending from the downtown area and two circumferential lines to the west (Fig. 2). The majority of the lines will be tunnel except for the river crossings and the portions of the lines in the less densely populated areas near the suburban terminals. For additional information see Reference 13.

San Francisco: Present plans are to extend the Daly City route underground to a point just beyond the San Francisco International Airport.

Washington: The Washington Metro will extend their original 25 mile ABS route with eleven separate radial extensions. (Fig. 3). The tunnel portion of the route occurs within downtown Washington; the suburban extensions are either elevated or at grade. For additional information see References 19 and 20.

Table 2 indicates that the transit authorities contacted spend over $3.1 billion on subway construction if the required financing is available.

Tables 3-6 give the breakdown of the major types of subway construction, e.g., rock tunnel, soft ground tunnel, cut and cover tunnel, and stations, for each city.

It is to be noted that of the 60.1 miles of planned rock tunnel, St. Louis alone accounted for 47.2 miles of this total, but the remainder of the data indicates that soft ground tunneling predominates in the metropolitan areas covered in this report.

The average cost per mile of a double track subway varies from about $12 million in rock, about $13 million for cut and cover construction to about $25 million for soft ground tunnels. The cost of a 600' station (suitable for eight car trains) is about $5 million.

Tables 7-10 show a breakdown of the type of tunnel construction by function for the entire project. It must be noted that tunnel construction is very site dependent and in a place like Washington, D.C. the site work, i.e., utilities, underpinning, dewatering, etc. can account for 25-30% of the total subway construction cost.

Table 11 lists the cities visited, the principal individual contacted, and the agency responsible for transit planning in each city. Tables 12 and 13 contain both construction cost index factors for 20 U.S. cities and construction cost inflation factors averaged for 20 cities. This information was compiled by Engineering News Record and was used to derive costs for construction projects completed at different times in different cities. For instance, in St. Louis no cost estimate was available for soft ground tunnel, so costs from San Francisco's soft ground tunneling were used, but because the San Francisco bid prices were 1966 or 1967 prices they were multiplied by the inflation factor to determine the cost in terms of 1970 prices. That price was then multiplied by the ratio of the cost indices for the two cities to arrive at an estimated cost for St. Louis.

Table 14 contains a compilation of itemized bid prices from contracts for BART subway stations and subway tunnel construction.

Tables 15-19 include a cost breakdown compiled by the author from WMATA bid price data on some of their early contracts. It is to be noted that the WMATA contracts include both station and subway in a single contract, so that an item such as mobilization, utilities or adjacent structure protection may refer to the amount for that item on the entire contract.

GLOSSARY OF TERMS

Cut and Cover - the process of excavating a trench from the surface, building the structure, back filling, and then restoring the surface to its original condition

Drill and Blast - A method of excavating rock tunnels with explosives using a cyclic operation of drilling, blasting and mucking

Lining - the structure used to support both the short-term erection loads and the long-term earth loads on a tunnel

Mechanical Excavators - refers to a variety of machines used in both soft ground and rock tunnels to disengage the material at the face of the excavation, they are commonly referred to as "moles"

Muck - sand, clay, mud or rock that is excavated from the tunnel face and removed from the tunnel

Rate of Advance - the rate (usually expressed in feet/day) at which the tunnel face is excavated

Rock Tunnel - tunnel excavated in rock that requires blasting or equivalent energy to break it, where the opening can stand unsupported until permanent supports are installed

Soft Ground Tunnel - tunnel excavated through soil in which the excavation is in immediate danger of collapse

Supports - ground control by stabilization of the face including underpinning

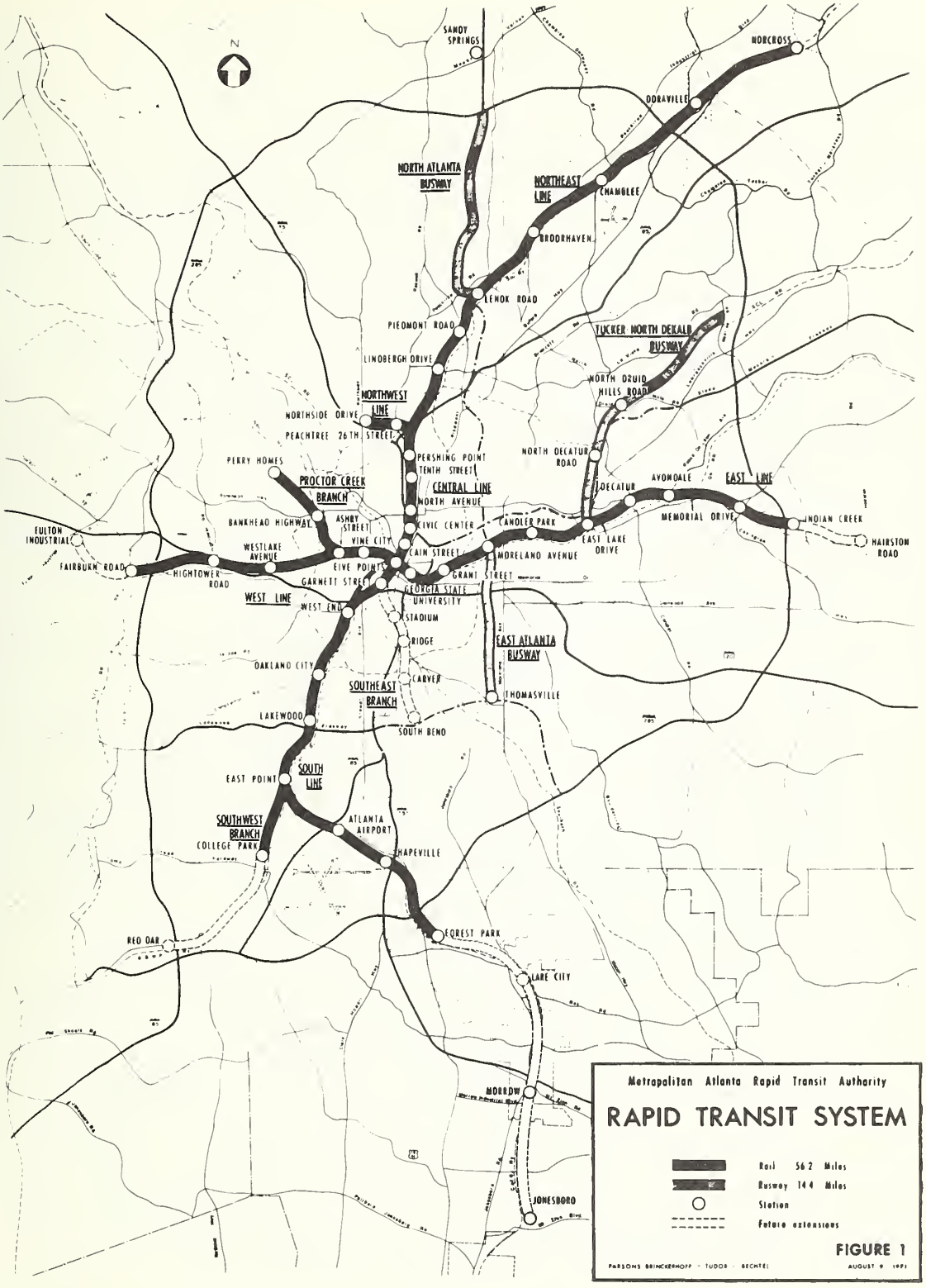


Figure 1. Metropolitan Atlanta Rapid Transit System

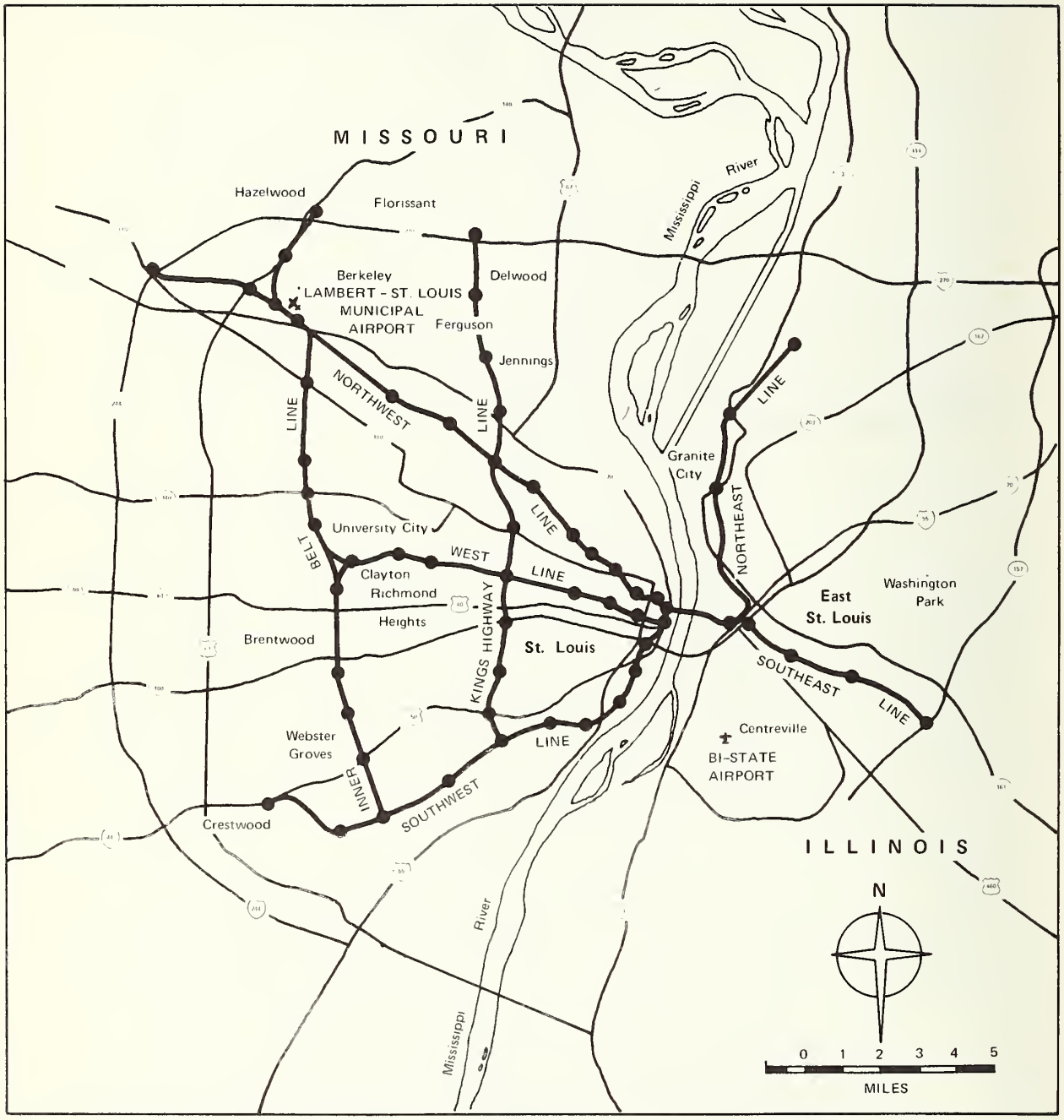


Figure 2. Proposed Rapid Transit Routes for St. Louis

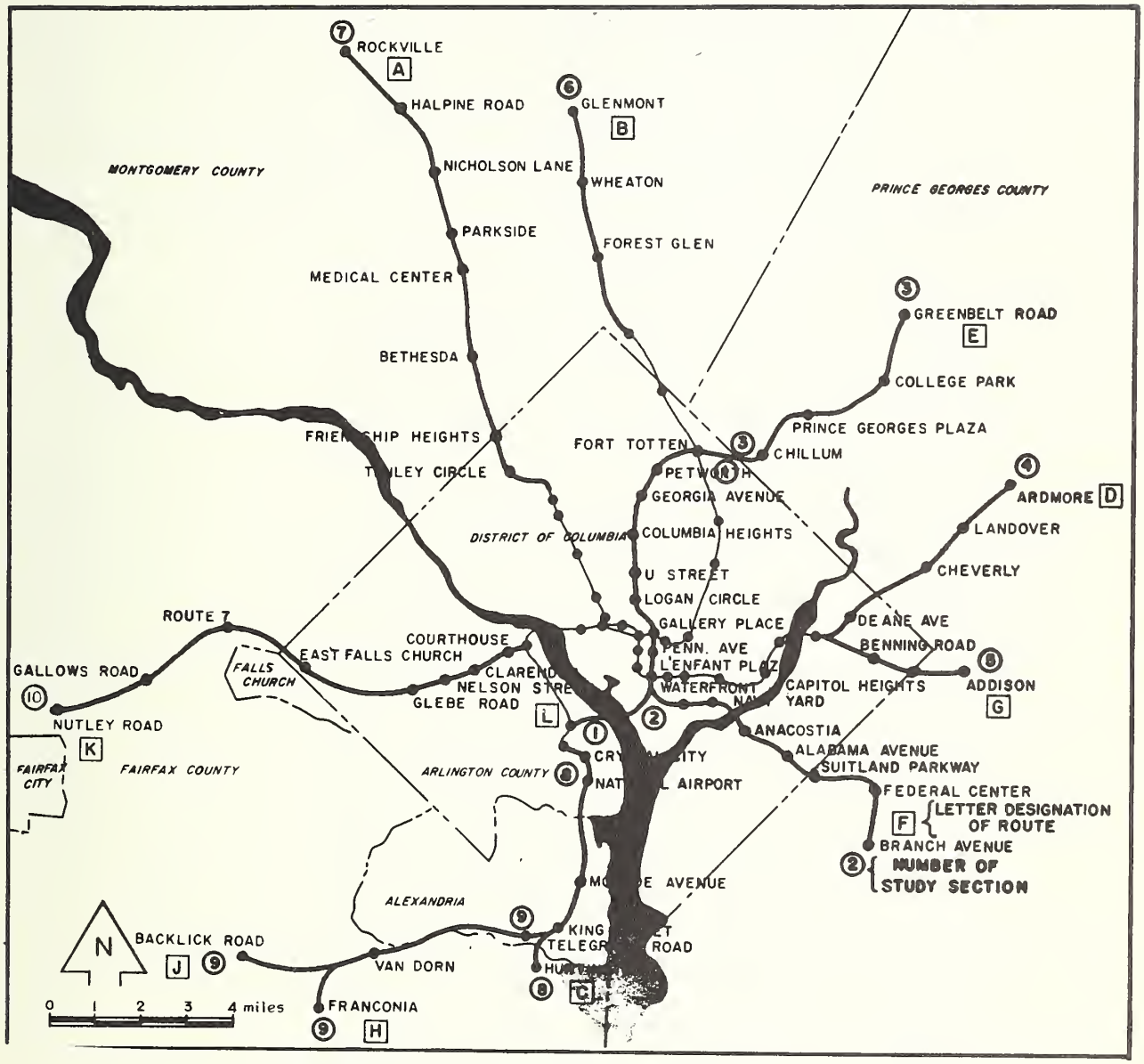


Figure 3. Adopted Regional System and General Location Rapid Transit Study Sections for Washington, D.C.

TABLE 1. PLANNED RAIL RAPID TRANSIT CONSTRUCTION

City	Existing Rail Rapid Transit	Future Construction	Future Tunnel Construction (Route miles including stations)	Anticipated Start of Construction	Remarks
Atlanta	No	56 mile rail rapid transit	3.6	1974	Preliminary engineering has been completed. Detailed Engineering being started.
Baltimore	No	28 mile rail rapid transit	9.6	1974	Includes only Phase I plan for one transit corridor. Other possible transit corridors have been identified but preliminary engineering has not yet begun.
Boston	Yes	Surface extensions of existing lines with one tunnel section	2.0	1974	Two possible routes exist for the tunnel. The tunnel section may be constructed using boring machines, but present plans call for cut and cover construction.
Buffalo	No	New 12.5 mile rail rapid transit	3.9	1974	Preliminary engineering complete. Detailed engineering in process. 12.5 mile route is first line that will be constructed. Other routes are anticipated, but no studies have begun.
Cleveland	Yes	Surface extensions of existing lines	None	NA	No definite plans are available on possible extensions.
Detroit	No	25 mile rail rapid transit	10.5	1974	Project definition report completed in August, 1971 on the Woodward Avenue line. Detailed engineering studies will soon begin. Other possible transit corridors have been identified, but no current studies have begun on other possible lines.
Los Angeles	No	89 mile rail rapid transit	22.2	1974	Preliminary engineering complete on complete 5 corridor system.
New York	Yes				Information not yet received.

NA = NOT AVAILABLE

TABLE 1. PLANNED RAIL RAPID TRANSIT CONSTRUCTION (CONTINUED)

City	Existing Rail Rapid Transit	Future Construction	Future Tunnel Construction (Route miles including stations)	Anticipated Start of Construction	Remarks
Phila-delphia	Yes	Several extensions of existing lines	9.8	NA	
St. Louis	No	100 mile rail rapid transit	68.8	NA	Feasability study on 5 transit corridors without detailed engineering analysis
San Francisco	Yes	10.6 mile extension to existing lines	4.1	NA	Recommended plan for possible airport extension.
Seattle	No	None	None	--	No present plans for rail rapid transit. A comprehensive rapid transit plan was completed in 1970 that included in its recommendations a 46.5 mile rail system. For the present Seattle has opted to invest transit money in upgrading their bus system.
Washing-ton	No	72 mile rail rapid transit	32.4	1973	72 mile Adopted Regional Lines to be added to 25 mile adopted Basic System. Presently being constructed.

NA = NOT AVAILABLE

TABLE 2. SUMMARY OF PLANNED SUBWAY CONSTRUCTION

	City	Length (Double Track)	Cost Estimate $/LF of Double Track	Cost Estimate $ Million	Remarks (Refer to Table 11)
Subway Tunnel Costs — Rock Tunnel	Los Angeles	2.7 miles	1350	19.2	Estimated cost from SCRTD
	New York				Information not received
	Philadelphia	0.6 miles	2750	8.7	Based on BART costs
	St. Louis	47.2 miles	2620	653.1	Based on 18'4" sewer tunnel through limestone in Chicago
	Washington	9.6 miles	3500	177.4	Estimate based upon WMARTA bid prices for similar construction
	TOTALS	60.1 miles		858.4	
Soft Ground Tunnel	Baltimore	3.8 miles	3800	76.2	Estimate of $15-20 million/mile for tunnel by Baltimore
	Detroit	9.2 miles	2000	97.1	Estimate of $10.5 million/mile by Detroit
	Los Angeles	16.2 miles	7930	165.1	Estimate by SCRTD
	San Francisco	3.7 miles	5100	99.6	Estimate based on BART bid prices for former work
	St. Louis	14.1 miles	5100	379.6	Estimate based on BART bid prices for soft ground tunnel
	Washington	7.6 miles	3250	130.4	Estimate based upon WMATA bid prices for similar type of construction
	TOTALS	54.6 miles		948.0	
Cut and Cover Tunnel	Atlanta	3.0 miles	3300	52.2	Estimate by MARTD
	Baltimore	5.0 miles	3300	87.1	Estimate by Metropolitan Transit Authority
	Boston	2.0 miles	2400	25.3	Estimate based on BART cut and cover bid prices
	Buffalo	3.1 miles	2750	45.0	Estimate by Niagara Frontier Transit Authority
	Philadelphia	8.9 miles	2400	112.8	Estimate based on BART cut and cover bid prices

TABLE 2. SUMMARY OF PLANNED SUBWAY CONSTRUCTION (CONTINUED)

		City	Length (Double Track)	Cost Estimate $/LF of Double Track	Cost Estimate Cost $ Million	Remarks
Subway Tunnel Costs	C&C (Cont'd)	Washington	10.6 miles	2400	134.3	Estimate based upon BARTD bid prices for similar construction
		TOTALS	32.6		456.7	
	Subway Station Costs	Atlanta	3300 LF	3000	9.9	Estimate by MARTD
		Baltimore	4500 LF	8500	38.3	Estimate based upon BARTD average bid prices
		Buffalo	4000	5150	20.6	Estimate by NFTA
		Detroit	7200	8820	63.5	Estimate by SEMTA
		Los Angeles	17600	8500	149.5	Estimate based on BARTD average bid prices
		Philadelphia	3000	7600	22.8	Philadelphia will build 5 subway stations. This estimate based on 600' per station
		San Francisco	2250	8500	19.1	Estimate based on BARTD average bid prices
		St. Louis	15600 LF (rock) 15000 LF (soft ground C&C)	9800 8500	152.8 127.5	Estimate based upon WMATA bid prices Estimate based on BARTD average bid prices
		Washington	6400 LF (rock) 18100 LF (soft ground C&C)	9800 6900	62.7 124.9	Estimate based on bid prices for similar stations on WMARTA Estimate based on bid prices for BARTD
		TOTALS	95850		791.6	

TABLE 3. PLANNED ROCK TUNNEL

City	Length (miles of dbl. trk excluding stations)	Tunnel Size & Configuration	Geological Conditions	Hydrological Conditions	Depth (Top of Rail to Surface)	Probable Excavation Technique	Probable Tunnel Liner	Remarks
Los Angeles	2.7 miles	2 single track tubes 16'6" inside diameter	Medium hard granite and sandstone	Significant seepage at geological fault lines	Varies-rock tunnel thru mountains	Mechanical excavator	Steel ribs with concrete	Tunnel through Santa Monica Mountains
Philadelphia	0.6 miles	NA	Decomposed Mica Schist	Ground water about 30' below ground surface	50'	Drill & Blast	Steel ribs with poured concrete	
St. Louis	47.2 miles	2 single track tube 15' inside diameter	Medium hard Limestone	NA	Generally 50'-70' 120' maximum	Mechanical Excavator	Shotcrete	
Washington	9.6 miles	2 track tunnel with vertical sidewalls	Generally bedrock Gniess with some construction in weathered rock	Ground water level about 25' below the ground surface	65' to 160' generally > 100'	Drill & Blast	Rock bolts and shotcrete incompetent bedrock. Ribs and logging with poured concrete in weathered rock.	Does not include tunnels under construction in Adopted Basic System

NA = NOT AVAILABLE

TABLE 4. PLANNED SOFT GROUND TUNNEL

City	Length (miles of double track excluding stations)	Tunnel Size & Configuration	Geological Conditions	Hydrological Conditions	Depth (Top of rail to Surface	Probable Excavation Technique	Probable Tunnel Liner	Remarks
Baltimore	3.8	2 single track tubes 16'6" inside diameter	Silty sand with some decomposed rock	Construction below ground water level	25' to 100'	Mechanical Excavator	Precast concrete or cast iron segments	
Detroit	9.2	2 single track tubes 19'0" diameter tunnel bore	Stiff homogeneous clay	NA	NA	Mechanical Excavator	Prefabricated steel segments	
Los Angeles	16.2	2 single track tubes 16'6" interior diameter	Silty, clayey sand with some boulders	Ground water generally < 25' from surface but up to 50' in some places	35'-70'	Mechanical Excavator	Precast concrete segments	
San Francisco	3.7	2 single track tubes 16'6" interior diameter	NA	NA	Approx. 50'	Mechanical Excavator	Prefabricated steel segments	Based on tentative route to airport. No detailed studies undertaken yet.
St. Louis	14.1	2 single track tubes 15' interior diameter	River deposits silt & sand	Ground water generally 25' below surface	NA	Mechanical Excavator	NA	
Washington	7.6	2 single track tubes 16'6" interior diameter	Clayey sand with some gravel. Some tunnel through plastic clay	Ground water about 20'25' below surface	60'-70'	Mechanical Excavator & hand mining	Steel ribs and lagging with cast-in-place concrete	Does not include tunnel under construction in Adopted Basic System

NA = NOT AVAILABLE

TABLE 5. PLANNED CUT & COVER TUNNELS

City	Length (miles of double track excluding stations)	Size & Configuration	Geological Conditions	Hydrological Conditions	Depth (Top of rail to surface)	Remarks
Atlanta	3.0	Double track concrete box 17'X35' interior dimensions	Silty sand	Ground water level 25'-30' below the surface	Generally 35'	Tunnel on central line. This is the only line with extensive tunnel although other lines may include short portions of cut & cover tunnel
Baltimore	5.0	Double track concrete box	Sandy soil with some weathered rock	Construction below water table	25' to 100'	Includes only Phase I. Other possible transit corridors will be planned at a future date.
Boston	2.0	Double track box	Sandy clay with some boulders	NA	Approx. 30'	May change design to 2-single track tubes.
Buffalo	3.1	Double track concrete box 13'6"X29'0" interior dimensions	Silty sand & gravel	Ground water 10'-20' below the surface	About 20'	
New York						Information not yet received.
Philadelphia	8.9	Double track concrete box 13'6"X30'0" interior dimensions	Clay, silty clay and mixed fill material	Ground water 15'-40' below surface, generally about 30'	30'-40'	
Washington	10.6	10.1 miles double track box 12'X29' interior dimensions 0.5 miles (double track) single track box	Clayey sand, plastic clay with some gravel. One segment through weathered rock	Ground water level about 25' below the surface	Generally 30' to 40' 20' minimum 100' maximum	Does not include tunnels under construction for Adopted Basic System

NA = NOT AVAILABLE

TABLE 6. PLANNED UNDERGROUND STATIONS

City	Configuration	Number	Construction Technique	Total Length (linear feet) of Double Track	Geological Conditions	Hydrological Conditions	Depth	Remarks
Atlanta	Two level transfer station - 4 tracks	1	Cut & Cover	550	Silty sand with some rock (granite)	Ground water level 25'-30' below the surface	About 50'	
	Single level 2 tracks	5	Cut & Cover	2,750	Silty sand with some rock	Ground water level 25'-30' below the surface	About 50'	
Baltimore	Two level transfer station - 4 tracks	1	Cut & Cover	450	Silty sand	Construction below water table	About 50'	
	Single level 2 tracks	9	Cut & Cover	4,050	1-soft clay 4-sand 4-decomposed rock	Construction below water table	43' to 75'	
Boston	NA	NA	NA	NA	NA	NA	NA	Future plans may include 1 or 2 stations but plans are only in conceptual stage
Buffalo	Single level two tracks	8	Cut & Cover	4,000	Silty sand and gravel	Ground water 10'-20' below surface	30'-40'	
Detroit	Single level two tracks	12	Cut & Cover	7,200	Stiff clay	NA	NA	
Los Angeles	Single level two tracks	22	Cut & Cover	17,600	Silty clay & silty sand	Ground water generally < 25' from surface, but in some places is from 25' to 50' deep	53'	Consultants recommend cut & cover construction; however, transit officials may try modified construction using mining techniques with 75'X75' cut & cover opening at each end
New York								Information not yet available
Philadelphia	Single level two tracks	5	Cut & Cover	NA	Clay, silty clay and mixed fill	Ground water about 30' below surface	Varies 20'-30'	

NA = NOT AVAILABLE

TABLE 6. PLANNED UNDERGROUND STATIONS (CONTINUED)

City	Configuration	Number	Construction Technique	Total Length (linear feet) of Double Track	Geological Conditions	Hydrological Conditions	Depth	Remarks
San Francisco	Single level two tracks	3	Cut & Cover	2,400	NA	NA	About 40'	
St. Louis	Double level 4 tracks	3	Cut & Cover	1,800	River deposits Glacial till	NA	50' minimum	
	Single level 2 tracks	22	Cut & Cover	13,200	River deposits sand and silt	NA	50' minimum	
	Double level 4 tracks	2	Drill & Blast	1,200	Medium hard limestone	NA	varies	
	Single level 2 tracks	24	Drill & Blast	14,400	Medium hard limestone	NA	varies	
Washington	Double level 4 tracks	3	Cut & Cover	2,400	Silty sand	Ground water level about 25' below surface	50'-70'	
	Single level 2 tracks	19	Cut & Cover	15,700	Silty clay Clay Silty sand	Ground water level about 25' below surface	50'-70'	
	Single level 2 tracks	8	Drill & Blast	6,400	Bedrock - schistose gniess	Ground water level about 25' below surface	100'-120'	

NA = NOT AVAILABLE

TABLE 7. SUBWAY TUNNEL COST BY FUNCTION, CUT & COVER

CITY	SITEWORK	MAINTENANCE OF TRAFFIC	UTILITIES	EXCAVATION & MUCKING	BACKFILL	STRUCTURES	MECHANICAL & DRAINAGE	ELECTRICAL	TOTAL MILL. $
ATLANTA	4.0	2.2	2.2	13.1	1.4	27.6	0.5	1.4	52.2
BALTIMORE	6.7	3.7	3.7	21.8	2.3	46.0	0.8	2.3	87.1
BOSTON	1.9	1.1	1.1	6.3	0.7	13.4	0.2	0.7	25.3
BUFFALO	3.5	1.9	1.9	11.3	1.2	23.8	0.4	1.2	45.0
PHILADELPHIA	8.7	4.8	4.8	28.2	2.9	59.6	1.0	2.9	112.8
WASHINGTON	10.3	5.6	5.6	33.6	3.5	70.9	1.2	3.5	134.3
TOTAL MILL. $	35.1	19.3	19.3	114.3	12.0	241.3	4.1	12.0	456.7

TABLE 8. SUBWAY TUNNEL COST BY FUNCTION, ROCK TUNNEL

CITY	SITEWORK	EXCAVATION*	MUCKING*	LINING	STRUCTURES	MECHANICAL	ELECTRICAL	MISCEL.	TOTAL MILL. $
LOS ANGELES	0.7	6.4	6.4	4.3	0.4	0.3	0.2	0.4	19.2
PHILADELPHIA	0.3	2.9	2.9	1.9	0.2	0.2	0.1	0.2	8.7
ST. LOUIS	24.8	217.8	217.8	145.0	13.1	11.8	8.5	14.4	653.1
WASHINGTON	6.7	59.1	59.1	39.4	3.5	3.2	2.3	3.9	177.4
TOTAL MILL. $	32.5	286.2	286.2	190.6	17.2	15.5	11.1	18.9	858.4

*Because of the many unknown site dependent constraints, the excavation and mucking function costs were arbitrarily assumed to be equal.

TABLE 9. SUBWAY TUNNEL COST BY FUNCTION, SOFT GROUND TUNNEL

CITY	EXCAVATION*	MUCKING*	SUPPORTS	LINING	UTILITIES	MISCEL.	TOTAL MILL. $
BALTIMORE	22.9	22.9	6.9	15.2	1.5	6.9	76.2
DETROIT	29.1	29.1	8.7	19.4	1.9	8.7	97.1
LOS ANGELES	49.5	49.5	14.9	33.0	3.3	14.9	165.1
SAN FRANCISCO	29.9	29.9	9.0	19.9	2.0	9.0	99.6
ST. LOUIS	113.9	113.9	34.2	75.9	7.6	34.2	379.6
WASHINGTON	39.1	39.1	**11.7	26.1	2.6	11.7	130.4
TOTAL MILL. $	284.4	284.4	85.4	189.5	18.9	85.4	948.0

*Because of the many unknown site dependent constraints, the excavation and mucking function costs were arbitrarily assumed to be equal.

**Does not include underpinning.

TABLE 10. SUBWAY STATION COST BY FUNCTION

CITY	UTILITIES	MAINTENANCE OF TRAFFIC	OTHER SITE WORK	EXCAVATION & MUCKING	BACKFILL	STRUCTURE	TUNNEL	MECHAN-ICAL	ELEC-TRICAL	MISCEL.	TOTAL MILL. $
ATLANTA	1.2	.5	.8	2.7	.1	3.4	.7	.2	.2	.1	9.9
BALTIMORE	4.8	1.9	3.0	10.4	0.6	13.2	2.5	0.7	0.7	0.4	38.3
BUFFALO	2.6	1.0	1.6	5.6	0.3	7.1	1.3	0.4	0.4	0.2	20.6
DETROIT	8.0	3.1	5.1	17.3	1.0	22.0	4.1	1.1	1.1	0.8	63.5
LOS ANGELES	18.8	7.3	12.0	40.7	2.2	51.6	9.7	2.7	2.7	1.8	149.5
PHILADELPHIA	2.9	1.1	1.8	6.2	0.3	7.9	1.5	0.4	0.4	0.3	22.8
SAN FRANCISCO	2.4	0.9	1.5	5.2	0.3	6.6	1.2	0.3	0.3	0.2	19.1
ST. LOUIS	35.3	13.7	22.4	76.2	4.2	96.7	18.2	5.0	5.0	3.4	280.3
WASHINGTON	23.6	9.2	15.0	51.0	2.8	64.7	12.2	3.4	3.4	2.3	187.6
TOTAL MILL. $	99.3	38.5	63.2	214.4	11.8	273.2	51.4	14.1	14.2	9.5	791.6

TABLE 11. TRANSIT PLANNING AUTHORITIES

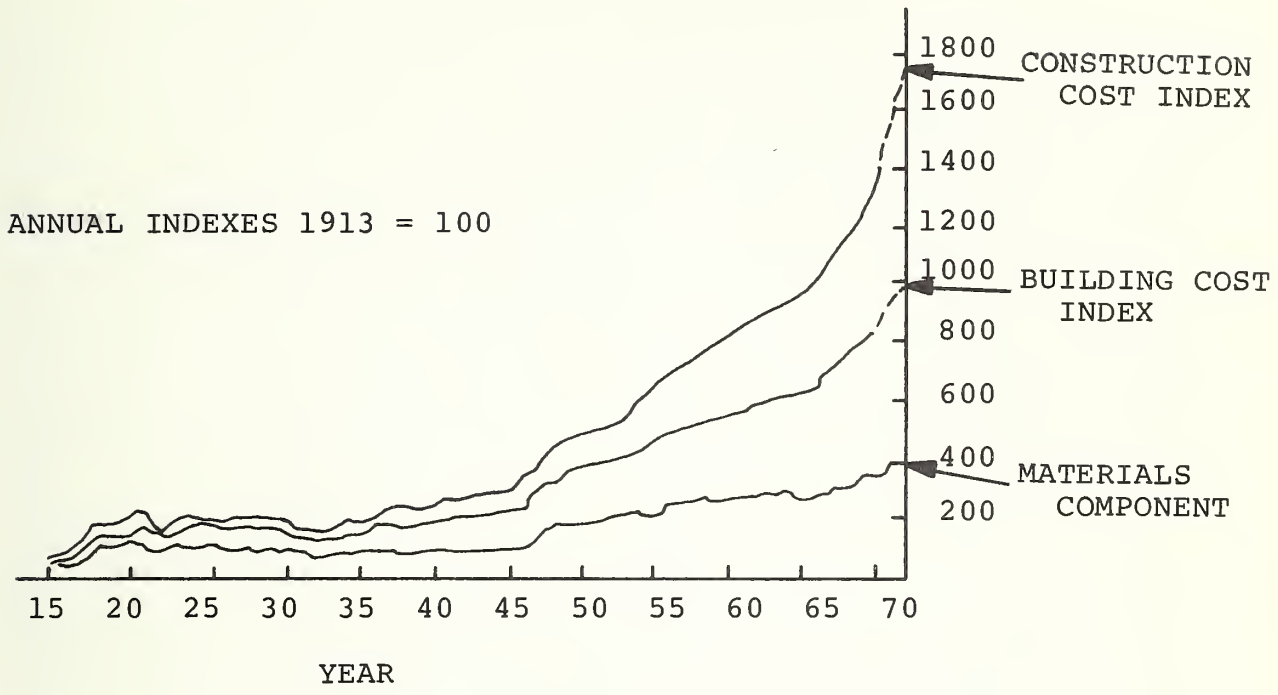
City	Authority and Person Contacted
Atlanta	Metropolitan Atlanta Rapid Transit District (MARTD) Mr. E.W. Nelson Chief Engineer (404)524-5711
Baltimore	Mass Transit Administration (MTA) Frank Hoppe (301)539-6281 Director of Engineering
Boston	Massachusetts Bay Transportation Authority (MBTA) George Duarte (617)722-6187 Planner
Buffalo	Niagara Frontier Transit Authority(NFTA) Gordon Thompson Chief Engineer (716)842-3311
Cleveland	Cleveland Transit System (CTS) Bert Stone (216)781-5000 Chief Engineer
Detroit	Southeastern Michigan Transit Authority (SEMTA) David Chaffin Chief Engineer (313)962-9800
Los Angeles	Southern California Rapid Transit District (SCRTD) Richard Gallagher Chief Engineer (213)749-6977
New York	New York City Transit Authority (NYCTA) Eugene Casey Division Engineer (212)852-5000
Philadelphia	Southeastern Pennsylvania Rapid Transit Authority (SEPTA) and Department of Public Property Robert Belfi (215)686-4496
St. Louis	Bi-State Development Agency Col. R.E. Smyser Executive Director (314)231-1727
San Francisco	Bay Area Rapid Transit District (BARTD) David Hammond Chief Engineer (415)465-4100
Seattle	Municipality of Metropolitan Seattle (METRO) William Mott Transportation Planner
Washington	Washington Metropolitan Area Transit Authority (WMATA) Vernon Garret Director of Engineering (202)484-2750

TABLE 12. LOCATION CONSTRUCTION FACTORS

Base Index: U. S. National ENR 20 Cities Averages, September 1971

Location	Construction Index	Building Cost Index
Far West		
Los Angeles	1.03	.96
San Francisco	1.07	1.09
Seattle	.90	.88
Mississippi to Rockies		
Dallas	.78	.87
Denver	.82	.96
Kansas City	1.15	.98
Minneapolis	1.07	1.01
St. Louis	1.13	.97
Middle West		
Chicago	1.12	1.07
Cincinnatti	1.14	1.04
Cleveland	1.20	1.13
Detroit	1.19	1.12
South		
Atlanta	.76	.87
Birmingham	.71	.81
New Orleans	.77	.85
Middle Atlantic		
Baltimore	.87	1.00
New York	1.32	1.21
Philadelphia	.91	1.03
Pittsburgh	1.01	1.12
New England		
Boston	1.05	1.02
Canada		
Montreal	.79	.77
Toronto	.85	.86

TABLE 13. CONSTRUCTION INFLATION FACTORS
U.S. 20 CITIES ENR AVERAGE*



Construction Inflation Factors

U. S. 20 Cities ENR Average*

Base 1913 = 100: Labor and Materials

	Construction Cost Index	Index Using 1966 Base	Building Cost Index	Index Using 1966 Base
1966	1034	1.00	655	1.00
1967	1098	1.06	687	1.05
1968	1201	1.17	755	1.15
1969	1305	1.26	802	1.23
1970	1445	1.40	866	1.32
1971	1645	1.59	990	1.51
1972	1890	1.83	1110	1.70 Est.

Source: Engineering News Record, March 1971

TABLE 14. BART SUBWAYS AVERAGE COST PER LINEAR FOOT PER TRACK

		6 CUT AND COVER LINE CONTRACTS				10 TUNNELED LINE CONTRACTS				2 ROCK TUNNELED LINE CONTRACTS				13 STATION CONTRACTS				TRANS BAY TUBE	
		MIN	MAX.	AVG.	AVG %	MIN.	MAX.	AVG	AVG %	MIN	MAX	AVG	AVG %	MIN	MAX	AVG.	AVG %	COST	%
SITE WORK	MOBILIZATION	—	$ 72	$ 31	4.7	$ 40	$365	$ 82	4.3	$ 18	$ 44	$ 22	2 1	$135	$450	$186	4 8	$ 93	3 5
	DEMOLITION AND REMOVAL	—	30	7	1.0	—	13	3	0.2	1	1	1	0.1	—	32	9	0.2	49	1 9
	TRAFFIC MAINTENANCE AND CONTROL	13	55	28	4 2	—	65	19	1.0	—	—	—	—	13	570	188	4 9	—	—
	UTILITIES BY OWNER	—	39	11	1 7	—	44	17	0 8	—	—	—	—	—	750	262	6 8	160	6 1
	UTILITIES BY CONTRACTOR	8	30	16	2.5	—	92	26	1.4	1	14	12	1 2	30	580	222	5 8	—	—
	ADJACENT STRUCTURE PROTECTION	—	4	1	0.1	1	430	56	3 0	—	6	1	0 1	—	255	77	2 0	2	0 1
	SURFACE RESTORATION	5	35	13	1 9	—	9	4	0 2	—	3	3	0 3	13	82	40	1 0	—	—
	SUBTOTAL	—	—	107	16 1	—	—	207	10.9	—	—	39	3 8	—	—	984	25.5	304	11 6
EARTHWORK	SUBWAY EXCAVATION	55	263	167	250	—	—	—	—	—	—	—	—	189	1,920	1,044	27 2	297	11 2
	SUBWAY BACKFILL	2	28	17	2 6	—	—	—	—	—	—	—	—	2	102	56	1 5	[a] 246	9 3
	INSTRUMENTATION	—	—	—	—	—	—	—	—	—	—	—	—	2	73	32	0 8	[b] 76	2 9
	SUBTOTAL	—	—	184	27 6	—	—	—	—	—	—	—	—	—	—	1,132	29 5	619	234
STRUCTURE	STRUCTURAL CONCRETE	147	269	204	30 5	—	—	—	—	—	—	—	—	185	940	614	16 0	558	21 2
	MISCELLANEOUS CONCRETE	3	38	12	1 8	—	—	—	—	—	—	—	—	2	75	31	0 8	18	0 7
	REINFORCING STEEL	51	90	69	10 3	—	—	—	—	—	—	—	—	100	395	191	5 0	143	5 5
	STRUCTURAL STEEL	—	—	—	—	—	—	—	—	—	—	—	—	—	1,450	431	11 2	575	21 9
	MISCELLANEOUS IRON AND STEEL	6	16	9	1 3	—	—	—	—	—	—	—	—	15	79	33	0 8	9	0 3
	WATERPROOFING	—	41	11	1.7	—	—	—	—	—	—	—	—	6	67	25	0 7	[c] 189	7 2
	BEARING PILES	—	91	13	2 0	—	—	—	—	—	—	—	—	—	—	—	—	[d] 39	1 5
	SUBTOTAL	—	—	318	47 6	—	—	—	—	—	—	—	—	—	—	1,325	34 5	1,531	58 3
TUNNELS	TUNNEL EXCAVATION FREE AIR	—	—	—	—	247	3,630	985	52 0	645	860	683	66 7	—	610	172	4 4	—	—
	TUNNEL EXCAVATION COMPRESSED AIR	—	—	—	—					—	—	—	—	—	—	—	—	—	—
	LINING	—	—	—	—	139	430	319	16 9	206	332	228	22 2	—	203	64	1.7	—	—
	CROSS PASSAGES	—	—	—	—	4	26	12	0 6	6	8	7	0 7	—	4	—	—	—	—
	TERMINATIONS	—	—	—	—	—	38	12	0 6	—	—	—	—	—	40	10	0 3	—	—
	INVERT CONCRETE	—	—	—	—	2	71	41	2 2	—	—	—	—	—	21	5	0 1	—	—
	MISCELLANEOUS IRON AND STEEL	—	—	—	—	3	22	11	0 6	1	9	3	0 3	—	—	—	—	—	—
	INSTRUMENTATION	—	—	—	—	—	22	9	0 5	—	4	1	0 1	—	—	—	—	—	—
	SUBTOTAL	—	—	—	—	—	—	1,389	73 4	—	—	922	90 0	—	—	251	6 5	—	—
OTHER STRUCTURES	OAKLAND VENTILATION BUILDING	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	57	2 2
	VENTILATION SHAFTS	—	—	—	—	—	675	47	2 5	—	44	7	0 7	—	—	—	—	—	—
	PORTAL STRUCTURES	—	38	13	1 9	—	370	25	1 3	—	16	13	1 3	—	—	—	—	—	—
	CROSSOVERS	—	—	—	—	—	353	60	3 2	—	—	—	—	—	—	—	—	—	—
	LINE STRUCTURES	—	59	22	3 3	—	465	135	7 1	—	—	—	—	—	—	—	—	—	—
	SUBTOTAL	—	—	35	5 2	—	—	267	14.1	—	—	20	2 0	—	—	—	—	57	2 2
FACILITIES	MECHANICAL AND DRAINAGE	4	15	6	0.9	3	17	10	0 5	18	27	19	1 8	17	345	70	1 8	38	1 4
	ELECTRICAL	10	28	17	2 6	11	31	21	1 1	11	20	13	1.3	20	144	70	1 8	71	2.7
	ARCHITECTURAL AND FINISH	—	—	—	—	—	—	—	—	—	14	11	1.1	—	122	15	0.4	10	0 4
	SUBTOTAL	—	—	23	3 5	—	—	31	1 6	—	—	43	4 2	—	—	155	4 0	119	4 5
TOTAL		—	—	$ 667	100.0	—	—	$1,894	100 0	—	—	$1,024	100 0	—	—	$3,847	100 0	$2,630	100 0

(a) FOUNDATION COURSE, BACKFILL, RIP RAP PROTECTION
(b) DIKES ENCLOSING DISPOSAL AREA.
(c) LAUNCH, TOW, SINK, JOIN AND DEWATER JOINTS.
(d) JOINTS

Notes: 1. Costs cover main heavy construction contracts only, excluding tract, traction, electrification, train control, right-of-way, engineering, financing, and administrative costs. All costs based on low bids received.
2. "Station" contracts cover "shell" construction only, excluding architectural finish, most electrical and mechanical installations, and operating equipment.
3. Trans Bay Tube covers main tube contract, two ventilation buildings, mechanical and electrical work (excluding items listed in Note 1), and cathodic protection.

TABLE 15. WMATA SUBWAY CONSTRUCTION COSTS

	CONTRACT NO.	B002		B003		B003	
	DESCRIPTION	Cut & Cover Tunnel		Cut & Cover Tunnel		Union Station - Cut & Cover	
		$1,000	%	$1,000	%	$1,000	%
Site Work	Mobilization			360.0	17.8		
	Maintenance of Traffic	120.0	1.0	20.0	1.0		
	Decking	1315.4	11.3	42.4	2.1	84.8	2.8
	Utilities	1126.9	9.7	75.6	3.8		
	Adjacent Structure Protection	994.6	8.6	232.1	11.5		
	Surface Removal & Restoration	690.3	6.0	396.8	19.7		
	Dewatering	480.9	4.2	71.5	3.5		
	SUBTOTAL	4728.1	40.8	1198.4	59.4	84.8	2.8
Earth-work	Subway Excavation	1189.8	10.3	76.9	3.8	283.5	9.3
	Support of Excavation	2670.0	23.0	219.0	10.8	486.0	15.9
	Subway Backfill	667.0	5.8	68.0	3.4	124.0	4.0
	SUBTOTAL	4526.8	39.1	363.9	18.0	893.5	29.2
Structure	Structural Concrete	1722.4	14.9	342.5	17.0	1345.5	43.9
	Miscellaneous concrete					47.3	1.6
	Reinforcing Steel	579.7	5.0	83.0	4.1	523.6	17.1
	Structural and Misc. Steel					44.3	1.4
	Waterproofing			5.7	0.3	68.6	2.2
	SUBTOTAL	2302.1	19.9	431.2	21.4	2029.3	66.2
Tunnel	Excavation						
	Rock Bolts						
	Concrete						
	Structural Steel Supports						
	Reinforcing Steel						
	Miscellaneous Steel						
	SUBTOTAL						
Facil-ities	Mechanical and Drainage						
	Electrical	20.0	0.2	25.3	1.2	55.3	1.8
	Architectural and Finish						
	SUBTOTAL	20.0	0.2	25.3	1.2	55.3	1.8
	TOTAL	11,577.0	100.0	2,018.8	100.0	3,062.9	100.0
	Length-Feet of Double Track	2400		NA		NA	
	Bid Date	3/25/70		1/25/71		1/25/71	
	Remarks						

TABLE 16. WMATA SUBWAY CONSTRUCTION COSTS

	CONTRACT NO.	C005		C005		C005	
	DESCRIPTION	Cut & Cover Subway		Rock Tunnel Single Track Tube		Rosslyn Station	
		$1,000	%	$1,000	%	$1,000	%
Site Work	Mobilization	144.7	5.2	168.6	2.1	405.3	3.9
	Maintenance of Traffic	108.8	3.9				
	Decking	96.0	3.4				
	Utilities	460.1	16.6				
	Adjacent Structure Protection	5.0	0.2				
	Surface Removal & Restoration	73.9	2.7			13.6	0.1
	Dewatering	40.0	1.4				
	SUBTOTAL	928.5	33.4	168.6	2.1	418.9	4.0
Earth-Work	Subway Excavation	198.0	7.1			6454.9	61.0
	Support of Excavation	1030.0	37.1				
	Subway Backfill	27.0	1.0			90.0	0.8
	SUBTOTAL	1255.0	45.2			6544.9	61.8
Structure	Structural Concrete	209.6	7.6	3452.0	42.7	2554.5	24.1
	Miscellaneous Concrete						
	Reinforcing Steel	250.0	9.0			725.0	6.8
	Structural and Misc. Steel					346.5	3.3
	Waterproofing	94.7	3.4				
	SUBTOTAL	554.3	20.0	3452.0	42.7	3626.0	34.2
Tunnel	Excavation						
	Rock Bolts			472.1	5.8		
	Concrete			2760.4	34.2		
	Grouting			42.9	0.5		
	Structural Steel Supports & Lagging			917.5	11.4		
	Reinforcing Steel			100.0	1.2		
	Miscellaneous Steel			152.5	1.9		
	SUBTOTAL			4445.4	55.0		
Facil-ities	Mechanical and Drainage	40.0	1.4				
	Electrical			20.0	0.2		
	Architectural and Finish						
	SUBTOTAL	40.0	1.4	20.0	0.2		
	TOTAL	2777.8	100.0	8086.0	100.0	10,589.8	100.0
	Length-Feet of Double Track	200		3689			
	Bid Date	6/9/71		6/9/71		6/9/71	
	Remarks						
	Excludes rock tunnel turnout $1,519,700						

TABLE 17. WMATA SUBWAY CONSTRUCTION COSTS

	CONTRACT NO.	C003		C003	
	DESCRIPTION	Cut & Cover Subway		Foggy Bottom Station Cut & Cover	
		$1,000	%	$1,000	%
Site Work	Mobilization	450.0	2.8		
	Maintenance of Traffic	300.0	1.8		
	Decking	1000.0	6.1	600.0	6.6
	Utilities	1930.2	11.9		
	Adjacent Structure Protection	1150.0	7.1		
	Surface Removal & Restoration	663.6	4.1		
	Dewatering	266.0	1.6	150.0	1.6
	SUBTOTAL	5759.8	35.4	750.0	8.2
Earth-work	Subway Excavation	1669.4	10.3	1697.2	18.5
	Support of Excavation	2755.0	16.9	2000.0	21.9
	Subway Backfill	743.5	4.6	404.0	4.4
	SUBTOTAL	5167.9	31.8	4101.2	44.8
Structure	Structural Concrete	4661.3	28.6	2907.0	31.8
	Miscellaneous Concrete			176.0	1.9
	Reinforcing Steel	628.6	3.9	757.3	8.3
	Structural and Misc. Steel			192.9	2.1
	Waterproofing	56.6	0.3	158.7	1.7
	SUBTOTAL	5346.5	32.8	4191.9	45.8
Tunnel	Excavation				
	Rock Bolts				
	Concrete				
	Grouting				
	Structural Steel Supports				
	Reinforcing Steel				
	Miscellaneous Steel				
	SUBTOTAL				
Facil-ities	Mechanical and Drainage			60.0	0.7
	Electrical				
	Architectural and Finish			50.0	0.5
	SUBTOTAL			110.0	1.2
	TOTAL	16,274.2	100.0	9153.1	100.0
	Length-Feet of Double Track	2106		770	
	Bid Date	6/2/71		6/2/71	
	Remarks				

TABLE 18. WMATA SUBWAY CONSTRUCTION COSTS

	CONTRACT NO.	A001		A001		A002	
	Description	Cut & Cover Tunnel		Metro Center Station 2 level transfer station		Earth Tunnel Twin Tubes	
		$1,000	%	$1,000	%	$1,000	%
Site Work	Mobilization	450.0	2.9			500.0	7.0
	Maintenance of Traffic	743.9	5.0				
	Decking	465.8	3.0	1436.7	6.7		
	Utilities	3062.7	20.0				
	Adjacent Structure Protection	4941.6	32.3				
	Surface Removal & Restoration	631.7	4.1				
	Dewatering	212.9	1.4	1042.6	4.8	437.8	6.1
	SUBTOTAL	10,508.6	68.7	2479.3	11.5	937.8	13.1
Earth-work	Subway Excavation	582.0	3.8	2021.3	9.4		
	Support of Excavation	1237.7	8.1	3197.1	14.8		
	Subway Backfill	349.8	2.3	458.6	2.1		
	SUBTOTAL	2169.5	14.2	5677.0	26.3		
Structure	Structural Concrete	1822.9	11.9	8781.5	40.7		
	Miscellaneous Concrete			314.0	1.4		
	Reinforcing Steel	377.8	2.5	3008.7	13.9		
	Structural and Misc. Steel			683.8	3.2		
	Waterproofing	224.0	1.4			4.0	0.1
	SUBTOTAL	2424.7	15.8	12,788.0	59.2	4.0	0.1
Tunnel	Excavation					4961.3	69.6
	Rock Bolts						
	Concrete						
	Grouting					165.8	2.3
	Structural Steel Supports					731.8	10.3
	Reinforcing Steel						
	Miscellaneous Steel					329.9	4.6
	SUBTOTAL					6188.8	86.8
Facil-ities	Mechanical and Drainage			10.0	0.1		
	Electrical	24.0	0.2				
	Architectural and Finish			635.0	2.9		
	Temporary Bunkhead	172.2	1.1			2.0	-
	SUBTOTAL	196.2	1.3	645.0	3.0	2.0	-
	TOTAL	15,299.0	100.0	21,589.3	100.0	7132.6	100.0
	Length-Feet of Double Track	1022		1647		2188	
	Bid Date	6/17/70		6/17/70		12/2/69	
	Depth	40-45'					
	Soil Conditions	Silty & Sandy Clay		Silty & Sandy Clay		Silty & Sandy Clay	
	Remarks						

TABLE 19. WMATA SUBWAY CONSTRUCTION COSTS

	CONTRACT NO.	A003		A003		A004		A004	
	Description	Cut & Cover Tunnel		Farragut N. Station Cut & Cover		Rock Tunnel		DuPont Circle Station - Rock Tunnel Station	
		$1,000	%	$1,000	%	$1,000	%	$1,000	%
Site Work	Mobilization	250.0	2.1			600.0	13.8		
	Maintenance of Traffic	260.0	2.2	740.0	7.3	150.0	3.4		
	Decking	605.0	5.1						
	Utilities	2108.9	17.6			15.0	0.3	443.0	6.9
	Adjacent Structure Protection	1100.0	9.2						
	Surface Removal & Restoration	759.5	6.3					63.1	1.0
	Dewatering	224.7	1.9	209.0	2.1	20.0	0.5		
	SUBTOTAL	5308.1	44.4	949.0	9.4	785.0	18.0	506.1	7.9
Earth-work	Subway Excavation	1321.7	11.1	1357.7	13.5			251.2	3.9
	Support of Excavation	785.8	6.6	2150.0	21.3			62.9	1.0
	Subway Backfill	1650.0	13.8	463.2	4.6				
	SUBTOTAL	3757.5	31.5	3970.9	39.4			314.1	4.9
Structure	Structural Concrete	2398.5	20.1	2943.1	29.2			1492.7	23.4
	Miscellaneous Concrete			230.9	2.3			1.3	-
	Reinforcing Steel	426.4	3.6	1503.8	14.9			316.8	5.0
	Structural and Misc. Steel	0.7	-	351.8	3.5			42.0	0.7
	Waterproofing	37.7	0.3	127.0	1.3	21.9	0.5		
	SUBTOTAL	2863.3	24.0	5156.6	51.2	21.9	0.5	1852.8	29.1
Tunnel	Excavation					1392.3	32.0	3303.6	51.9
	Rock Bolts					233.0	5.4		
	Concrete					1490.1	34.3		
	Grouting					79.1	1.8		
	Structural Steel Supports					158.0	3.6	384.0	6.0
	Reinforcing Steel					114.7	2.6		
	Miscellaneous Steel					27.5	0.6		
	SUBTOTAL					3494.7	80.3	3687.6	57.9
Facil-ities	Mechanical and Drainage							10.0	0.2
	Electrical					50.0	1.2		
	Architectural and Finish								
	Temporary Bulkhead	17.0	0.1				-		
	SUBTOTAL	17.0	0.1			50.0	1.2	10.0	0.2
	TOTAL	11,945.9	100.0	10,076.5	100.0	4351.6	100.0	6370.6	100
	Length-Feet of Double Track	1838		770		4000		770	
	Bid Date	9/23/70		9/23/70		5/11/71	5/11/71		
	Depth (Ground Surface to Top of Rail)								
	Soil Conditions								
	Remarks								

REFERENCES

1. Atlanta, Metropolitan Atlanta Rapid Transit Plan, engineering report summarizing transit plan for Atlanta by Parsons, Brinckerhoff-Tudor-Bechtel, September, 1971.

2. Baltimore, Phase I Rapid Transit Plan, prepared by MTA, May, 1971.

3. Buffalo, Appendix 4 and 6 from Niagara Frontier Mass Transit Study, TEI Consulting Engineers, Inc.

4. Detroit, Woodward Rapid Transit Project Definition Report, engineering report by Louis Klander, consulting engineers, August 15, 1971.

5. Development of a U.S. Department of Transportation R&D Program Plan for Tunneling, report on potential areas for future R&D in transportation tunneling, March, 1971.

6. Fenix and Scisson, A Systems Study of Soft Ground Tunneling, U.S. Department of Transportation, May, 1970.

7. Kuesel, T.R., "Subway Construction Costs", report on tunneling costs for BARTD prepared by Parsons, Brinckerhoff-Tudor-Bechtel, April, 1970.

8. Los Angeles, Appendix A of the Final Report, appendix to the final report by Kaiser Engineers, May, 1968.

9. Los Angeles, Preliminary Foundation Investigation, soils study by LeRoy Crandall & Associates, April, 1968.

10. Los Angeles, SCRTD Final Report, transit report by Kaiser Engineers, May, 1968.

11. Mayo, Roberts, Tunneling - The State of the Art, U.S. Department of Housing and Urban Development, January, 1968.

12. RMC, Inc., Draft of report on transportation guideway costs, December 23, 1971.

13. St. Louis, Engineering report by Parsons, Brinckerhoff-Tudor-Bechtel, August, 1971.

14. Seattle, The Rapid Transit Plan for the Metropolitan Seattle Area-Technical Appendix, engineering report by DeLeuw, Cather and Company, March, 1970.

REFERENCES (CONTINUED)

15. Tunneling Cost Analysis, report with tabulated tunnel costs, by RMC Inc. for Federal Railway Administration, Office of High Speed Ground Transportation. Report No. FRA-RT-71-73, 1971.

16. Urban Transit Development in Twenty Major Cities, Automobile Safety Foundation, March, 1968.

17. Washington, Final Report, Subsurface Investigation Volumes 1-3, soils report on Authorized Basic System by Meuser, Ruteledge, Wentworth & Johnston, December, 1967.

18. Washington, Final Report, Subsurface Investigation, Volume 4 and Appendix A, soils report on Authorized Basic System by Meuser, Ruteledge, Wentworth & Johnston.

19. Washington, Preliminary Design and Capital Costs, engineering report by DeLeuw, Cather & Co. on Added Regional Lines, February, 1968.

20. Washington, Preliminary Subsurface Investigation, preliminary soils report by Meuser, Ruteledge, Wentworth & Johnston on the Added Regional Lines, February, 1969.

21. Washington, Bid Tabulations for Contracts 1A001, 1A0021, 1A0031, 1A0043, 1A0044, 1B0021, 1B0032, 1C0031, and 1C0051.