Report No.

TUNNELING

The State of the Industry

Prepared by

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FINAL REPORT
MAY 1976

Prepared for
US DEPARTMENT OF TRANSPORTATION
OFFICE OF THE SECRETARY
Washington DC
20590

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle TUNNELING: The State Of The Industry		5. Report Date May 1976 6. Performing Organization Code
		8. Performing Organization Report No.
7. Author(s) R. S. Mayo, J. E. Barrett & R. J. Jenny		
9. Performing Organization Name and Address Cresheim Company, Inc. 1408 E. Mermaid Lane, Philadelphia PA, 19118 (215) 836-1400		10. Work Unit No. (TRAIS) 11. Contract or Grant No. DOT-TSC-1091
12. Sponsoring Agency Name and Address U. S. Department of Transportation Office of the Secretary Washington, DC, 20590		13. Type of Report and Period Covered Final Report July 75 - May 76 14. Sponsoring Agency Code DOT-TST-45

15. Supplementary Notes

16. Abstract

Tunneling is examined as an industry. The demand for its services, makeup of the industry, some history, and its problems and prospects are analyzed. Industry participants are listed: owners, engineer firms, tunnel builders and specialized suppliers. How business is obtained, an estimate prepared, and a project conducted are described. Decision making and risk management with private, public, and multi-industry tunnel building firms is described and analyzed. Manpower, technology and R & D needs are reviewed. Coverage is for transport, water and sewer tunnels with emphasis on rapid transit.

17. Key Words

Underground construction; Business aspects of tunneling; Mass transit; Management, tunnel construction; Risk management; Demand for tunnels; Suppliers; R&D Nees, tunneling.

19. Security Classif. (of this report)	20. Security		Price
None	None		

Form DOT F 1700.7 (8-72)

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PREFACE

The tunneling industry is an important yet relatively unknown segment of the U.S. heavy construction industry. To effectively plan and organize major transportation projects for which it is responsible, the U.S. Department of Transportation had to know more about the structure of the industry.

Initially, we were concerned with the capacity of the industry. During the course of the study, we perceived that greater emphasis should be placed on the risks in tunneling. Our technical monitor, Dr. Robert E. Thibodeau of the Transportation Systems Center, and our sponsor, Russell K. MacFarland, of the Office of the Secretary of Transportation, supported this change of direction.

The information contained in this report will be of interest to governmental agencies, contractors, engineers and suppliers. It describes where the industry has been, where it is now, and where it may go. We have found that the personal experience and judgment of the members of the tunneling fraternity have had a major influence on the development of the industry. While this condition is not amenable to analysis within the scope of this study, it is noted and should be considered.

We gratefully acknowledge the assistance of our colleagues who provided vital input to the study:

James E. Barrett, III, Robert W. Luce, Elfreida (Freddie) Roth and G. Park Rouse, III of Cresheim Company.
Thomas E. Krakowski of Jenny Engineering Corporation.
Joginder S. Bhore of Greenfield Construction Company (formerly of Woodward-Clyde Consultants).
Dennis Lachel of Woodward-Clyde Consultants.

Data on tunnels built and planned was furnished by the many people listed in Appendix I to whom we wish to express our appreciation. More than 100 people assisted us in the contractor study; six in the insurance and bonding study; and over fifty people helped with the engineering firm study. Many of them provided candid comments and confidential information on a not-for-attribution basis, so we have had to omit entire categories of people while acknowledging to them personally our indebtedness.

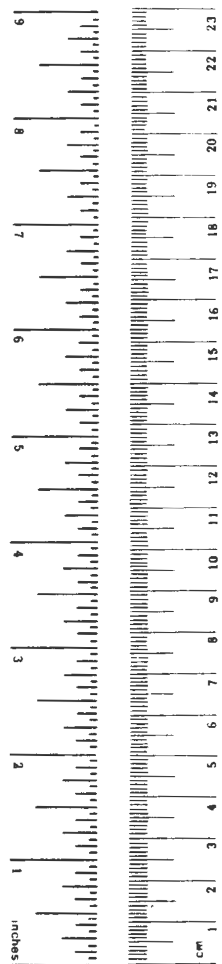
Robert S. Mayo James E. Barrett Robert J. Jenny

Philadelphia, Pa.
May 1976

METRIC CONVERSION FACTORS

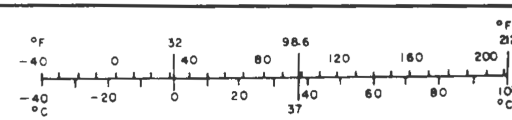
Approximate Conversions to Metric Measures

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

LIST OF ILLUSTRATIONS AND TABLES

LIST OF ILLUSTRATIONS AND TABLES (cont'd)

DEFINITIONS, CLASSIFICATIONS AND ABBREVIATIONS

Listed below are some words, information classifications and abbreviations or acronyms used prominently in this report. The definition which is applied in this report is shown below.

TUNNEL. Webster defines tunnels as subterranean passages. A recent conference group developed this definition: "Tunneling: construction by any method of a covered cavity of predesigned geometry whose final location and use are under the surface and whose cross-sectional area is greater than two square meters."

This report uses this definition: A tunnel is a subterranean passage used for transporting people or things which has been built by tunneling methods: excavating, boring, or cut and cover. Minimum size is 8 feet outside diameter.

Included are: rapid transit lines, even if box-built in an open cut; sunken tubes for harbor tunnels built by marine contractors; and underground power plants and facilities that involve combined tunnel building and mine construction. Excluded are: sewer or water lines built in open cut; highway underpasses; pipe-jacking types of construction; pipelines; and storage caverns excavated underground.

USE OF TUNNEL. These classifications are used in this report.

- A - Access tunnels
- MV - Highway vehicle tunnels
- RR - Railroad tunnels, principally freight
- RT - Rapid transit rail cars or light rail vehicles
- S - Sewer, sanitary, or drainage tunnels
- W - Water supply tunnels

CONSTRUCTION METHOD CLASSIFICATIONS

1. Cut & cover tunnels (traffic maintained overhead)
2. Rock tunnels
3. Soft ground tunnels
4. Sunken tubes tunnels (under rivers and harbors)

CONSTRUCTION NOTES. Because of technical and economic interest, the following are noted when known to be present:

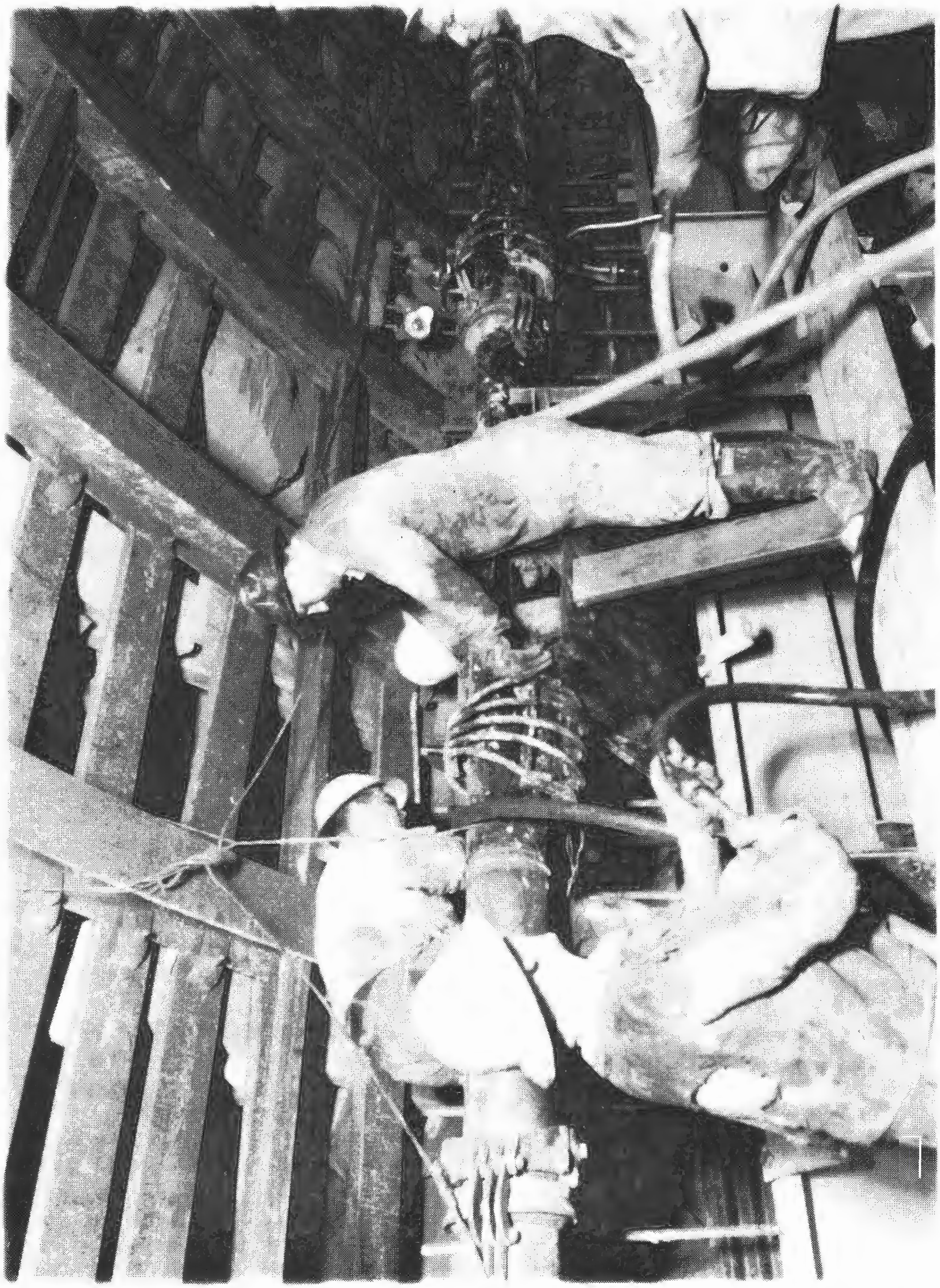
1. Compressed air in use
2. Drill & blast method
3. Mole equipment in use
4. Shield-driven method

ABBREVIATIONS AND ACRONYMS

BART	-	Bay Area Rapid Transit Authority, San Francisco
BuMines	-	Bureau of Mines, U. S. Dept. of Interior
BuRec	-	Bureau of Reclamation, U. S. Dept. of Interior
BWPC	-	Bureau of Water Pollution Control, New York City
BWS	-	Bureau of Water Supply, New York City
CTA or CUT	-	Chicago Transit Authority or Urban Transit
C of Eng	-	Corps of Engineers, U. S. Army
DOT	-	Department of Transportation, United States*
DRT	-	Denver Rapid Transit
FHA	-	Federal Highway Administration
GCMSD	-	Greater Chicago Metropolitan Sewer District
JV	-	Joint Venture
MARTA	-	Metropolitan Atlanta Rapid Transit Authority
MBTA	-	Massachusetts Bay Transit Authority, Boston
METRO	-	Metropolitan Baltimore Rapid Transit
MWD	-	Metropolitan Water District of So. Calif., Los Angeles
NYCTA	-	New York City Transit Authority
NYMTA	-	Metropolitan Transit Authority for New York City Region
PATCO	-	Philadelphia to Lindenwold, N. J. Port Authority Line
PATH	-	Port Authority Trans Hudson Lines N. Y. & N. J.
SCRTD	-	Southern California Rapid Transit District, Los Angeles
SEPTA	-	Southeastern Penna. Transportation Authority, Philadelphia
SFWD	-	San Francisco Water Department
TSC	-	Transportation Systems Center of DOT
UMTA	-	Urban Mass Transit Administration of DOT
WMATA	-	Washington Metropolitan Area Transit Authority

* There are 51 entities referred to as DOT, as that abbreviation is also used at the state government level.

HARD GROUND AND SOFT GROUND TUNNELS. There is considerable disagreement and numerous attempts to arrive at a generally accepted definition have not yet borne fruit. For purposes of this report, hard ground is any earth formation that will stand by itself after excavation long enough to get the supports in. Anything else is soft ground.



View showing ribs and lagging, slick line and concreting crew.

Chapter 1

SUMMARY

The recent construction experience in transportation related tunnels has been disastrous. Federally funded projects have encountered price escalation, delays and disruptions, litigation, and erosion of local political support. Demand projections in this report indicate that there will be another ten years of high demand levels for overall tunneling, given Federal support. There is now a serious question as to whether the Government can or should finance more transportation tunneling to relieve the urban transportation problem.

This report assesses the structure and capacity of the U. S. tunneling industry, with an emphasis on transportation tunnels. Historical and future demand is charted for the period 1955 through 1985. Owners, engineering consultants and construction contractors are described. Corporate decision making in these firms is examined. Because the report looks at tunneling as a commercial as well as a technological enterprise and because it treats the people as rational decision makers, it shows clearly that the main problems in the industry are not technological. It is the primary conclusion of this report that in transportation tunneling, an institutional system has evolved which strongly discourages innovation in design or practice. Little improvement in productivity will occur until two facets of this system are addressed: Accountability and Risk Sharing.

As one response to these two facets, the report recommends a peer review system in the design step, which is probably the most important step in terms of final costs. Other recommendations include the coordination of Federal R & D with industry needs, the smoothing of overall demand, the use of contractual risk sharing, the development of broader graduate programs, and the development of measurement methodology for productivity.

Exhibit 1-A **Working at the heading in a soft ground tunnel.**

Chapter 2

OVERVIEW OF THE REPORT

The need for this study emerged when it became obvious that current rapid transit tunneling projects were encountering severe price escalation. Could the industry meet great anticipated demand without further inflationary impact? The purpose of this study was to answer this question by analyzing the capacity of the industry.

Statistical information about tunnels traditionally has been combined with that about bridges or with information about all forms of underground construction. Tunnel construction is not a separate information category, but it is generally known that the mix of tunnel work has moved from rural to urban jobs and from water to transportation end uses. Given the differences in these operating environments, the paucity of good information about the dimensions of the industry became more important.

There has been a major increase in urban transportation construction in the two decades from 1955-1975. In the first ten years of that period the emphasis was on roadbuilding, with much of the stimulus related to the Interstate Highway program. That vast enterprise, while largely rural in mileage, included many major urban segments and connectors. In addition, the states and cities built expressways and other supporting roads to supplement the Interstate System.

While the roadbuilding program was underway, it became apparent that the highway program alone would not suffice for urban areas as it does in the countryside. The individual choice, speed, comfort, flexibility and other advantages offered by automobile and truck travel in the countryside on the new highways somehow kept translating themselves into problems in the cities. Building the highway was not enough; one had to provide parking places for cars and workspace for trucks as they came off the highways.

UNDESIRABLE SIDE EFFECTS IN THE CITIES

As attempts to cope with these undesirable side effects were put in place, the central areas of many cities began to look as though they had been ravaged by a war. Cries arose that the automobile is the enemy of the city and that long declining rapid transit systems would have to be restored or new ones planned and built. Surveys and studies repeatedly showed that there would not be enough ground area in the cities to provide for roads, parking and related activities. Transportation had to include use of space either above or below the ground.

A number of elevated highways supplemented those at ground level, always accompanied by furious opposition. On balance, underground construction has been much more acceptable to those affected than elevated works. In the dozen largest cities, plans were made to develop or to refurbish rapid transit systems involving trains and tunnels. By 1965, San Francisco was the scene of a commitment to a major, brand new regional rapid transit system. In the decade that followed the cities of Washington, Atlanta and Baltimore committed themselves to build large-scale brand new rapid transit systems.

As this enormous effort got underway, questions arose. Those leading to this study included:

1. WHERE ARE THE POTENTIAL BOTTLENECKS IN URBAN TRANSPORTATION CONSTRUCTION? There were several answers. One that was crucial and lacked facts: tunneled construction.

2. HOW MUCH TUNNEL BUILDING COULD THE TUNNEL INDUSTRY TAKE ON AND COMPLETE IN THE COMING DECADE? Some earlier estimates had indicated that volume might be quadrupled in a decade.

3. WHAT OTHER DEMANDS FOR THE SAME RESOURCES WILL EXIST AT THE SAME TIME? Plans for tunnels for water, sanitary uses, or other functions could compete for men and equipment. The rapid growth of coal mine demand due to oil supply changes might affect engineers and equipment.

4. WHAT IS THE EXPANSION CAPABILITY OF THE INDUSTRY? Can companies enter tunnel construction work easily?

5. WHAT ARE THE DIMENSIONS OF THE TUNNELING INDUSTRY? Who is in it? Why? Are they well-managed firms? Is new technology important? What are the current and prospective problems of the industry?

6. WHAT TYPE OF ORGANIZATION IS MOST EFFECTIVE? Individual firms or joint ventures? Public or private ownership? Broad-based or specialist?

7. WHO ARE THE PARTICIPATING FIRMS and what types of employees are on a tunnel project? What are their traditional relationships? How are these changing? What overlaps of division of work, technology, or performance are evident or foreseeable? Can we anticipate shifts in organizational relationships or modifications of job classification from current trends?

8. WHAT IS THE ECONOMIC HEALTH OF THE INDUSTRY? Is it made up of undercapitalized firms, supported with too little enthusiasm by banks, investors and insurers? Are the larger healthy firms likely to retain a commitment to tunnel work? To what incentives do they respond? To what degree are they willing to forego large profits to be involved in technically advanced projects?

9. IS THE SUPPLY OF PEOPLE ADEQUATE in competence and in numbers? How transferable are the skills involved? Are social trends among young professionals that show a lessened willingness to accept family mobility a threat to this industry?

10. HOW HAVE THE INDUSTRY'S COSTS BEEN AFFECTED RECENTLY? Are they especially vulnerable to inflation?

Our response to these questions has been to investigate the fundamental technological and commercial relationships which influence the supply of tunneling services. Particular emphasis is placed on urban transit tunnels. The report consists of 17 chapters.

Chapters 1 and 2 are introductory. Chapters 3 through 7 provide a general description of the industry. Chapter 3 examines basic demand patterns and describes the important sub-markets, such as water and sewer tunnels. Historic trends are traced and projections through 1985 are shown. Chapter 4 explains what happens on a tunnel job and what the responsibilities are for each major participant. In the remaining chapters, the relationships during a job and the normal sequence of work events is examined in detail. Different management approaches to tunnel projects, such as the BART or WMATA methods, are reviewed.

Chapters 8-11 move from a general functional level to a thorough analysis of the firms (including owners) in the industry. Extensive material is presented for active owners, engineers, contractors, and suppliers. The general characteristics of these organizations are shown, as well as the recent trends in their tunneling activity. These chapters, in effect, list the current capacity of the tunneling industry.

By now the basic industry setting has been established. The technology and the market relationships have been described in simple terms. Chapters 12 through 14 examine the critical management decisions made in the industry, such as the design of a tunnel, the bid decision, and the investment in research and innovation. For each of these decisions the attitude of the decision-maker and the relative rewards and costs are examined. Risk, a pervasive element in the industry is considered in some detail as it affects these decisions. Chapters 15 and 16 present description and comment on three forces which determine the industry's ability to expand output. These are the supply of qualified professionals for the key jobs, the extent of innovation in equipment and materials, and the entry of new firms into the industry.

Throughout the report, factors which influence expansion in the industry have been highlighted. These items are summarized in Chapter 17 and their policy implications stated. Policy recommendations are proposed for DOT which would provide the proper incentives to increase capacity in the industry.

The report does not, and was not intended to, cover two important areas. First, although it reviews existing technology and costs at a general level, it is not a technical report on equipment as such. Cost models are not developed, nor are cost/benefit ratios shown for specific technical investments. The authors feel that there is an abundance of such work being done. The missing research has been in the understanding of why industry participants behave as they do. No one has accurately assessed, for example, the rewards and costs to owners, engineers, and contractors resulting from innovative tunnel design. A primary purpose of this report is to properly describe this and other critical decisions in the industry so that DOT can use more intelligent incentives in the quest for efficiency and innovation.

The other omission is the avoidance of the question: Should these tunnels be built at all? This question is obviously the fundamental one in a decision to spend public funds. The authors feel that insuring a supply of full and accurate information to the political process is the most important research step at present. By encouraging efficiency and innovation in the tunneling industry, this work will lead to more realistic prices for tunnel projects versus other public works. That, in turn, will help in the political-process decision making.

DEMAND FOR TUNNELS IN THE UNITED STATES

The next decade will be a busy one for the tunnel construction industry. Activity from 1975-1985 will be about the same as that in the 1965-75 period, but with a substantial shift in end-use market segments. Transportation tunnels will be up and water tunnel volume will be down.

On a linear-feet-of-tunnel-driven basis, the 1965-75 period was the most active for tunneling ever recorded in the United States. Water supply projects in the west provided the bulk of this work, with significant transportation contributions from the subway systems of San Francisco and Washington, D. C. This volume will drop from an estimated 1,347,700 linear feet of tunnel driven in 1965-75 to an estimated 1,128,795 linear feet in 1975-85.

However, as Exhibit 3-C shows, this will actually mean relatively similar tunnel excavation volume in the forthcoming ten years. This is based on cubic yards of tunnel to be built rather than on the simple total of linear feet of tunnel driven. The cause is that most 1975-85 tunnel work is in the larger dimensioned rapid transit tunnels underway or planned in Washington, Atlanta and Baltimore. Rapid transit tunneling is in lusty health while other end-uses are in sharp decline.

On the basis of present information and estimates, the 1985-95 decade will see less tunnel volume (as rapid transit systems are completed). However, we believe that forecasts beyond ten years must be viewed skeptically since so many factors can influence them.

EXHIBIT 3-A TUNNEL BUILDING DEMAND BY DECADE

(Expressed in linear feet of tunnel driven)

Tunnel End Use	1955-65 Actual Ft.		1965-75 Actual Ft.		1975-85 Estimate Ft.	%
Rapit Transit	2,900	0.2	211,200	16.	346,000	30.7
Water & Sewer	902,900	93.3	1,108,300	82.	696,700	61.8
Motor Vehicle	46,700	4.8	28,200	2.	51,195	4.5
Railroad	15,700	1.7	0		5,000*	.4
Other+	N.A.		N.A.		29,900+	2.6
Total	968,200	100	1,347,700	100	1,128,795	100

*The only railroad tunnel now planned is in Philadelphia to connect the Reading and Penn Central commuter lines into one network. It is therefore a rapid transit link, though in railroad lines.

+Two tunnels for Seabrook, N. H. nuclear power station.

Source: Cresheim surveys. See Appendix A for survey detail.

SOME BACKGROUND ON TUNNEL DEMAND

Later in this chapter the thirty-year trend lines by end-use market segment are shown and discussed. However, before studying those, it is useful to consider some unique aspects of tunnels and their planning, financing, and construction which influence the demand for tunnel construction in significant ways. A brief historical excursion will be worthwhile.

The planning and building of tunnels has been part of the business of heavy construction for centuries. Early uses involved mining and water transmission. Beginning in the nineteenth century transportation tunnels for freight and passengers became economically feasible. These began with canal tunnels in 1820, progressed to railroad tunnels from 1831, vehicle tunnels in 1866 (Washington St. tunnel under the Chicago River), and urban rapid transit tunnels about 1890. The only new end-uses since then have been tunnels for sewers and for power-generation.

Like bridges and dams, tunnels are on the romantic side of heavy construction. They are expensive, risky in all dimensions, and have enormous economic and social impact upon completion. Once successfully built, they last a long time. Roman water aqueducts built before the Christian era are still in use. The oldest American tunnel, built on the Union Canal near Lebanon, Pa. in 1827, is still usable, though it is now a civil engineering monument.

Many railroad tunnels in the 70-100 year-old age range are still in active daily use. Senior among these is the Boston and Maine Railroad's Hoosac Tunnel through the Berkshires in western Massachusetts. It was begun by a private group in 1854 and completed by the Commonwealth of Massachusetts in 1876. Both dynamite and power drills had their first practical application in tunnel driving on the Hoosac job. Freight trains use its 25,000 ft. length daily.

The Baltimore Belt Tunnel of 1891, providing more than a mile and a half of underground, double-tracked capacity, is part of the main line of the Baltimore and Ohio Railroad. This uses a five-ring brick arch for support. The Haskins Tunnel, begun in 1876, stalled from 1882-1902 for lack of money, and finally completed in 1905 as part of the "Hudson Tubes" is still in daily service on the New Jersey to New York runs of the Port Authority Trans Hudson lines.

All of the rapid transit tunnels built in American cities in this century are in use with minor exceptions due to route changes. Transit construction engineers regard this long life as standard and are very conservative in their designs.

Transportation tunnels respond to desires for ease of movement. Many of them are ways to connect places otherwise difficult to reach. Urban tunnels relieve surface congestion. Tunnels through mountains eliminate the time-consuming trip up, over, and down the natural barrier between two points. A few tunnels have major economic and military implications. One of the leaders in that category is the proposed channel tunnel to connect England and France: a century-old dream.

Utility tunnels respond to needs to bring in water or to remove water or sewage. The twin demand forces for these tunnels are population growth and nature's weather cycle. A prolonged drought has the same effect on water tunnel work as does considerable population growth.

Substantially all tunnels today are publicly financed projects. Their enormous costs, cost overruns, and problems related to scale, site complexity or public doubt about the desirability of any given project all are continuations of century-old trends.

HOW THE DEMAND FIGURES WERE DEVELOPED

Staff members of financing, grant, and owner-operator agencies were interviewed. Their estimates of future timetables seem quite reliable, particularly when they related their estimates of future work to events of the past few years. Representatives of several agencies described their original timetables and revisions or abandonments due to defeats of referenda and bond issues or to lack of legislative support at the local or state level.

Levels of construction activity for each of the principal end uses (see exhibits) are based on information reported to us by tunnel owners and operating agencies. The graphs illustrate relative levels of activity for the period 1955 through 1985, and should <u>not</u> be interpreted as showing actual number of linear feet driven in any calendar year. Data reported to us was based on year tunnel was put in service, or year the project was completed, as determined by the operating agency. There is an obvious distortion if the entire length of a tunnel is shown as being the product of one year's work, (that in which it was finished).

To minimize this effect where the length of the construction period was known, in round years, the tunnel was recorded as being built in equal segments during those years. For example, a 40,000' tunnel reported complete in 1972 and taking 4 years to build would be recorded as 10,000' in 1969, 1970, 1971 and 1972. In cases where the length of the construction period was not available, two years was used. The area most subject to errors of omission is the water and wastewater tunnel construction in smaller communities. Any such inadvertent omissions are not believed to materially affect or distort the trend lines and projections.

SIZE OF THE MARKET IN MONEY TERMS

Dollar revenue is difficult to develop with accuracy. Using the high and low ranges of tunnel revenues reported by firms active in the business (Appendix C) suggests actual revenues for 1975 for U. S. tunnel building of between $1.2 and $2.2 billion. This would account for 5-10% of all domestic heavy construction.

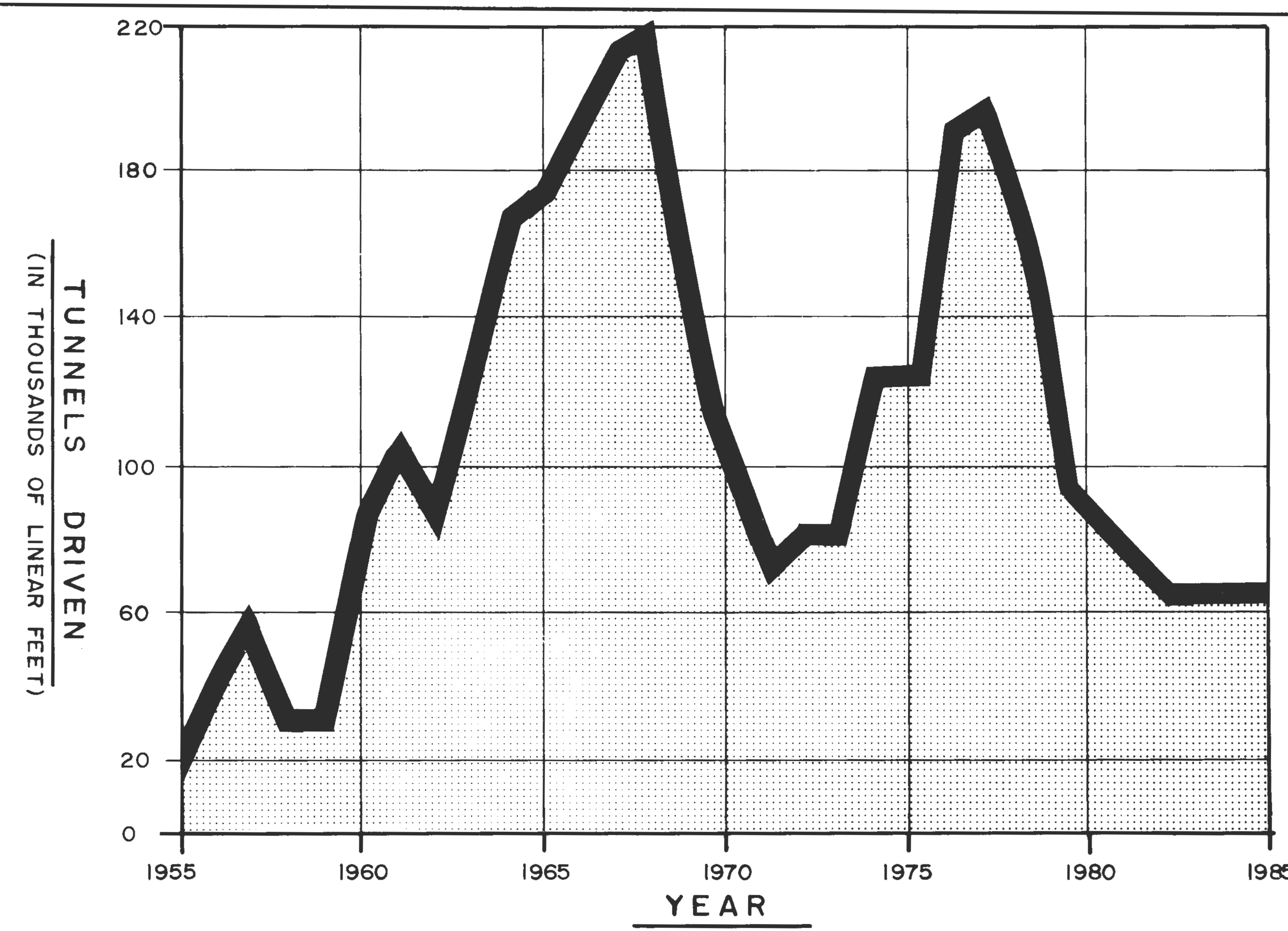
Contractors traditionally have been very secretive. Our sources are contractors or their employees. The publicly held firms who file reports with the Securities and Exchange Commission all are in other businesses in addition to tunneling. Where the larger firms provided line-of-business information it was at the level of "construction revenues" and not further subdivided. Heavy construction is expected to have a compound growth rate of 8.7% in the 1974-80 period, based on Handbook of Economic Statistics data. This estimate excludes all international work by domestic firms.

Also, it has to be emphasized again that the planning, financing and construction cycle for tunnel projects makes information for the forthcoming five years fairly reliable. This does not apply farther in the future. As shown in the rapid transit data, there has been a continuing softening of forecasts of demand in that area. Water tunnel demand is down now but sharp changes in birthrates or weather would modify that.

Some nuclear power plants include tunnels and the rate of construction of these is quite uncertain. The forthcoming election in California (June 1976) may provide a good indicator since there is an initiative petition on the general ballot raising the question of public policy on construction and operation of nuclear power plants. Some of this construction is very significant for industry work. A current project, for example, is the Seabrook, N. H. cooling tunnels to be built from the seashore power plant under the Atlantic Ocean. The intake tunnel is to be 13,500 feet and the discharge tunnel will be 16,400 feet, both with 21 foot diameter. Contract value is $68,000,000.

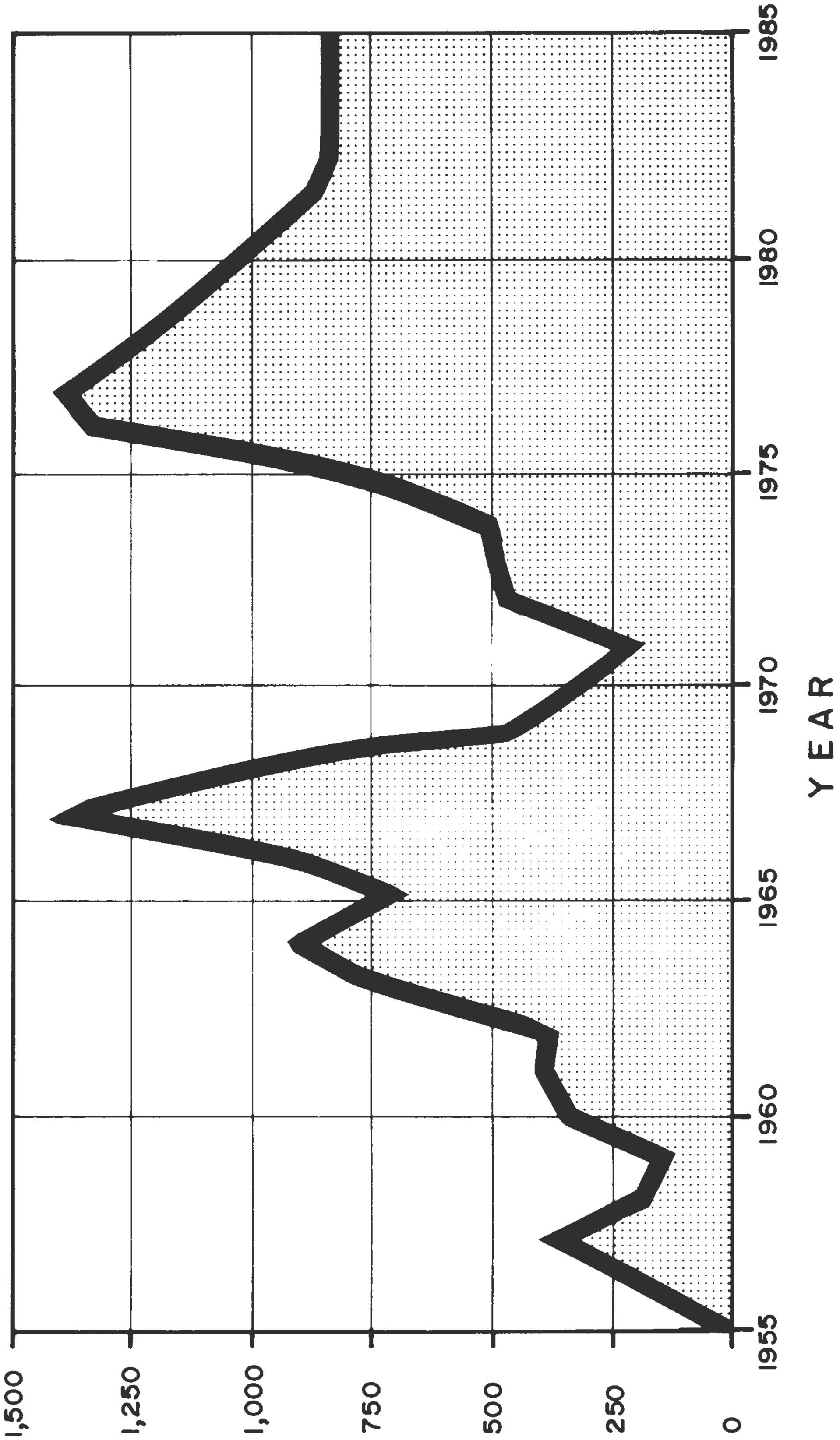
The continuing supply problems in energy and raw materials were considered in these demand projections. After some study, it was concluded that direct impact on underground construction will be in materials and equipment costs in the next ten years. Beyond that, the effects of these changes are mainly questions of economics on the national scale.

General economic growth trends and population movements probably will be of only tangential importance to many agencies involved in tunneling. Those engaged in large scale projects, such as the Greater Chicago Metropolitan Sanitary District, are probably not expecting any calamitous change in their demographics and will probably not be forced to materially change their plans.



LINEAR FEET OF TUNNELS DRIVEN
1955 - 1985

EXHIBIT 3-B SOURCE: CRESHEIM CO. STUDY, 1975



TUNNEL CONSTRUCTION ACTIVITY
CUBIC YARDS OF EARTH EXCAVATED
ALL END USES 1955-1985

TUNNELING EARTH EXCAVATION
(IN THOUSANDS OF CUBIC YARDS)

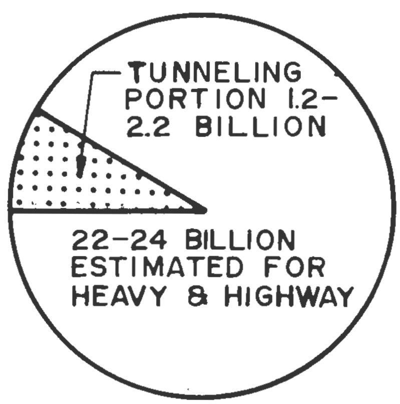
 SOURCE: CRESHEIM CO. STUDY, 1975

In comparing Exhibits 3-B (Linear Feet of Tunnels) and 3-C (Cubic Yards of Earth Excavated) the reader will note that either view of industry volume still results in sharp peaks and valleys. Due to the way the trend lines were developed (described on Page 3-3), some of the peaks and valleys may be sharper than shown. Those firms participating in the industry adopt policies and practices that allow them to survive in this environment and those developments are discussed in detail in Chapters 8 to 16.

RAILROAD TUNNELS

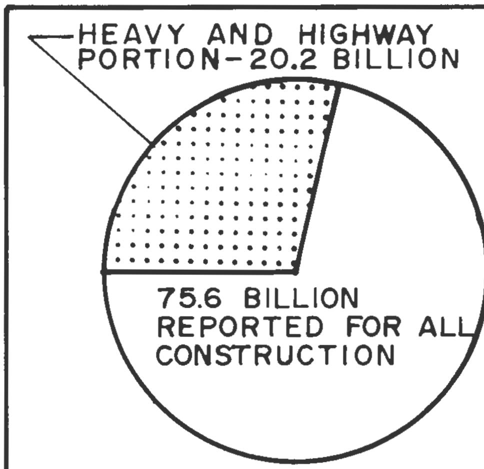
Major tunnel building period for the railroads was 1890-1930. Since World War II, there has been little tunneling except to relocate routes. The advent of much larger cars meant that a few tunnels were abandoned, but most were simply deepened since the cars are now higher and longer but not much wider. There has been no construction since the mid 60's and little is planned except in center city Philadelphia. The Philadelphia rail tunnel is actually to be part of the metropolitan area rapid transit system operated by SEPTA. No end-use demand chart is included for railroad tunnels.

TUNNEL SEGMENT OF HEAVY CONSTRUCTION



TUNNELING AS A PORTION OF TOTAL 1975 HEAVY & HIGHWAY CONTRACT VOLUME

SOURCE: CRESHEIM COMPANY CONTRACTOR INTERVIEWS 1975



1974 INDUSTRY CONTRACT VOLUME
(IN BILLIONS)

20.2	HEAVY & HIGHWAY
34.2	INDUSTRIAL
9.5	GENERAL BUILDING
11.7	OVERSEAS
75.6	TOTAL 1974 CONTRACTS

SOURCE: ENGINEERING NEWS RECORD ENR TOP "400" LIST APRIL 10, 1975

EXHIBIT 3-D

WATER AND SEWER TUNNEL DEMAND

There are two segments to this part of the market. One is the tunnels to transmit water for a major distance. These are long rural tunnels. While transit, rail and motor vehicle tunnels generally are less than two miles long, water transmission tunnels often are 15 to 25 miles in length. They're smaller in diameter, have less costly ventilation and access requirements, and offer a relatively simple construction environment.

These tunnels have been associated with economic and agricultural development programs. The demand charts show enormous linear footage of tunnel construction of this type in the Fifties and Sixties. For the present it appears to be adequate. The Metropolitan Water District in Southern California has deferred until after 1985 all future construction, based on reduced demand for agricultural and drinking water.

In major metropolitan areas, water aqueducts help to deal with population growth and connect to water distribution systems. Most programs in the East were done in the Thirties as part of the WPA public works program of the Depression. Activity continued after WW II at a reduced level. Sewer tunnels are benefiting presently from EPA spending.

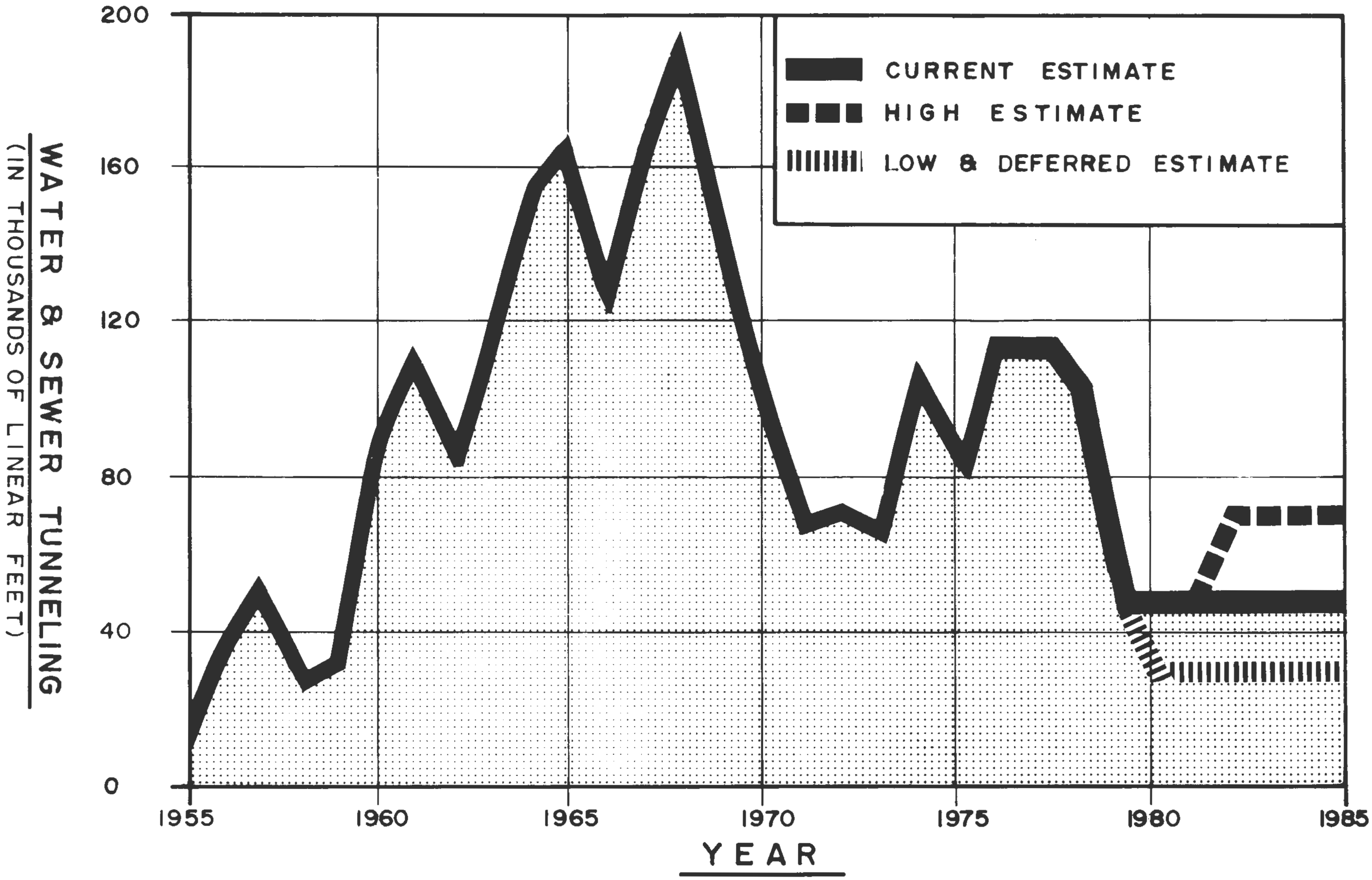
The water tunnel demand data in Exhibit 3-E on Page 3-9 assume completion by 1985 of New York City's Water Tunnel No. 3. This 13.7 mile tunnel project is troubled at present. The contractors have defaulted, citing rising costs and bad ground. Extensive litigation and municipal money problems make forecasting difficult.

Three levels of water and sewer tunnel construction activity have been projected. The median level is a projection based on data supplied by operating agencies. The lowest broken line is the level assuming construction now planned for the next ten years is stretched out over 15 years, reducing activity levels by one third. The highest broken line represents current planning with the addition of new tunneling demand by either the Metropolitan Water District of Southern California or the California Dept. of Water Resources.

Both agencies have no new tunnel construction planned for 10 and 5-7 years respectively. If water usage should change within the next few years, these agencies might consider accelerating their construction programs. Accordingly, we have increased the level of activity to reflect a demand for 20,000 feet of tunnel per year, a rate both agencies have required at various times in the past 20 years.

EXHIBIT 3-E

SOURCE : CRESHEIM CO. STUDY, 1975



WATER AND SEWER TUNNELING
LEVEL OF CONSTRUCTION ACTIVITY 1955-1985

MOTOR VEHICLE TUNNEL DEMAND

The need for such tunnels has always been lesser than that for railroad or rapid transit systems since automobiles routinely and easily climb much steeper grades. Serious motor vehicle tunnel building occurred in the Thirties as the national road network was substantially enlarged. There was then little activity until the construction of the Interstate Highway System dating from the late Fifties.

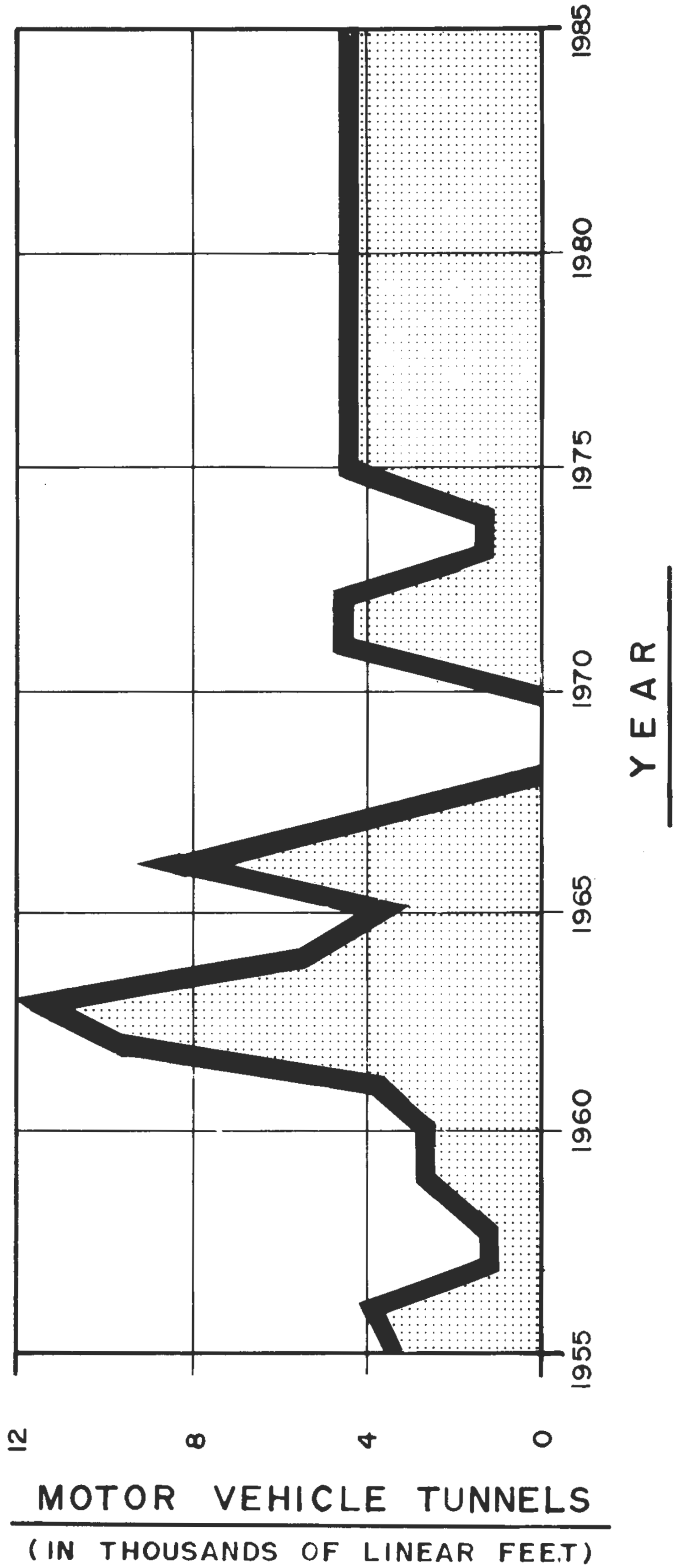
In the Sixties and early Seventies the earlier routes of the Thirties frequently were improved by adding twin tunnels to the original bores. The only significant mountain tunnel job now under construction is the second bore of the Eisenhower Tunnel in Colorado. In the East, the lower mountain ranges make elevation of the roadway practical instead of tunneling. However, a half-dozen subaqueous motor vehicle tunnels are either in planning or construction stages. Those in Maryland and Virginia involve sunken tube work under Baltimore Harbor, Chesapeake Bay and various rivers. The U. S. has an enormous road system, with numerous possible tunnel applications, and Exhibit 3-F usefully displays this diversity.

EXHIBIT 3-F URBAN VEHICLE TUNNELS OVER 500 FT.

Tunnel Location	1975 Actual	1990 Proj.	Annual Growth
At intersections	18.39	34.58	3.4%
Airports	7.98	11.06	2.2%
Parks and monuments	12.84	37.99	7.5%
Subaqueous	51.24	73.13	2.4%
Topographic	28.61	37.94	1.9%
Miscellaneous	.45	.45	0

Note: Above numbers are lane-miles, the common measure used by highway professionals. Nearly all other numbers in this report are in linear feet of tunnel. A 1000' tunnel of four lane width shows above as 4,000' or .76 lane-miles. Source: Federal Highway Administration.

From time to time suggestions for vehicle tunnels under major cities are put forth. For example, some see this as a way to complete those Interstate routes now left with urban segments undone due to various conflicts or problems. There is apparently serious effort in Boston to consider demolishing the elevated Central Artery vehicle expressway and replace it with an underground highway incorporating rapid transit and the fifty-year dream of connecting North and South Stations (the city's commuter rail terminals).



MOTOR VEHICLE TUNNELING
LEVEL OF CONSTRUCTION ACTIVITY 1955-1985

RAPID TRANSIT TUNNEL DEMAND

Tunnel building activity related to urban rapid transit systems is buoyant but not growing explosively as had been predicted (or feared). Expectations now are lower than were projections from prior years. Events in the intervening years have tended to reduce the amount of tunneling expected rather than increase it. However, mass transit construction has a long stormy history.

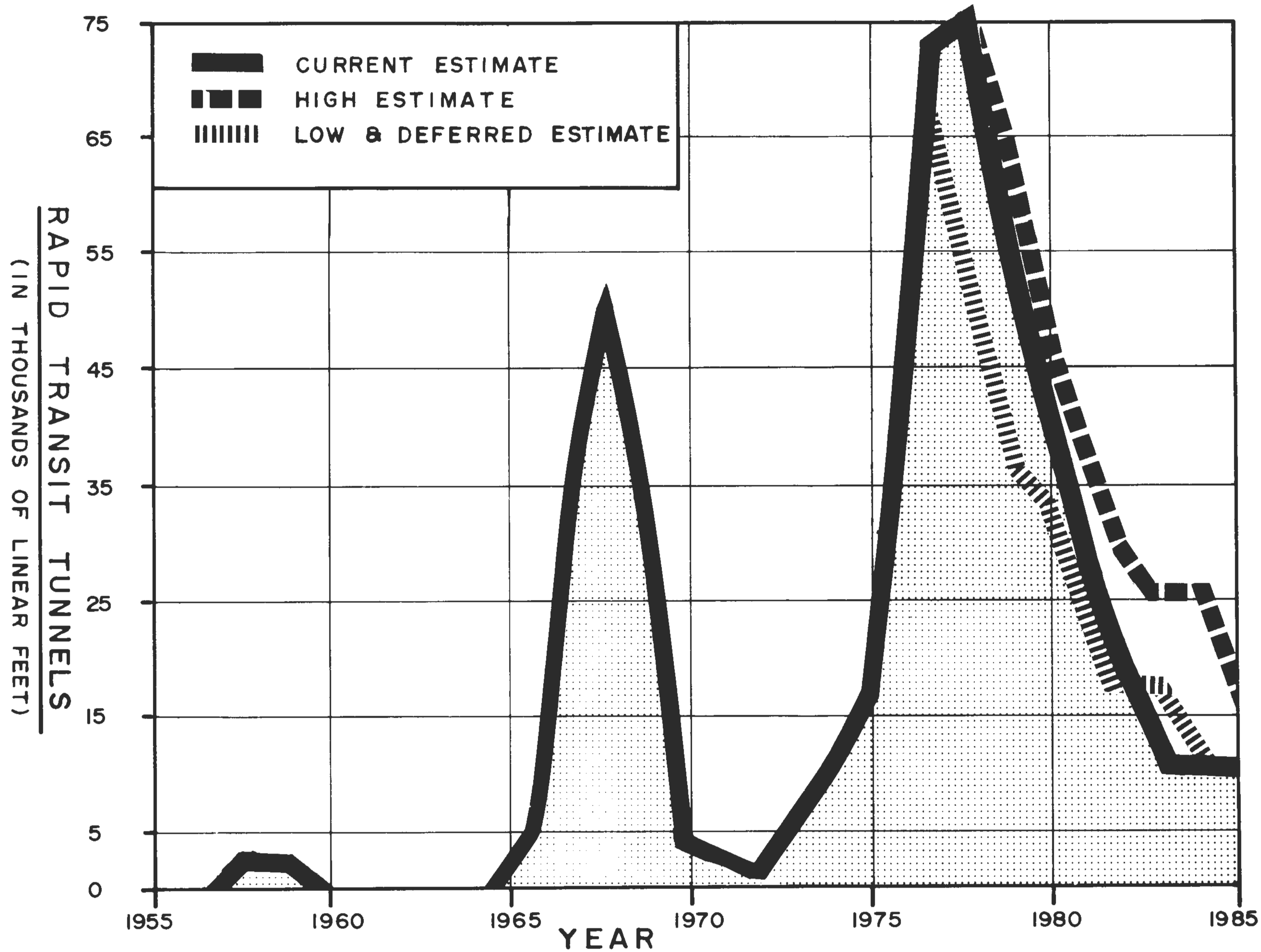
The spate of urban transit system construction in the 1890-1910 era was followed by another burst in the Twenties which extended into the Thirties in some areas as part of the depression era public works program. There was another small round of activity after World War II. However, the major transit system construction in the last half of the twentieth century is in the 1965-85 period. New systems in Atlanta, Baltimore, San Francisco and Washington are fully committed or underway. Also, as part of this surge, Boston, Chicago, Cleveland, New York, and Philadelphia all have added to their systems.

Some cities have rapid transit plans in various stages of development that sit idle awaiting a mandate from a higher authority. In Minneapolis, for example, plans for regional rapid transit are well developed. Also, there is quite a bit of enthusiasm among the technical staff because of excellent geologic conditions encountered in construction of wastewater tunnels. Despite this, the system has not moved beyond the planning stage due to inaction in the state legislature in the past two sessions. Prospects for passage of an act enabling final design and construction apparently are not regarded as good for the 1976 session.

Further development of other systems has been halted by outright voter opposition. In July 1975, the Cleveland Transit System was changed from municipal to a regional transit authority, allowing it a direct tax allocation. As part of this package, however, the voters approved a five year moratorium on expansion of systems facilities in an effort to maintain fares at their current level. In New Jersey, defeat of a bond issue in the November 1975 general elections severely limits the prospect for expansion of rapid transit in both the northern and southern parts of that state.

Some planners have found that the requirements of other programs have expanded to the point of excluding public works construction from municipal budgets. In Newark, N. J., planners have found little direct opposition to their program to expand the subways in that city. A continuing commitment to large scale health and welfare programs, however, has relegated most public works construction to a lower priority, creating a social and political dilemma. The city has now suspended active planning while an overall policy is developed that will outline some of the decisions to be made.

EXHIBIT 3-H



RAPID TRANSIT TUNNELING
LEVEL OF CONSTRUCTION ACTIVITY 1955-1985

SOURCE: CRESHEIM CO. STUDY, 1975

Rapid transit operating agencies were interviewed to obtain data on variables affecting projected construction. In most cases this took the form of public or legislative approval. Operating agencies were also asked to assess the probability of having to defer or cancel construction. Based on that information three lines were projected representing demand levels under three circumstances; the most probable; a high estimate, incorporating marginal or cancellable tunnels; and a low estimate, incorporating construction deferrals and eliminating tunnels that have probable alternatives.

The "high" estimate differs from the "probable" estimate by including the Dallas rapid transit system and the Queens trunk line in New York City. It projects construction of the Minneapolis-St. Paul rapid transit system as starting in 1978.

The "low" estimate differs from the "probable" estimate by omitting the planned new tunnel construction in Denver, Detroit, Honolulu, Los Angeles, Newark, Pittsburgh and Rochester. It also assumes a two year delay in starting construction in Chicago, Buffalo, Minneapolis-St. Paul, and Rochester, N. Y.

These delay situations highlight one of the most problematical areas of construction in the public sector: the need for coordination between the technical staff, the elected and appointed administration, and the public. In some cases, those responsible for planning and implementation assume a level of financial and political support that may not be reached.

EXHIBIT 3-I METROPOLITAN AREAS PLANNING NEW RAPID TRANSIT SYSTEMS

NAME	PLANNED TUNNELS (IN MILES)	CONSTRUCTION
Minneapolis/St. Paul	36	
Chicago	12	Cut & Cover
Atlanta	10.1	Mainly Cut & Cover
Detroit	9.2	
Buffalo	5.2	Cut & Cover & Moles
Baltimore	4.5	Stations: Cut & Cover Tracks: Shield
Los Angeles	2.6	
Denver	1.2	Cut & Cover

The clear trend visible in any study of previous forecasts of rapid transit construction and related tunnel building is that various factors interrupt or erode support for these plans and the overall level of anticipated demand therefore softens.

EXHIBIT 3-J FACTORS AFFECTING TRANSIT TUNNEL DEMAND

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1. Consistency of UMTA Funding - Recent retrenchments on the part of UMTA, and its impact on systems such as Atlanta, have caused uncertainty among planners.

2. DOT Policy - Some cities were leaning towards conventional heavy steel wheel rail systems. After their preliminary plans were reviewed at the federal level, light rail vehicles were suggested as less expensive.

3. Congressional Budget Changes - Changes mandated by congress affect major tunnel funders like Corps of Engineers and Bureau of Reclamation, changing their timetables for projects.

4. Changes in Environmental Policy towards irrigation and municipal water and sewer needs. As the EPA enforces regulations, new wastewater systems are restricted in cities like New York and Austin, Texas.

5. Financial Problems of Owners - Utilities encounter rate hike delays; local government does not want to raise taxes; bonds are difficult to sell; and there is voter resistance to costs.

6. Changes in Public Interest - To some extent enthusiasm over mass transit is civic pride manifesting itself in big public works projects, as stadium building has been over the last 10 years.

7. Assessments of Technological Improvements - After well publicized tests of PRT and Dial-a-Ride in several localities it appears that more owner agencies are moving to the bus/subway/trolley system, a concept dating back to the turn of the century.

8. Impact of Energy Crisis on ridership and route selection.

9. Increased Urbanization and Effects on travel time and cost from point to point.

OTHER UNDERGROUND CONSTRUCTION

Owners and planning authorities also were asked about other underground construction. Here are the highlights:

BOSTON is renovating its Essex, Park Street, South, Summer and Washington MBTA stations and tunneling under Winter Street (a pedestrian way) to Washington Station. The objective is to provide underground access to new and existing facilities. It is a $220,000,000 program with completion scheduled for 1977.

DALLAS is planning underground pedestrian walkways connecting Thanksgiving Square's four major buildings. Cost is $4.6 million with completion planned for 1982.

KANSAS CITY plans underground garages and walkways to link a convention center and hotels. Completion in 1976 is planned.

MEMPHIS's University of Tennessee plans a pedestrian and utility tunnel (380 feet) connecting two sides of the campus.

CONCLUSIONS

1. The Union Canal and Hoosac tunnels demonstrate the unusual longevity expected of these tunnels. Such a requirement leads to very conservative design. Although cost is an important factor, safety and durability are the prime considerations in these structures. This affects overall demand.

2. The two recent peaks in transit tunneling have coincided with periods of strong demand for water and sewer tunnels. As a result the industry was operating at record levels in each of these periods.

3. Based on present information, total tunneling demand will drop after 1980. This statement reflects uncertainty about rail transit, vehicular, and power plant tunnels.

4. The funding of urban transit tunnels has become a Federal, rather than a local, affair. The relative commitment of mass transit funds through UMTA can greatly stimulate or depress the tunneling industry.

5. Transit tunneling projects are unusually large public projects. In a tight economy, they face sharp competition for public funds.

Chapter 4

TUNNEL PROJECT STAGES AND PARTICIPANTS

There are eight definable stages for a tunnel project and they necessarily extend over a period of several years.

1. Determination of Need
2. Approval of Scope
3. Financing
4. Engineering
5. Construction Preparation
6. Construction
7. Acceptance and Use
8. Claims and Litigation

These stages are much the same whether the end use of the proposed tunnel is for water transmission, sewage or transportation (motor vehicle or rapid transit). The difference among projects that is critical is not the end use - it is the environment. Therefore, to show both tunnel project detail and the potential problems of the environment, the illustration selected is an urban rapid transit tunnel. It is complicated, large and long, hardest to finance, controversial, and requires massive public support over a long period of time if the project is to succeed.

COMPLEXITY OF URBAN TRANSPORTATION CONSTRUCTION

A major management challenge and risk factor in tunnel construction is the urban environment. For example, a rural tunnel can be handled essentially as a civil engineering project. The needed people, equipment and supplies are moved to the job site and blasting or boring begins. Within broad limits the only constraints are time, cost, specifications and natural laws. Tunneling in a city, on the other hand, requires concern for stability of nearby buildings; great concern for the environment in matters like noise, vibrations, and dust; adjustment to neighborhood needs like full maintenance of automobile traffic or access to nearby stores; and adjustments to urban problems like burglary and vandalism.

The photograph in Exhibit 4-A illustrates this. The Bureau of Reclamation's tunnel somewhere in the western United States was able to use rotating tunnel cars to quickly dump excavated muck not far from the portal of the tunnel. For contrast we have Exhibit 4-B showing a WMATA tunnel for the Washington, D. C., subway system. The enormous degree of difference in complexity of the work environment is immediately apparent.

When a major urban transportation construction project is being planned and announced, much of the focus is on the trains or individual cars, the signal systems, fare collection devices and other items immediately of interest to the riding public. The improvements in the proposed items over the prior models, if any, are highlighted. So, too, are the changes in purchase costs of the new versus the old.

Rarely is much attention paid to the tunnels or the above-ground sections to run beside highways, or on abandoned and converted railroad lines, or elsewhere. One solid reason for this is that they are not news. Passenger cars have graduated from overhead fans and mechanical support systems to good air-conditioning and fully electronic operation. Meanwhile, there is little visible change in the way tunnels are built now as compared to fifty years ago. Yet, this slowly changing construction part of the transit system may cost 80% of the total spent, while the cars, signals and tracks account for 20%.

STAGE 1. DETERMINATION OF NEED

The impetus for considering seriously whether or not an urban transportation project is required may come from one or several locations: planners, operating agencies, an elected or appointed official, citizen groups, etc. From one of these sources the idea will be referred (in this example) to the group responsible for long-range planning of transit needs. Only rarely is anyone very surprised by the general concept. Major transit projects ideas usually have been around for a very long time before they're built.

The group to initially study the idea may exist, or it may have to be formed, which is another time-consuming process. This regular or special agency or commission will need power to perform its task and funds to conduct studies. These may be provided by a state, county, municipality or regional entity. Consultants are then employed to study origins, destinations, potential passenger volumes, routes, fare structures, details of elevated or tunneled portions necessary, and economic feasibility aspects necessary for long-term financing.

Consideration of the consultants' report may lead to support for the project; a conclusion that its scope or timing should be modified; or to non-support and a recommendation that no action be taken.

EXHIBIT 4-A

TUNNELING IN THE OPEN COUNTRY

View of the Bureau of Reclamation's concrete-lined four-mile-long, 12-foot-diameter tunnel through River Mountains to carry municipal and industrial water from Lake Mead to the Las Vegas Valley as part of the $81 million Southern Nevada Water Project. This aerial photograph shows the outlet portal, construction camp and dumping area for the material.

EXHIBIT 4-B

These photos illustrate the enormous complexity which contractors for urban mass transportation tunnels face when the cut and cover technique is used in cities. There are substantial effects on motorists, pedestrians, and the nearby general public.

Cut and cover tunneling in Washington D.C.

The next step is for the local group to forward their report, presumably with enthusiastic endorsement, to the legislative group and the local, state and federal fund granting agencies. Their approval, if obtained, may be conditional and require certain matching commitments, elements of performance, etc. This is particularly true in projects involving numerous cities and towns with regional representation and management. At this stage things usually move faster in a place with an existing system than in one with a new system to be built.

APPROVAL OF SCOPE AND FINANCING STAGES

Approval at this stage is of the general need and of a conceptual design and preliminary cost estimate. With this support in hand the agency that will own or operate the project upon completion can begin serious work. This includes these crucial, time-consuming tasks:

1. Obtaining the approval of, and financial commitments from, the affected localities.

2. Obtaining voter approval for a general obligation bond issue sufficient for that portion of the cost to be paid by the local communities. This has to be done at a regular or special election.

3. Engaging a general consulting engineer.

4. Acquiring rights of way if they are not already owned or under control.

5. Obtaining federal funding commitments.

6. Obtaining state or county funding commitments.

7. Preparing for and negotiating the sale of bonds.

It is important for all participants to realize that at this point the decision is a political and economic decision rather than a technical question. Crucial issues that arise during the scope and financing stages have to do with the relative participation of various cities, counties or towns and of the federal and state granting agencies. The basic capital commitment requires some discussion of who is responsible for later operating deficits if they occur.

Also, the general obligation bond issue will be for a fixed amount based on project cost estimates. The recent experience with inflation and cost escalations has made this aspect difficult and troublesome.

ENGINEERING

The controlling agency (owner) may act as its own engineer or engage a general engineering consultant. In most cases public agencies with an ongoing program of construction maintain a staff engineering capability. Those owners who are new, or who have intermittent construction programs, use outside consultants.

General engineering consultants and their supporting special consultants provide these services for the owner:

GENERAL ENGINEERING CONSULTANT

1. Preliminary design.

2. Selection & definition of standards for design and construction.

3. Coordination of public agencies and environmental impact studies.

4. Selection of section designers.

5. Supervision and coordination of design effort.

6. Assistance to owner in preparing contract documents, advertisement for bids, selection of contractors and award of contracts.

7. Assistance to owner in supervising construction and administering contracts.

SPECIAL ENGINEERING CONSULTANTS AND THEIR FUNCTIONS

1. Geotechnical Consultant (if none on staff)

   Overall control of soil/rock exploratory program and defining parameters for structural design, groundwater control and protection of existing structures.

2. Environmental Consultant (if none on staff)

   Assistance in developing environmental impact statement.

3. Acoustics Consultant (if none on staff)

   Determination of nuisances during construction and operation. Evaluation and solutions to problems of noise and vibration.

4. Corrosion Consultant (if none on staff)

   Definition of potential corrosion problems on structures and submitting solutions for effective control.

5. Special Tunnel Consultants (if none on staff)

   Study and designs, equipment studies, methods, cost estimates, advice and recommendations.

   a. Design

   b. Construction Methods

   c. Blasting and/or Mining Methods

   d. Materials Handling

   e. Cost Estimate

6. Section Designers (Some firms may use the services of special consultants such as Mechanical, Electrical and Tunnel Consultants)

The section designers prepare detailed drawings of the tunnels, stations and associated structures together with very detailed specifications on how the excavation is to be done and the structures are to be built. A full set of complete contract documents for use in the project is also prepared and submitted to the general engineering consultant.

Section designers must operate within as many as a dozen codes limiting their design. They must also be aware of relative material costs and local work rules or practices in writing specifications. One thing that can be counted on is their conservatism when it comes to ensuring long life and safety of the tunnel.

Once built, the tunnels have a good safety record. The Washington Street tunnel under the Chicago River was completed in 1866. After the great fire of 1871, the tunnel provided the only means of crossing the river for a long time. English transit tunnels provided air raid shelters for the citizens of London during World War II because they're deep. Today, in San Francisco, citizens anticipating the projected earthquake due before the year 2000 are planning to try to get to the BART tunnel under the bay which was built with earthquakes in mind. (Few tunnelers are!)

In today's environment various pressure groups or other constraints may force changes in the design after it has been completed but before construction begins. Another source of change is passage of new laws or issuance of new or modified regulations.

Later, during the construction stage, the section engineer will provide advice and recommendations on changes. Some of these occasions will arise from unanticipated conditions while others may come as requests or suggestions from the contractor. Frequently there are several ways to accomplish an objective. A contractor may wish to have an interpretation of a specification or procedure to see if it is acceptable under the contract. Since the section engineer may also serve as the owner's inspector, the contractor is well advised to clear such matters in advance.

Unanticipated changes may require rather sudden and extensive work for the section design engineer. On the Eisenhower Tunnel in Colorado (first section) there were extensive design changes during the project to accommodate geological conditions.

There also were design changes because of shortages of materials. To keep the job going, new materials acceptable within the overall design were substituted.

CONSTRUCTION PREPARATION

This stage of the project involves the contract preparations, bidding or negotiations, awards, and mobilization for work. It is a stage about which there is considerable industry dissatisfaction and a number of efforts to induce change are underway or proposed.

Both public agencies and private owners issue contract documents that include detailed plans and specifications prepared by the consulting engineer. Public agencies usually issue these to all contractors who express an interest as a result of public notices while bidders are usually prequalified in the private sector. That is, their qualifications to perform the work are investigated and approved before the bidding documents are issued to them.

The owner's staff engineers or the consulting engineer retained for the project perform or secure subsurface investigations, analyze the results (or have them analyzed by engineering geologists) and prepare designs, plans and specifications, cost estimates, and performance-time schedules for construction.

Prospective bidders will respond to a firm-fixed-price contract (most common) or to a cost-plus contract of some type. Presently the contracts still are called "fixed fee" but the proliferation of provisions for escalation and changed conditions makes this description less than wholly accurate. Contractors complain that some engineers draw up "win-lose" contracts, leading to adversary conditions.

Contractors receive copies of the general contractual provisions (those applying to all contracts of that type) plus special provisions applying to the specific job at hand. They also receive the technical specifications for the jobs and sets of plans and drawings (public owners require a deposit from all bidders who receive sets of specs and plans).

THE BIDDING PROCESS

Most public agencies are required by law to operate on a sealed bids basis rather than working with prequalified contractors. The bids must be backed up by performance and payment bonds to guarantee completion of the work and payment of all suppliers. Contractors obtain these bonds from insurance (surety) companies, or they can deposit cash or cash equivalents in lieu of bonds. Private owners generally forego the bond requirement.

Public agencies open all bids at a specified time and announce the engineer's estimate and make all bids available for inspection. This auction atmosphere compares markedly with the private treaties used by private owners. Public agencies generally will not allow a bidder to qualify or restrict a bid. The owner's terms will govern.

The low bidder must satisfy the owner after bid opening that he has a satisfactory record of performance of like work, and the management capability, financial strength, and equipment availability to assure performance of the job as specified and on the agreed schedule. Most public agencies must award the job to the lowest responsible bidder. Private owners are not bound to do this.

STRENGTHS AND PROBLEMS OF THE BIDDING SYSTEM

There is little opportunity for unfair favoritism in a pure bid system. The conditions of operation preclude selection of contractors on any basis but responsiveness to the bid specifications, lowest price offered, and certification as a responsible bidder. Therefore, one might be surprised at the rising support for prequalification of bidders as a preliminary step.

Such a procedure reduces the number of bidders, may restrict competition, and potentially increases difficulty of entry into the industry by new firms. Its advocates point out that it also tends to eliminate low bidders who have a past record of poor performance, insufficient management, limited financial strength, not enough equipment, or a well developed inclination to seek extra money through litigation.

Another problem: many public sector bids don't permit submission of alternative designs. This can adversely affect costs or inhibit introduction of new processes or materials.

CONSTRUCTION STAGE

The contractor, armed with a signed contract to build the tunnel, puts his organization to work to mobilize for the project, prepare for tunnel excavation and to line and otherwise equip the tunnel. He has considerable assistance from subcontractors and suppliers. Specialty subcontractors include:

Mechanical	(Heating, ventilating, air-conditioning, plumbing)
Electrical	(All electrical installation and maintenance)
Dewatering	(Ground water control)
Muck Disposal	(Disposal of tunnel muck)
Acoustics	(Acoustical work)
Tracks	(Track laying)

During mobilization he will purchase all of his equipment or make arrangements for rentals or leases. He will also complete negotiations for supplies and services for the project. Suppliers of highly specialized tunnel equipment, described in Chapter 11, usually sell, fabricate or custom build the equipment a contractor needs. They estimate costs to help him bid and may help him dispose of equipment after the job.

Mobilization also includes preparations like the erection of plants and outbuildings; bringing in office, safety and medical facilities; sinking access and ventilation shafts and completing job staffing. These preparations are also affected by the choice of excavation method, the type of tunnel liner to be used, the ground conditions, and the general tenor of support for the project.

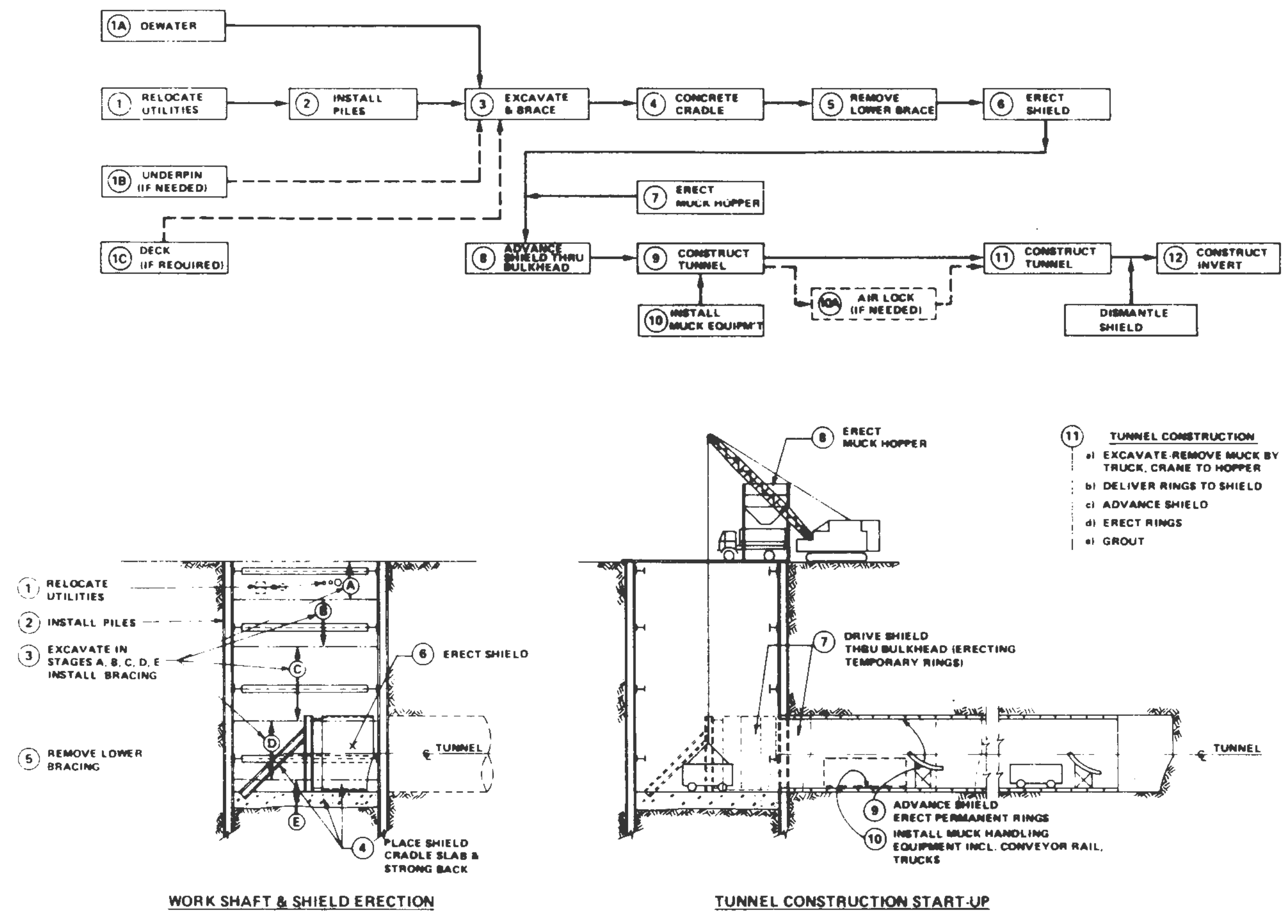
PRINCIPAL CONSTRUCTION CONSIDERATIONS

Tunnel excavation involves a tight repetitive cycle of events which must be carried out on an optimum schedule if the job is to be effective and profitable for the contractor. Introducing fast equipment is not useful, in many cases, since the cycle limits any individual component. For example, the speed of a tunnel boring machine (mole) is limited by the speed of the muck removal system. All steps are highly interdependent.

The ground through which the tunnel will be constructed may be hard rock (east and west U. S. coast and mountain area) or soft ground (all areas of the country but most common in the midwest). Pure tunneling may require a Tunnel Boring Machine (T. B. M. but more commonly known as a "Mole"). If it is a soft ground tunnel, 4000 to 6000 feet in length, a T. B. M. will probably be used.

Exhibit 4-C

TUNNEL CONSTRUCTION EVENT SEQUENCE



Source: Systems Analysis Rapid Transit Underground Construction

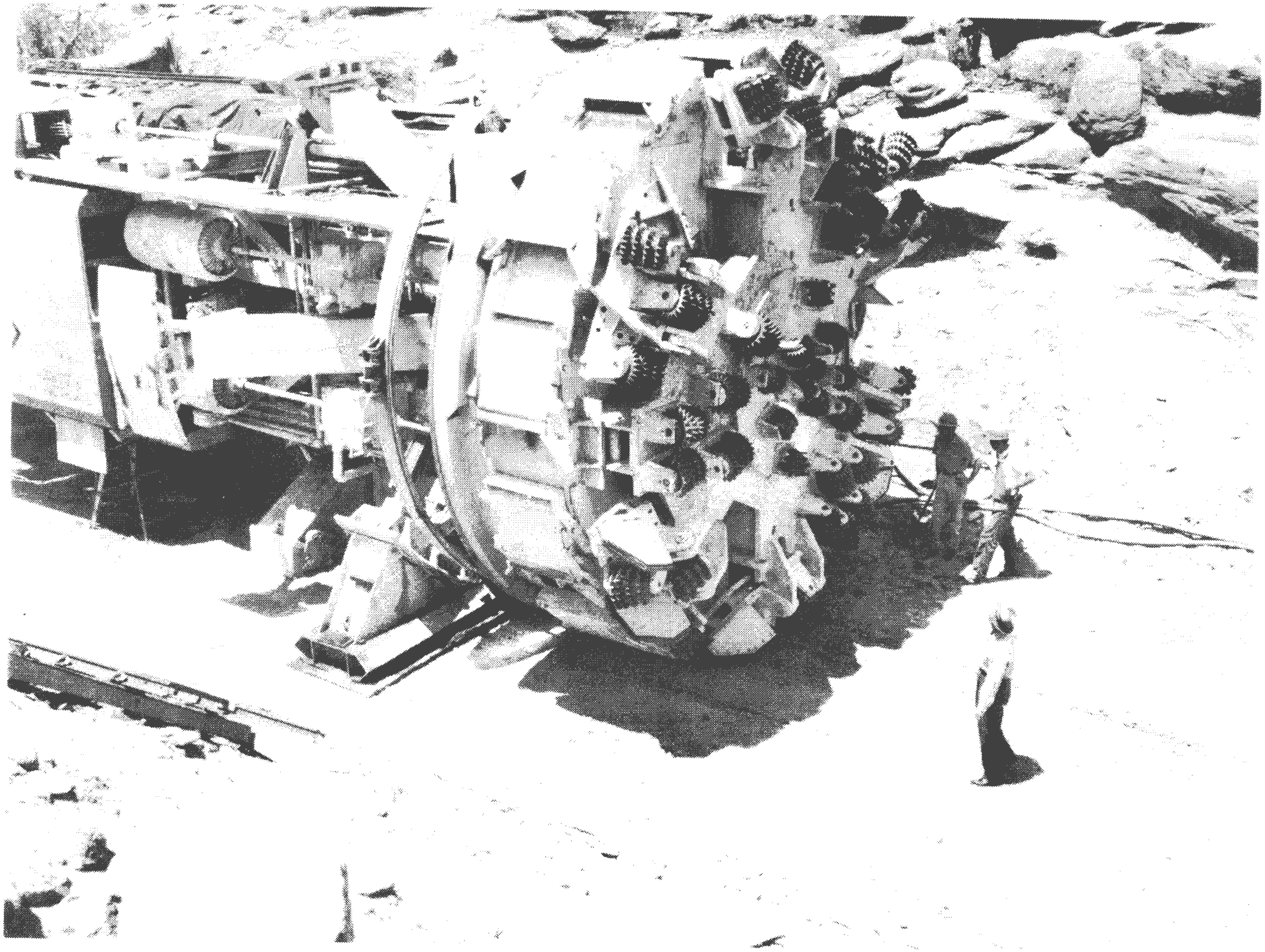


Exhibit 4-D

Tunnel boring machine for a rock tunnel is shown above. Purchase of these major pieces of excavation equipment (known to tunnel specialists as rock moles) are part of the mobilization stage of the project.

HARD ROCK TUNNELING

Most rock tunnels today are driven full face. The entire forward space (heading) being excavated is drilled and then blasted. Rock includes not only actual rock but soils like hard pans and glacial tills. Rocks are classified in different ways. The compressive strength classification, measured in pounds per square inch (psi) is somewhat important when tunneling machines are considered. Rock with compressive strengths below 6,000 psi is considered soft. Over 25,000 psi is "hard" rock, with the balance classified as medium.

For lengths of 8,000 to 10,000-ft. and over, a T. B. M. will often be employed in spite of its high first cost and long delivery time, because of its greater speed and lower labor requirements. If the contractor already has a mole of the correct size, or if he can rent one at an attractive price, it could be used for shorter tunnels.

EXHIBIT 4-B

DRILL-BLAST-MUCK CYCLE

Drilling Cycle

Move in drill jumbo and connect air and water lines
Set ribs or roof bolts
Drill blast holes
Load powder
Disconnect air and water lines and move jumbo back

Blasting Cycle

Connect blasting leads
Move gang back to safety
Blast
Ventilate (period is known as "smoke time")

Mucking Cycle

Scale roof, clean up fly rock
Move in mucking machine
Muck out the round
Extend track
Move out the mucker

The next five paragraphs are from "Tunneling-The State of the Art" by Robert S. Mayo, Robert J. Jenny and Thomas Adair.

Blast holes generally are drilled 8 or 12 feet deep. An 8 foot hole will "pull" about 7-1/2 ft. of tunnel, a 12 foot hole will pull 11-1/2 ft. On each job, a study should be made to determine the best method of attaining the maximum footage per 24-hour day. There are many variables. For instance, a 12 foot hole will take longer to drill than an 8 foot hole, and powder consumption will be higher. Also, a longer round will break

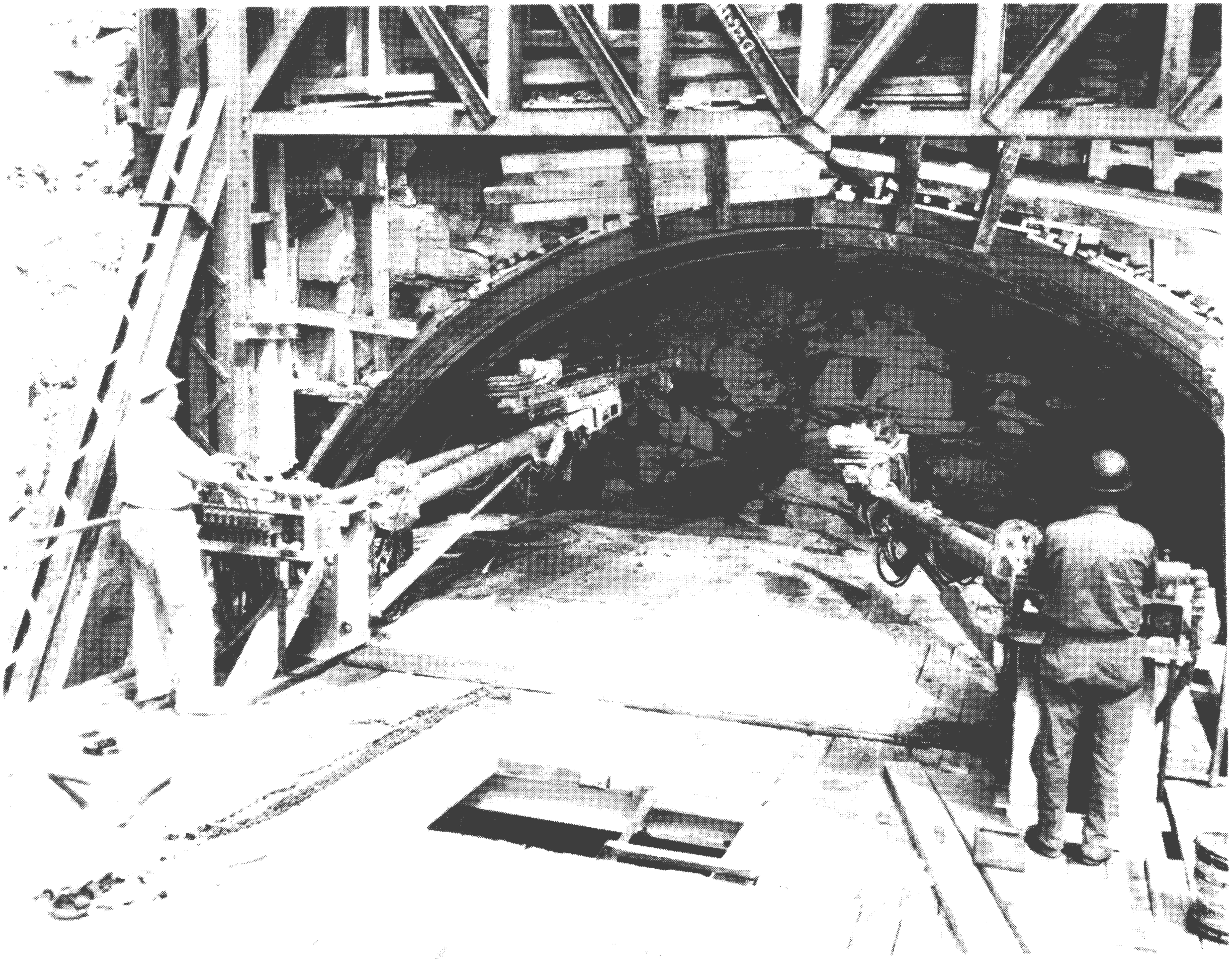


Exhibit 4-F

The conventional approach to rock tunnel excavation is the use of a drill jumbo. The photo shows tunnel workers on the top level of this three level equipment.

out more material, which increases mucking time. Therefore, the job study must compare the number of rounds that can be obtained per day by different drilling and blasting methods. If the contractor can produce six rounds with 12 ft. holes, his overall progress should be slightly better than if he fires nine rounds with 8 ft. holes. The length of the round should not be greater than the width of the tunnel (6-ft.-deep holes probably would be used in an 8-ft.-diameter tunnel). Usually one drill hole is required for approximately every 6 sq. ft. of face.

Normally, a rock tunnel in free air (not compressed is driven in three 8-hour shifts. However, in some areas the "portal-to-portal" rule applies. This means that the miners' shift begins at the portal or on the surface. It may take 20 minutes to transport the men to the face and another 20 minutes to bring them back to the surface. With a 30-minute linch period, this means the men are actually working only 7 hours per shift. In some cases, the men are given 9 hours pay for an 8 hour day and the shift change takes place right at the face. In this way, the only actual lost production time is the lunch period.

On one recent job, the gangs were organized into four 6 hour shifts but each shift received pay for 8 hours. The shifts were changed right at the face and there was no lunch break; the men ate lunch during a ventilation period after blasting. With this procedure, in a 12-ft.-diameter, 25,000-ft.-long tunnel driven from one shaft end, the contractor progressed at the rate of six rounds per day. The 12-ft.-deep blast holes pulled about 11-1/2 feet of tunnel.

When experienced miners are in short supply it is common to work two 10-hour shifts, with the men receiving pay for 11 hours. The 4-hour shutdown period is used for maintenance of equipment, extending track and installing pipe lines.

SOFT GROUND TUNNELING

Where the soil makes it feasible, nearly all soft ground and some soft rock tunnels of over 6000 feet in length are candidates for use of a tunneling machine. The introduction of this mechanical excavating machinery was expected to have the same positive impact on productivity as the new equipment in use in coal mines had had. However, the use and accomplishments of the tunneling machines (known as "Moles") do not yet match the expectations of their enthusiasts.

One machine used in a clay area of San Francisco had four independently activated cutter blades, each operating in a ninety degree quadrant of the tunnel bore. The cutters scrape the face of the tunnel operating like windshield wipers. Behind the cutting arms was a bulkhead through which the material being excavated was channeled out a conveyor belt and then to a muck train which removed it from the tunnel.

Exhibit 4-G **Muck pile after blasting.**

EXHIBIT 4-H

COMPARISON OF SHIELD DRIVEN AND MOLE TUNNELING

EXCAVATION CYCLES	SHIELD DRIVEN OPERATION	TUNNEL MACHINE
Remove material from face; breasting and mucking	30 minutes	
Shove shield forward	30 minutes	
Shoving and excavation		20 minutes
Erect liner ring; inject pea gravel	45 minutes	
Erecting ring & grouting		45 minutes
Time required to advance 2.5 feet	105 minutes	65 minutes

COMPARATIVE STATISTICS		
Feet advanced per day	33 feet	55 feet
Typical crew for 24 hours	17.5 men	21 men
Length of tunnels involved	6,272 feet	6,970 feet
Average footage per 24 hr. day	25 feet	40 feet
Maximum footage per 24 hr. day	55 feet	105 feet
Crew man hours required per foot of tunnel excavation and lining	14.5 man/hr.	12.5 man/hr.

HEADING CREWS		
Heading Engineer (Laser Beam Control)	1	1
Shift Foreman	1	1
Operator	1	1
Mechanic	1/2	1
Electrician	0	1
Face excavation & ring erection	4	
Pea Gravel injection	2	
Ring erection & unloading		6
Hog rods & grout crew	6	8
Motorman & brakeman	2	2
TOTAL	17.5	21.0

Source: BART project engineers

Where soil is not appropriate for machines, hand mining of soft ground tunnels proceeds with the use of tunnel shields. They use a couple of dozen shove jacks to shove the shield forward. Various mucking methods can be used. A backhoe mounted in the interior framing of the shield can dump material on a conveyor leading to a muck train. Or, for short tunnels, a rubber tired loader with a large bucket can carry the material all the way to a dumping point at the tunnel portal. Or an overhead bucket can be used to move material from the face to the muck cars.

CONTROL OF SOFT GROUND

If a contractor must build a subaqueous tunnel, as in the New York river crossings, he will have to use a compressed air environment. This is also true in some tunneling through soils in places like Chicago, Detroit and Milwaukee. Compressed air will be used to prevent inflows of water, mud or quicksand. Generally, 4.33 pounds-per-square-inch of pressure per foot of water must be maintained. In clays that do not yield water readily, little or no pressure may be required. In other situations, higher pressures may be necessary.

When a tunnel penetrates saturated sand, compressed air will dry out the sand, which will stand on a vertical face for a short time and then crumble and fall. Here again, differential air pressure is an important factor; too much air causes sand to dry out and fall and too little pressure permits the moisture-laden sand to flow. If a sand contains considerable amounts of clay or silt, it is much easier to mine because there is less loss of air. But it is extremely difficult to drive tunnels in coarse gravel because open channels through the gravel allow air to escape. This makes it difficult, if not impossible, to maintain enough air pressure to keep water from flowing into the lower portion of the tunnel. "Mudding" will be required to prevent air from escaping; breast boards at the face must be set as close together as possible and then any openings between them or at their ends are plastered with a good plastic blue clay.

Only small areas of the breast boards are removed at one time to advance the face, and after the advance has been made the boards are replaced and again caulked with clay. Sometimes the primary lining is not tight enough and miners must locate air leaks, plug them with clay and recaulk or grout. If a tunnel is driven in this material under an open waterway, a clay blanket is dumped on the river or bay bottom from barges to reduce the loss of air. Tunnels can be constructed through sand or gravel under city streets, without compressed air, if the soil is pre-drained prior to driving. Fortunately, gravel and coarse sand in the latter situation can be dewatered easily with well-points or deepwell pumps.

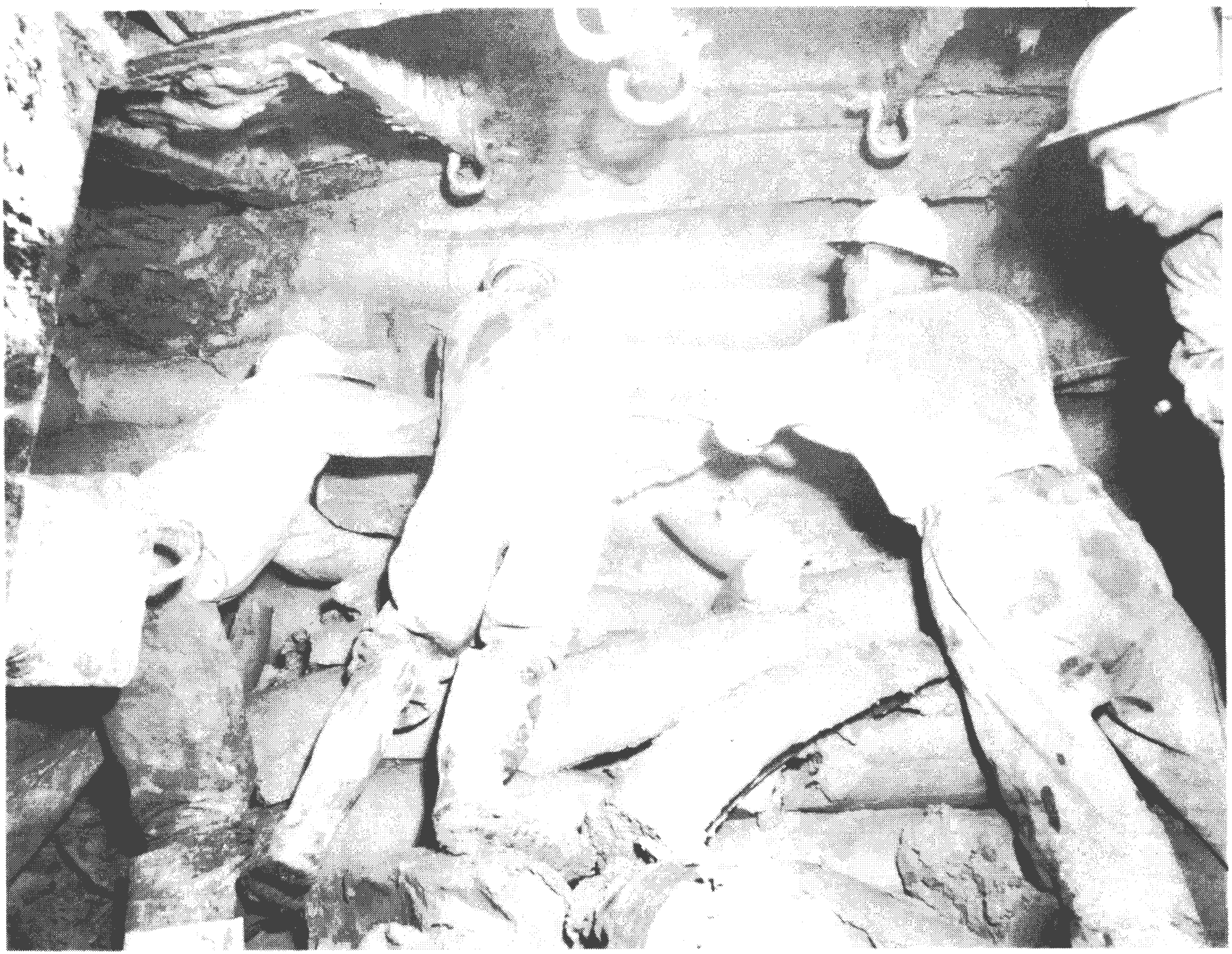
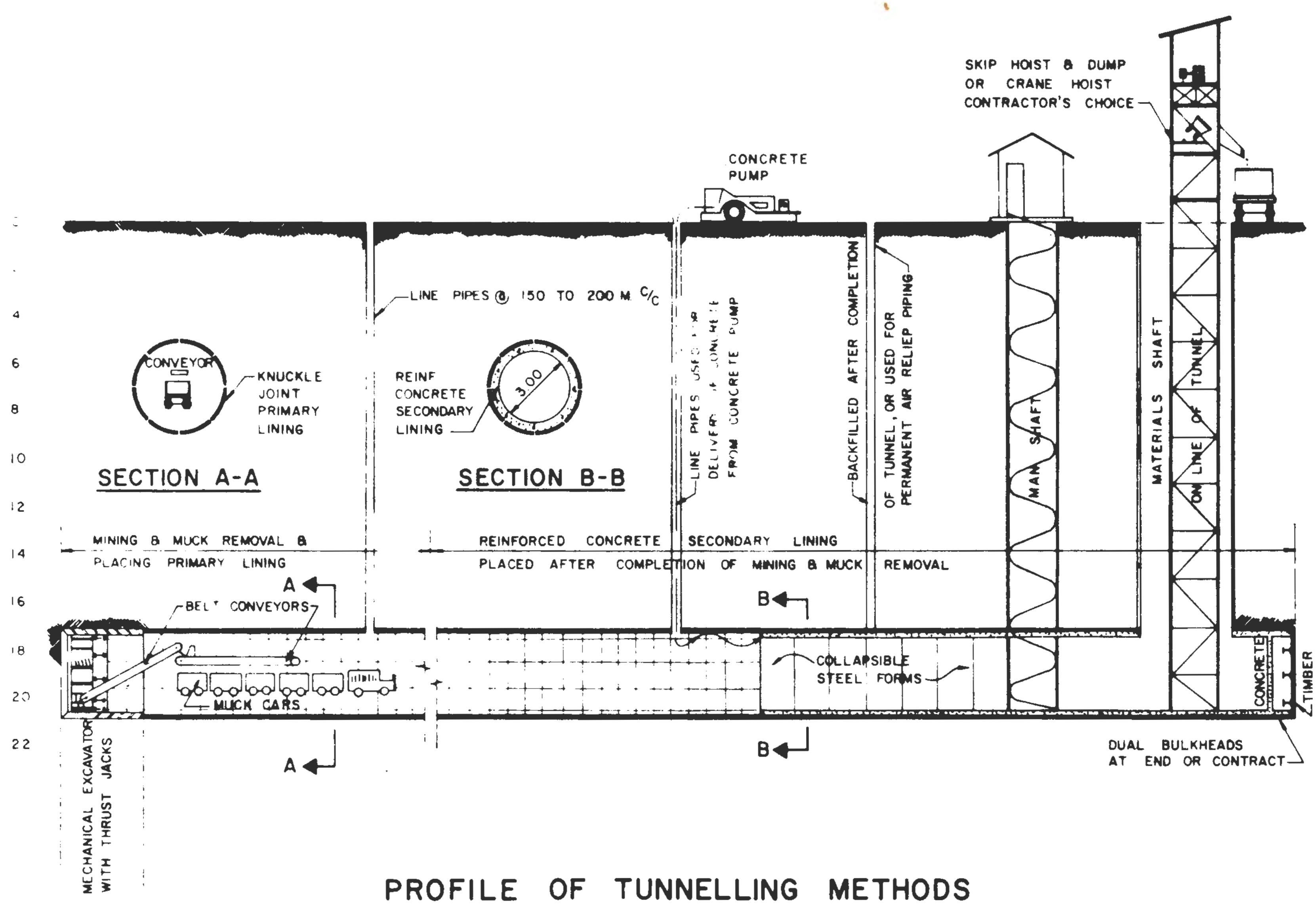


Exhibit 4-I **Mining in clay at the face of a soft ground tunnel using a power draw knife.**

EXHIBIT 4-J

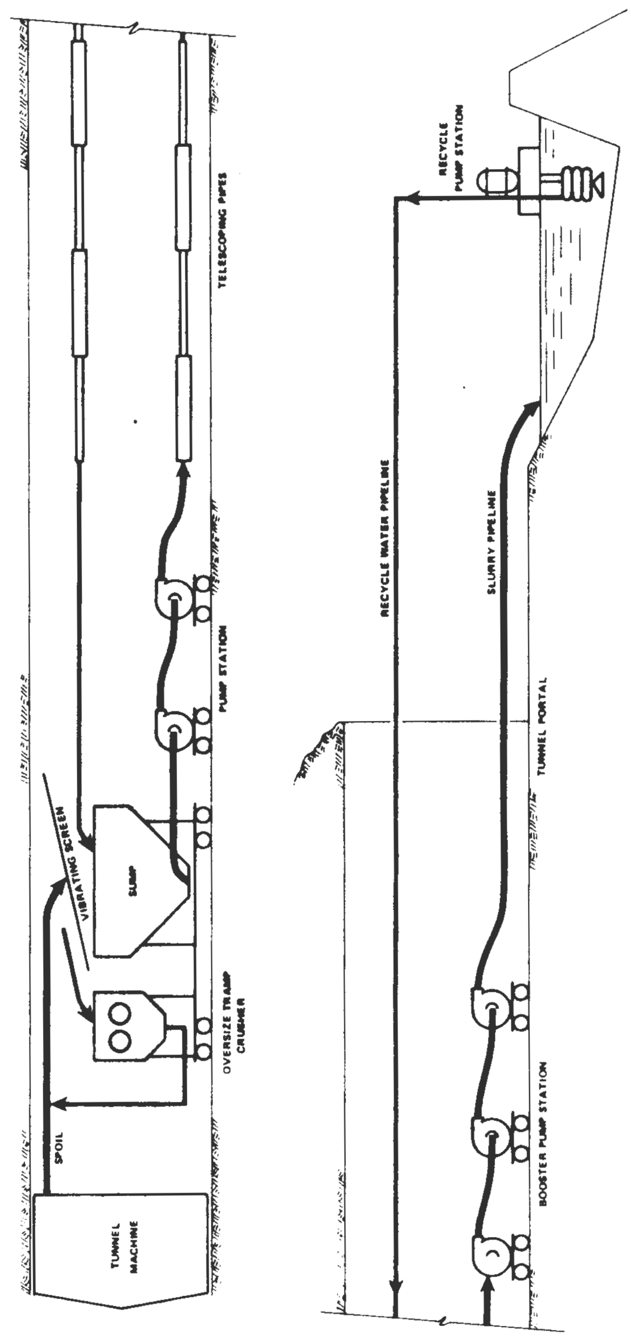


PROFILE OF TUNNELLING METHODS FOR LARGE SIZE - MACHINE MINED SECTION

Source: Jenny Engineering

EXHIBIT 4-K

HYDRAULIC MUCK-REMOVAL SYSTEM



Source: <u>Systems Analysis Rapid Transit Underground Construction</u>

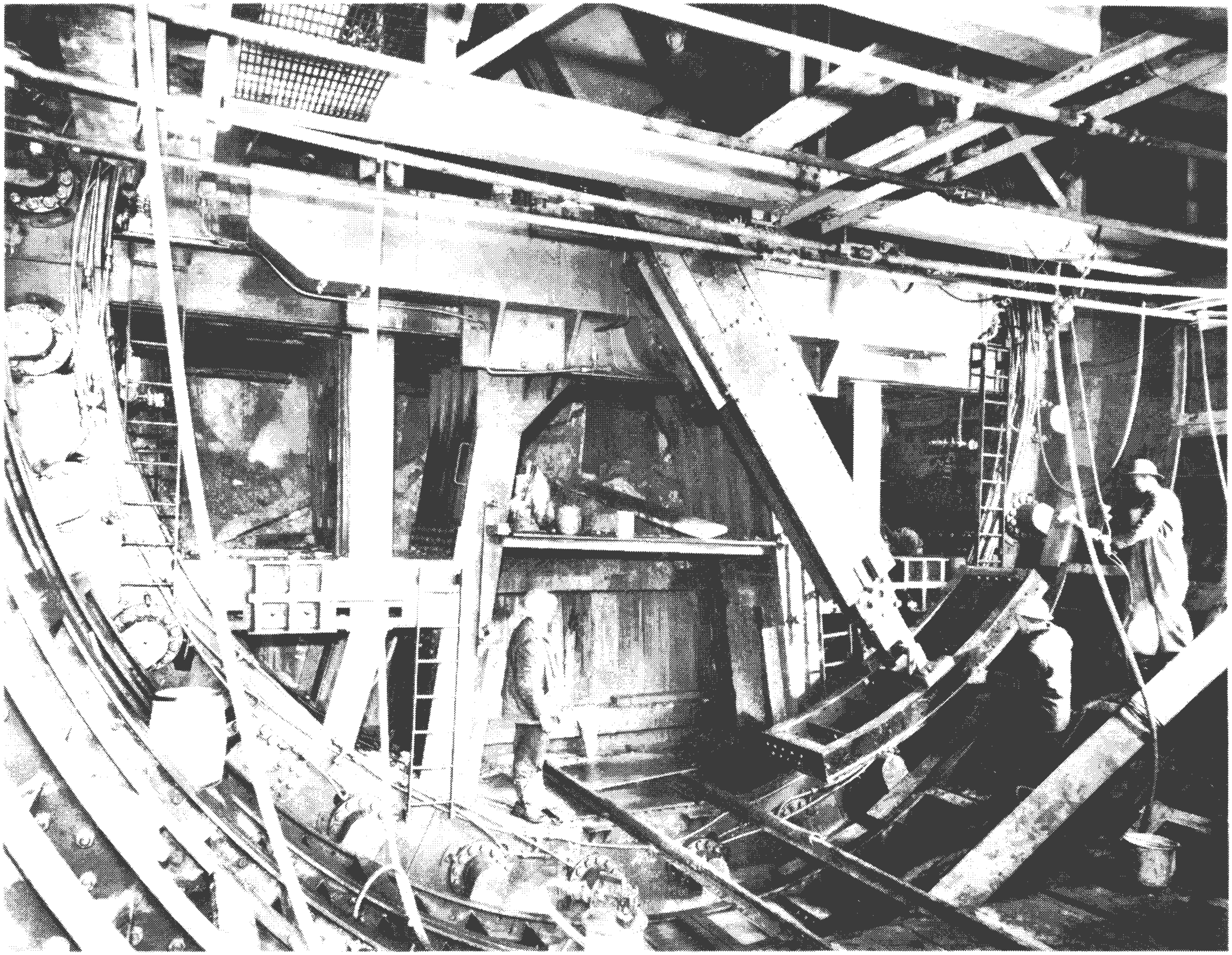


Exhibit 4-L **Erecting tunnel liner in a subaqueous vehicular tunnel.**

TUNNEL CONSTRUCTION COSTS

In hard rock tunnels the principal costs (about 60%) are related to excavation. Equipment, drilling, blasting and related activities overshadow other costs. In a soft ground tunnel, major expenditures cover excavation and primary lining.

Hard rock tunnels are often self-supporting. In the nineteenth century they were either lined with brick or left unlined. Indeed, some railroad tunnels still in main line service have no linings. Today, of course, all transit tunnels are lined. Since the cost of a permanent lining is a major element in total costs for soft ground tunnels, we asked R. J. Jenny to provide data to compare different linings. From recent tunnel projects, he developed the information shown in Exhibit 4-M.

EXHIBIT 4-M

SOFT GROUND TUNNEL COSTS

Type Liner	Labor, Mat'l. & Equipment	10% Contingency	15% Profit	1975 Estimates Cost/Linear/Ft.†
Ribs & Lagging*	$ 3,760	380	620	4,760
Cast Iron Lining	4,360	440	720	5,520
Fab Steel Pan	4,570	460	750	5,780
Precast Concrete	3,750	370	620	4,740
Horseshow Rib*	5,650	570	940	7,160
Fabricated Structural Steel	5,220	520	860	6,600

*With concrete secondary lining.
†Cost for twin 16' soft ground tunnels in "fair" soil.

COST ESCALATIONS

The severe inflation evident in the early Seventies was particularly difficult for heavy construction. Cost rises delayed several tunnel projects and we asked R. J. Jenny to comment. He responded by sharing with us a 1975 update of a rock tunnel rapid transit project estimate. Originally in December 1973, the 16' interior diameter tunnel was estimated at $1040 per linear foot in December 1973 and at $1340 per linear foot in September 1975. Twin tunnels are needed so the cost is doubled to $2680 per linear foot. With his extensive experience in cost work, Jenny then made adjustments for exceptionally good or poor rock and arrived at a range of $2180 to $3140 per linear foot of the twin tunnels for this project.

Exhibit 4-N

Erected primary liner. Cars are the muck train. This photo shows the complexity of work operations during the tunneling cycle. Muck must be removed, supplies brought in and work speed maintained.

EXHIBIT 4-O

TUNNEL COST ESCALATION

	1969	1975	% Change 4/75 to 7/75	% Change 7/74 to 7/75
Concrete lined tunnels	1.06	1.92	+ 3.2%	+ 19.3%

Source: Bureau of Reclamation of the U.S. Dept. of the Interior (a detailed index of project costs on BuRec projects in the 18 Western states including Alaska. Base year (1.0) is 1967.

Another contribution to costs and to cost overruns and disputes among owners, engineers and contractors is the various delaying items which cause a project to get off schedule. Here is a summary of those problems in several situations.

EXHIBIT 4-P

TUNNEL PROJECT DELAYS

	A		B		C		D	
DELAY ITEM	Days Delay	% Time Extend	Days Delay	% Time Extend	Days Delay	% Time Extend	Days Delay	% Time Extend
Changed work conditions	54	27%			97	35%	Major	
Elevator for handicapped							110	
Ground water problem			118	39%				
Interface contract delay			60	20%				
Machine breakdown			92	31%				
Materials shortage delays	56	28%						
Strikes by suppliers	61	31%						
Strikes on the job					77	27%		
Strikes by teamsters					99	35%	90	
Traffic detour delays					9	3%		
Underpinning problems							Major	
Weather problems	27	14%						
Other			32	10%				
TOTAL	198	100%	302	100%	282	100%	225	100%

A - BART Project K0016 B - BART S0022 C - BART S0031
D - WMATA C0021

Source: DOT, Systems Analysis of Rapid Transit Underground Construction

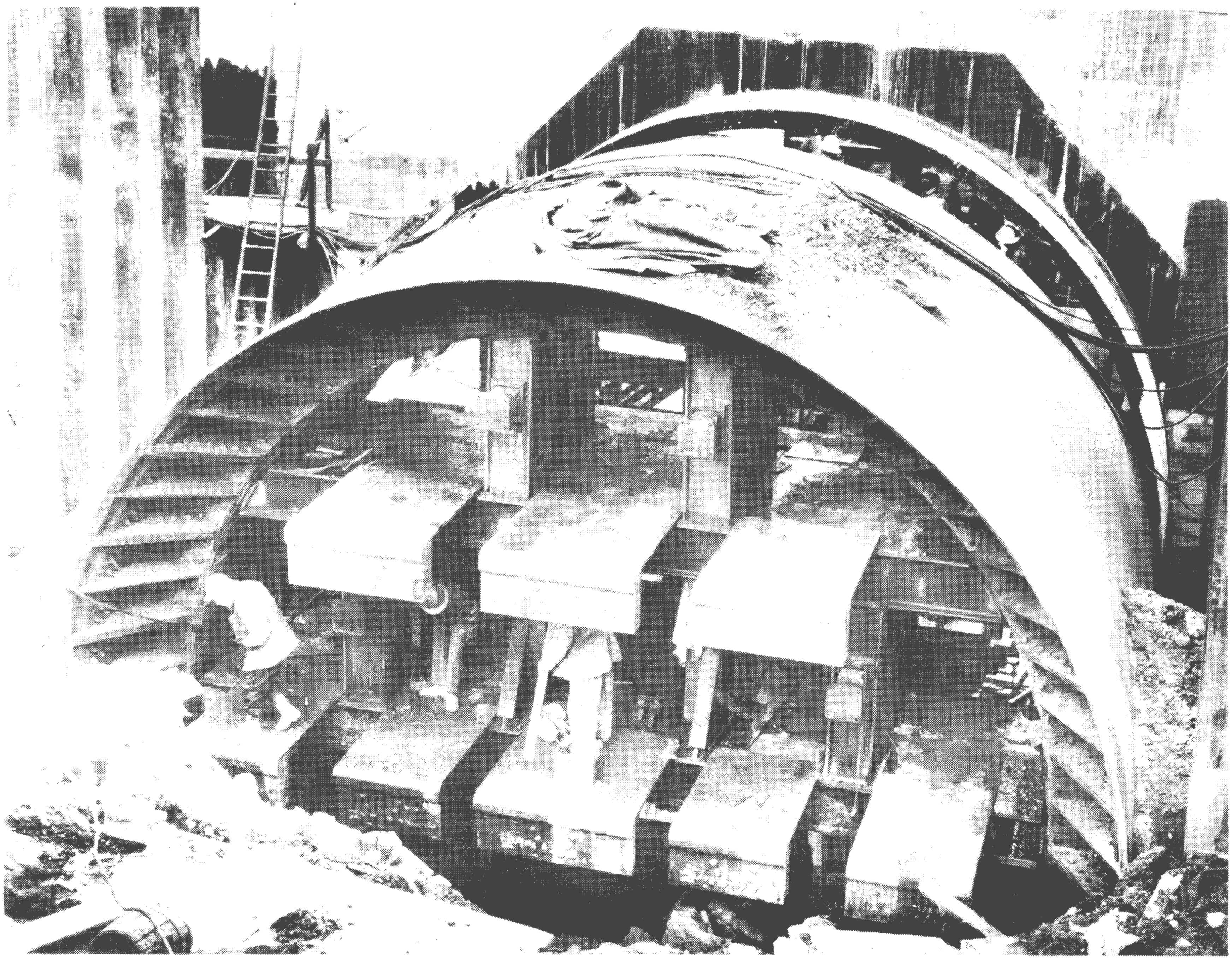


Exhibit 4-Q A rarely seen view of the front end of a tunnel shield after holing through.

To summarize, there are many potential problems in building a tunnel. The most complex and expensive in both human costs and cash expenditures seem to be those listed below. All are discussed later in this report.

Unexpected ground conditions. Rocks, boulders and water are three common examples.

Design modifications. An example was installation of elevators to allow the handicapped access to WMATA.

Accidents. A tunnel engineer's rule of thumb in the Sixties was two deaths per mile of tunnel built. This has lead to aggressive safety programs.

Strikes that shut down the job or the flow of supplies. (The tunnel boss has to live with work rules he inherits.)

Cost escalations due to changed conditions or, as has been the case recently, rapid inflation of prices.

Design constraints that result in difficult construction problems. (Tunnel men have to build someone else's design.)

Relations with owners or engineers. These may be difficult. (The tunnel boss is running a fixed price job with provisions for changes - if they can be agreed.)

Equipment's major problems are of hidden cost. If a new piece of electronic equipment is purchased, or a complex unit like an advanced mole, there is a higher initial purchase price which is visible. That is taken into account in the analysis of projected output of the unit. Invisible costs are the maintenance and malfunction down-time.

Introduction of less-than-qualified people in compliance with various regulations.

Continuance of work practices which often negate the productive gains of new equipment.

Addition of ancillary jobs to accommodate various financial, technical and operational requirements of owners or regulating agencies. These raise costs by increasing the total force.

Project size means that complexity is normal. More sophisticated and expensive planning, scheduling and control systems are required. Use of computers, while efficient, raises the contractor's fixed cost base. The project's overall "Cost of Coordination" advances rapidly.

Exhibit 4-R **A bored rock tunnel before installing concrete lining.**

ACCEPTANCE AND USE

If all has gone reasonably well, the last 5% of a transit tunnel can appear to the public to be galloping progress. Actually, little of it is tunnel builders' work. Track laying, installation of permanent signal or ventilation equipment, erecting of signs and installation of station operating equipment all are handled by subcontractors. When these details are complete and the consulting engineer and owner have accepted them as such, the tunnel is ready for opening ceremonies and use.

CLAIMS AND LITIGATION

There tends to be an adversary environment surrounding tunnel contracting which relates heavily to the fixed price bid system and to the still common owner practice of withholding full details of geological studies. When unexpected conditions are encountered the contractor or the owner often will enter litigation to seek to enforce his point of view.

Tunnel contractors, engineers and others with whom we talked were nearly unanimous in predicting the eventual end or major modification of the fixed-price bid system. They point out that a fixed-price agreement with a large and intricate number of escalation clauses will eventually become so difficult to administer that it will make a cost-plus contract look attractive.

Similarly, the prevailing informed opinion appears to be that there will have to be a break in the adversary situation in which the parties involved in tunnel building spend too much valuable time and energy on claims and adjudications. Several commented that the larger public agencies with lots of heavy construction work are now much better in approaches to this aspect than they formerly were. They criticize small owners as lacking the staff or sophistication to proceed in the same direction.

One example of this is in San Francisco where BART has sued its general engineering consultant (joint venture) for $85,000,000, contractors for $50,000,000 and car builders for $96,000,000. Meanwhile one of the car supply firms which is being sued for $55,000,000 by BART is asking BART for $15,800,000 it claims is due because of delays caused by BART and the general engineering consultant. A California legislator is calling for state engineers to do all this work in lieu of private firms.

In Milwaukee a contractor who encountered gas and artesian water and was bankrupted is suing to settle under the changed conditions clause. Both the bonding company and AGC (Associated General Contractors) have filed Amicus Curiae briefs contending the judge did not correctly interpret the changed conditions clause. The job was rebid in 1972 and finished by another contractor. Opposing the contractor's case is the National Association of Sewage Plants.

Undoubtedly the largest lawsuit involving defaults and contractor failures is New York's Water Tunnel Three. The $223 million job was half completed when the contractors stopped work. The lawsuits involve claims for $280 million and will be in the news for some time to come.

CONCLUSIONS

1. The impetus and support for a new transit tunnel, especially in a new system, must come from a broad political base. The acceptance of these projects by public officials is much more than a technical decision.
2. The bond issue, along with whatever Federal funds are available, fixes the dollar amount of the overall project. The owner knows how much he has to work with. Although this step can be repeated to expand the budget, it is difficult and risky to go before the public again.*
3. The difficulty of obtaining and sustaining political concensus, and the fixed funding, encourage the owner to place an emphasis on smooth completion of the project. Disruptions and adverse publicity are to be avoided. (Innovative techniques are somewhat risky and offer less incentives since the money amount is fixed.)
4. The engineering firm which handles overall design for the owner is usually given design limits within which to work. They also are working under conditions which approximate a fixed fee. Both of these offer little incentive since the engineer would (1) run the chance of alienating his employer, and (2) be paying for this time out of his own pocket.
5. Alternative designs are not encouraged in public bidding. Though some owners point to value engineering programs, little of substance has occurred. Among other impediments is the notion that alternative designs, if accepted, reflect poorly on the engineers who developed the initial design.
6. Muck removal is not organized by owners but is an extra task (and extra cost) for the contractor.
7. Tunnel excavation functions must be done within a rigid work cycle: (a) the slowest step sets the pace for the entire operation; (b) new equipment must be tested on site to achieve absolutely accurate performance statistics (and costs).

*UMTA is beginning to change this system with the Baltimore Mass Transit project. Under the revised approach, UMTA grant money may be used only for construction of system sections that will be operational as a result of the project funded.

Chapter 5

ROLE OF TUNNEL OWNERS AND OPERATORS

The owner of a tunnel is almost always a public body. Usually the same organization operates the tunnel. In most cases where the operating unit does not own the tunnel the owner used to operate it. For example, several regional transit authorities formed since World War II have absorbed city transit systems that included tunnels. To avoid large bond issues for purchase of these assets, various leasing arrangements have been made, with the city remaining the nominal owner of the tunnel.

Planning for new tunnels is usually handled by the planning staff of any owner-operator which has a continuing program of construction. A relatively continuous stream of projects makes a permanent staff economically feasible. Examples of such resident groups of employees are available in the Corps of Engineers, Bureau of Reclamation, water agencies of the larger states, etc. Industry engineers and contractors generally credit these resident groups as competent, progressive, and easy to work with.

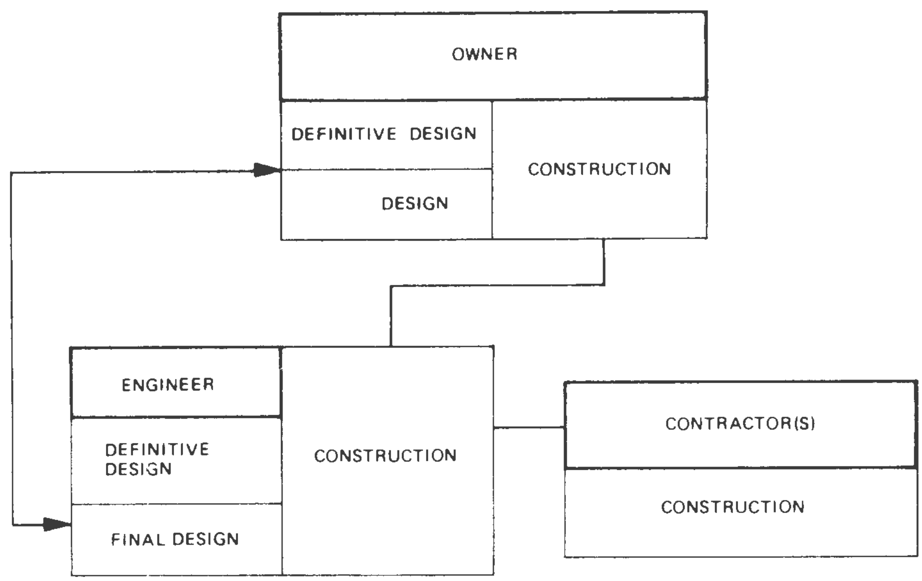
In the absence of a continuing construction program, outside project help is used for planning, engineering, and construction management. The major states, cities and other units (like port or transit groups) again generally are credited with a professional, effective approach. Industry complaints are aimed at smaller states and cities which have infrequent projects, relatively small ones, and too little activity to attract, support or retain the people they need.

For the study of tunnel owner organizations, two transit tunnel projects were selected. They are much more complex than other tunnel jobs, largely due to the urban construction location. Many projects involve additions of lines to existing transit systems. However, those described here are massive multiple projects for the construction of entire new systems. The owner organization changes dramatically during system construction as the exhibits that follow will show.

When the owner or operator is a new entity, much of the planning is done by someone else at first. It may be a planning board or some other unit which has its charter broadened temporarily. However, the owner-operator staffs for, and assumes, these duties as early in its own life as is possible.

A very important early decision has to do with philosophy of organization. In the traditional organizational setup, an engineering firm serves as final design consultant to the owner and also supervises the contractor. This is called the O-E-C (owner-engineer-contractor) type organization. The relationships are shown in Exhibit 5-A. At this writing, the largest application of such an organizational approach is the San Francisco BART project. It appears that the Atlanta and Baltimore organizations will be similar in concept, though they will vary in detail.

Exhibit 5-A OWNER-ENGINEER-CONTRACTOR ORGANIZATION



Source: Systems Analysis of Rapid Transit Underground Construction

A variant of this form of organization is that selected for the Washington system (WMATA). It involves engineering firms and contractors for the various project sections. The section engineers are responsible to the general engineering consultant. Section engineers and the general engineering consultant do much of the traditional technical work. In WMATA, a separate firm of engineers supervises construction. The effect is to add a layer to the organization. Engineers, contractors, and insurance people queried for preferences all stated they prefer the O-E-C system used in BART. Suppliers to the project generally have no preference as to organizational arrangement.

The owner organization performs four functions over a long period of time during a transportation construction project. The tunnels and stations are usually the major portion.

1. OPERATION OF THE TRANSIT SYSTEM. Whether the existing system includes rail rapid transit or is only a surface system of buses, and possibly light-rail (trolleys), it must continue to provide daily service for its riders.

2. MANAGEMENT PLANNING AND CONSTRUCTION. The extraordinary size of transportation construction projects, as compared to other construction (like office buildings or housing) has an enormous impact on any city where it is occurring. Purchases, employment, and effects on the travel time of others are measurable economic effects. Though the performance burden is on the engineer and contractor, the owner has final responsibility.

3. ACQUISITION OF NECESSARY RESOURCES. After initial approvals by everyone with a stake in the project, and power to hold it up, have been obtained, the remaining needed resources are people and money. Generally the people can be employed or retained if money is available. The big money comes from federal agencies. In the case of transportation systems, UMTA generally provides 80% of the money. The remainder comes from state or regional grants, local taxes or bonds sold to the public.

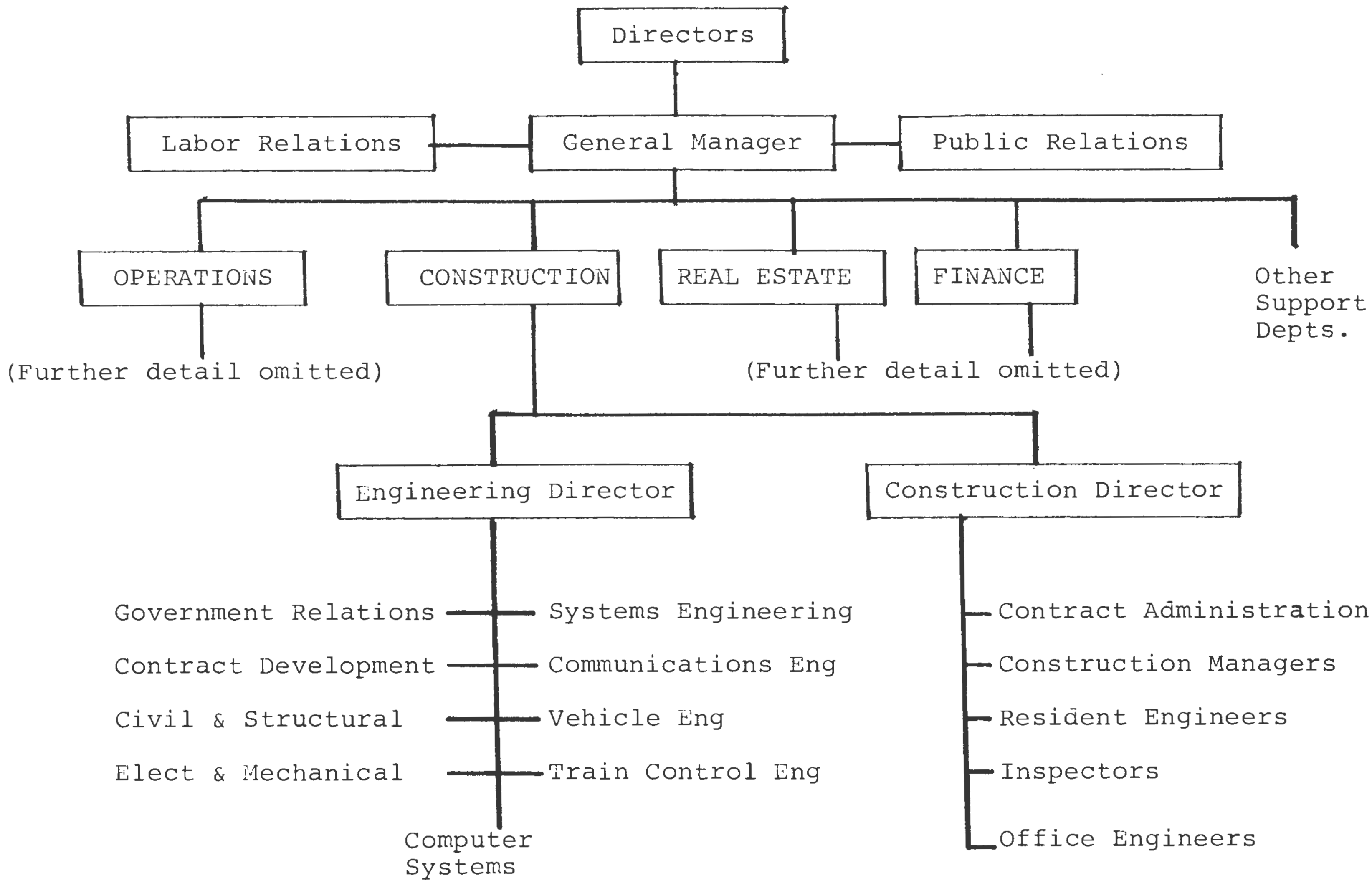
4. MAINTENANCE OF RELATIONSHIPS AND SUPPORT. Transportation construction projects that involve tunnels usually stretch over a decade from planning to dedication. Many changes will occur in the ten or more years and it is a principal need of the project that the owner maintain good relationships with the dozens of pressure groups involved. Their support is necessary for completion of the project. This activity is a political exercise.

In each of these functions there is an established history of potential problems sufficient to keep the owner staff fully occupied. In system operations, the flow of labor relations incidents, weather effects, and urban special events affecting traffic load must be handled. In the construction activity the unanticipated includes bad soil, poor rock, accidents, schedule foulups, lack of supplies, strikes or actions by opponents to delay the project.

Resources and relationships problems are many. Among the largest is the lack of continuity of federal funding, coupled with the intrusions of military actions and recessions which compete for resources. Because this study is concentrating on construction economics related to tunnels, the emphasis of detail in Exhibit 5-B is on engineering and construction.

EXHIBIT 5-B

TRANSIT TUNNEL OWNER ORGANIZATION
During Extensive System Construction



Source: Organization Chart of a Large Owner

Transit tunnel owners finance their projects through a combination of grants from federal, state and other sources and the sale of bonds. These arrangements are based on the best estimates available at the conclusion of planning and they are brought up to date during the approvals and financing stage. Though there are provisions for contingencies like bad soil or labor cost escalation, the financing is so arranged that most participants regard it as a fixed amount of money. These arrangements also inhibit innovations. Owners on a fixed budget can best assess their contingent risks on a project from historical information, which isn't available for new methods.

If it proves to be a substantially satisfactory funding, there is no particular incentive to try to save money. The owner executives cannot be awarded bonuses for good cost performance. There is, of course, continuing fear that various project cost overruns will exceed the available contingency funds. That requires a return to the various sources of funds (legislative, federal or public) hat-in-hand to explain why more is needed and accept public criticism of one's work. In the first half of the Seventies, a roaring construction cost inflation made this situation much worse than it had been.

Cost inflation leads to rises in contract costs even when an owner is covered by fixed-price contracts awarded on bids. Any contractor who begins to lose money on a job will seek reimbursement. If it cannot on regular terms, the tendency is to file claims or initiate litigation.

CONCLUSIONS

1. Owners of tunnels are involved in building very durable major works. Some tunnels last for centuries.
2. Owners with continuing programs of tunnel construction tend to have in-house staff engineering groups and internal review boards which build competence and provide decision-making mechanisms to deal with risk and innovation. Owners with new, or occasional, projects find it more economical to use outside consultants.
3. The owner's organizational philosophy appears to be important, particularly as it affects the engineer consultant's role and responsibility. While hard evidence is not available, bidding programs seem to be tending toward the BART approach. Engineers and contractors look with favor on the organizational form that has the fewest layers and clearest lines of authority.
4. Public sector bid conditions generally do not encourage the submission of alternative designs. This may adversely affect costs or inhibit introduction of new processes or materials. Value engineering programs intended to overcome these problems generally have not been as successful as anticipated.

CONCLUSIONS (CONT'D.)

5. The owner begins the project with a fixed amount of funds and a fixed set of contracts. There is little incentive to be cost-effective, since unused money will not be returned.

6. The owner has to perform many other tasks besides administer the construction; the existing system must be operated and plans prepared for future projects.

7. Urban tunnels, in particular, have very high visibility. Besides the sidewalk superintendents, there are numerous VIP visits and recurrent reviews in the press of fiscal matters and all problems that emerge during planning and construction. The maintenance of support from all interest groups is a very important continuing task for owners.

NOTE: Discussion of current owners is in Chapter 8.

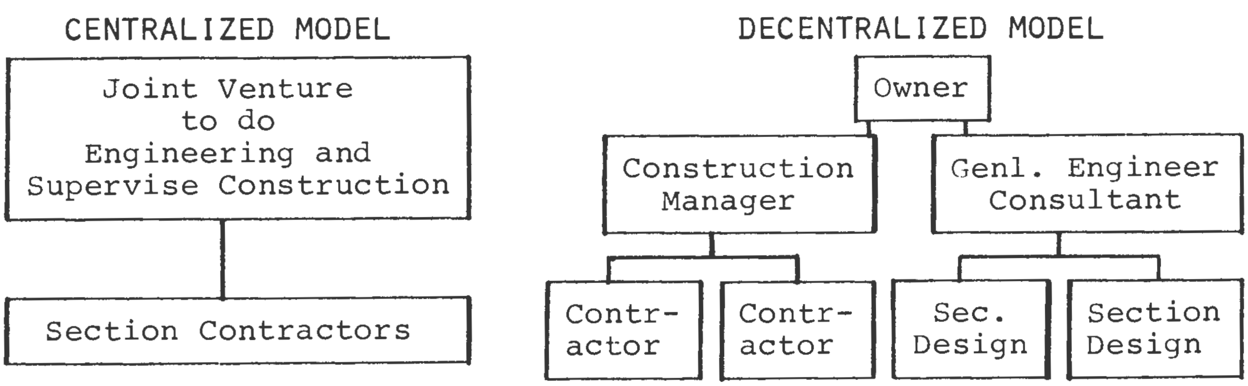
Chapter 6

CONSTRUCTION MANAGERS, ENGINEERS AND CONSULTANTS

In major transit construction projects the engineer supervises the contractor as is true in nearly all construction arrangements. For smaller projects there is only one engineering firm while the large, system-wide jobs necessarily have more people and a more complex organization. Two general organizational models have emerged as noted in Section 5. In BART's more centralized model, all section contractors were supervised by a central construction management and engineering group. Most engineers and contractors interviewed favor this arrangement.

In Washington, WMATA elected to use a construction manager who supervised an engineering firm for each section of the job. Those firms, in turn, each supervised a contractor. In addition, the construction management firm in WMATA has the broad assistance of a general engineering consultant. For smaller transit additions and most water-sewer tunnel projects, the traditional owner-engineer-contractor organization prevails. Some owners with continuing construction work use staff engineers.

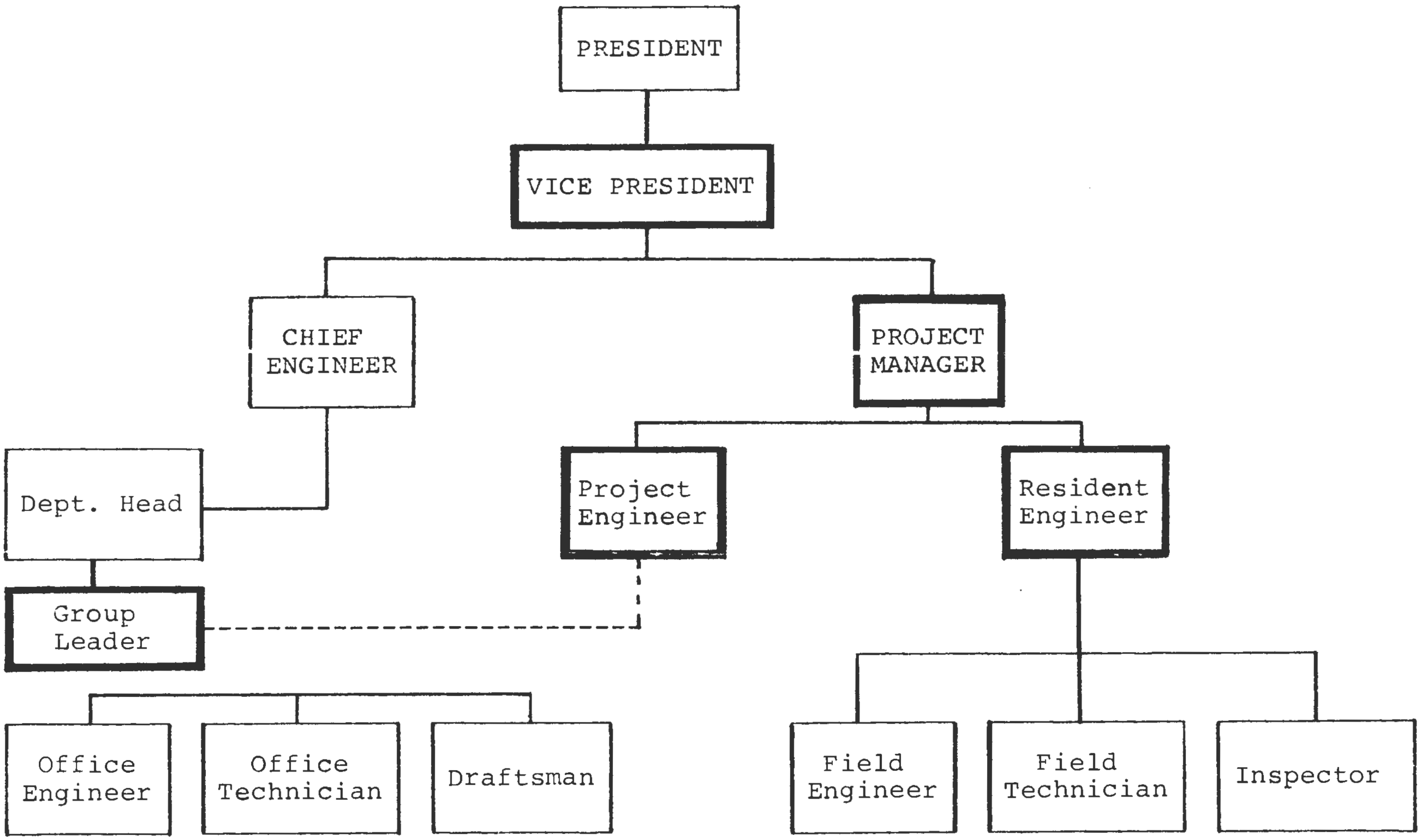
EXHIBIT 6-A COMPARATIVE ENGINEERING ORGANIZATION MODELS



(See Exhibit 6-B) (See Exhibit 6-C)

The construction manager, as a firm, usually has a number of projects underway or in preparation at any given time. It must balance its workload and revenues to hold its staff together and make a profit, or at least break even. Typically, the firm will have internal groups, organized by specific disciplinary field, and project groups. When more heads or hands are needed they recruit people, subcontract, or joint venture with others.

PROJECT ORGANIZATION WITHIN ENGINEERING FIRM



Key Project Personnel

Details in Chapter 15

From a project point of view, the key people in an engineering firm are the vice-president or partner-level executive in general charge of the project, the project manager, project and resident engineers, and those group leaders in the firm's offices providing substantial project support. These people are easily identifiable in Exhibit 6-B, which is based on specific transit tunnel engineering firms.

The task forces organized and deployed by the engineering firms perform all the functions outlined for engineers in Section 4, doing the work directly or through consulting engineers whom they engage. Generally, they have both professional and commercial motivations. As a firm, and as practising individuals, their desire is to do a thorough, professional job worthy of the praise of their peers. From a business viewpoint they would like to earn a fair profit and definitely avoid a loss.

Engineering fees may be negotiated or be a percentage of the estimated cost, of the job, or arrived at on some other basis. One tunnel engineering firm showed us estimates for its services which were built up for several jobs. These were then compared with the cost curves published periodically by the American Society of Civil Engineers so there would be some indication of how close they were to averages. This is a defensive check to see if anything has been missed. As it turned out, preparing the fee estimate by build-up happened in these cases to be extremely close to the traditional percentage fee.

DEFENSIVE APPROACH

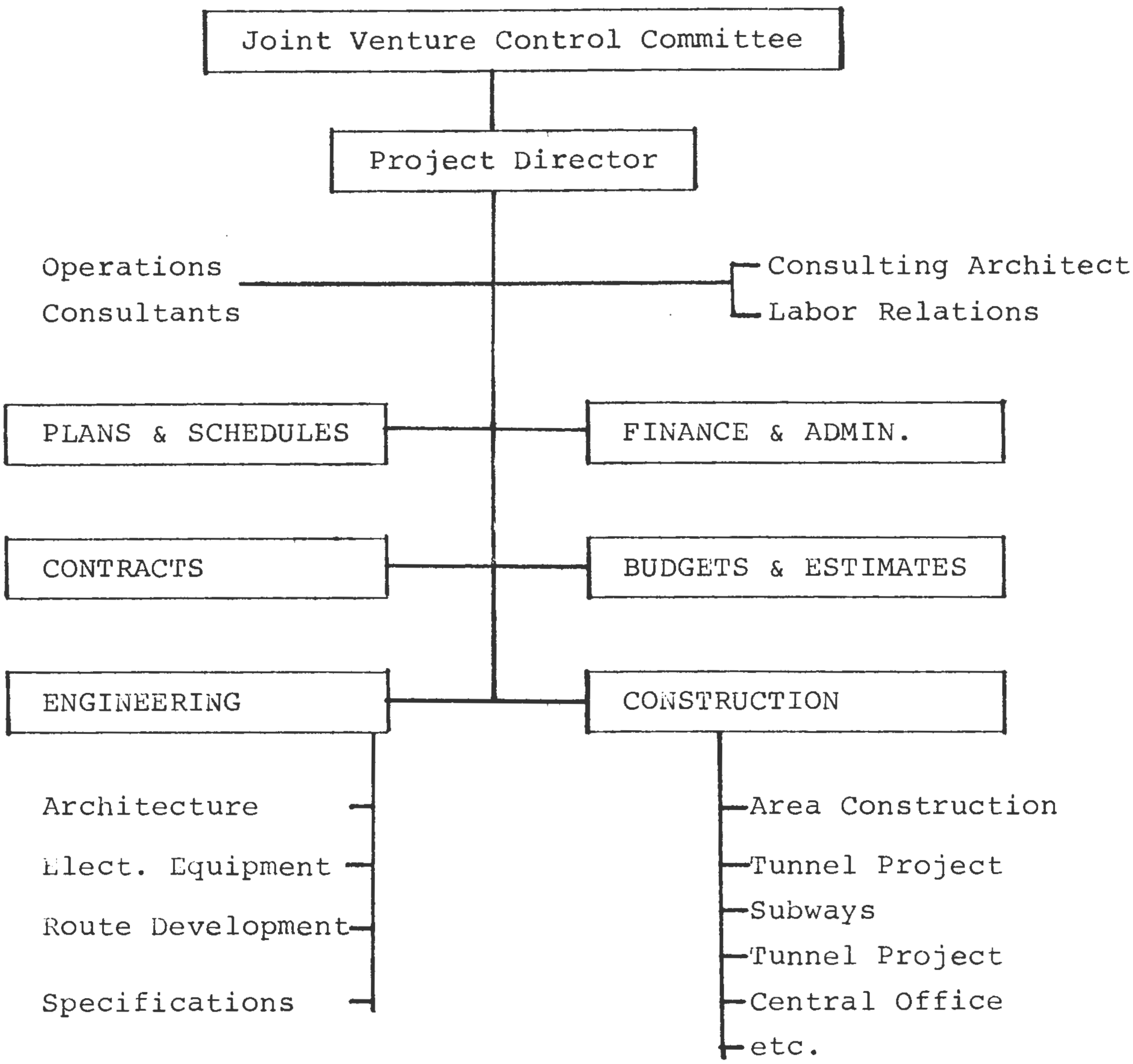
The approach of most engineers is cautious and conservative, like that of the owners and contractors with whom they work. There is little room for styling in a tunnel, so the free-flowing imaginative design freedom occasionally available to an architect is never available to a tunnel design engineer. Design is, or might be,influenced by a very cautious approach to new materials. One transit project engineer told us of being reluctant to use steel-reinforced concrete because they don't know enough about the life of the steel embedded in the concrete. Instead, they relied on mass, specifying a six foot thickness of concrete to obtain the strength desired.

During the study of the introduction of new technology (discussed in Section 16) it became apparent that the lack of incentive for engineers and owners to experiment is a major barrier. The contractor can build to the specifications, but engineers specifying for a tunnel that fails will be ruined professionally and, probably, financially.

A defensive approach is apparent, too, in joint ventures, which nominally enable the partners to handle together a job too large for an individual firm.

Exhibit 6-C

JOINT VENTURE ORGANIZATION



ENGINEERING STAFFING FOR A PROJECT

A study was made of a general engineering consulting firm's staffing for a large transportation construction project. A section design engineering project also was studied. The totals of people required are shown in Exhibit 6-D.

Exhibit 6-D

TUNNEL PROJECT ENGINEER STAFFING

	GENERAL ENGINEERING FIRM				SECTION DESIGN FIRM
	Engrg. Groups	Estimating & Control	Admin. Staff	TOTAL	TOTAL
Key-job engineers	46	3	2	51	12-13
Non-key engineers	69	13		82	5-12
Engin. technicians	22	3		25	3-12
Draftsmen	23	1		24	2-8
Clerical & Other	7	4	12	23	2-3
TOTAL	167	24	14	205	24-53

In examining the personnel statistics in Exhibit 6-D it is important to note that this is project staffing and does not represent company staffing. Details by job are included in Exhibits 6-E and 6-F which follow. Key personnel are those without whom the firm would not wish to be responsible for the work. Non-key people can provide the needed work whether they come from the firm's regular staff or are hired at an operating location.

Results required of key personnel, together with their requirements for appointment, job responsibilities, work relationships they have to maintain, and the usual job success measurements are included in the Key Personnel Descriptions in Section 15 on People. Information recruiting, education, professional associations, and on industry communication is also in Section 15.

OPERATING PROBLEMS FOR ENGINEERS

Most operating problems relate to new technology, new materials, new procedures, new organizational arrangements, schedule conflict or human error. Tunnel engineering does not involve much new technology or new materials and only a few new procedures. Schedule conflicts and human error abound, which is why inspection and control is an important function of the engineering firm on the project.

Exhibit 6-E

GENERAL ENGINEERING CONSULTANT
PROJECT PERSONNEL CLASSIFICATIONS

	Key Project		Non-Key Project				
	Managers	Group Leader	Engineers	Technicians	Draftsmen	Admin. & Clerical	Others
I. ENGINEERING							
System Safety		2	3	1			
Civil		5	11	4	7		
Yards, Shops & Trackwork		3	6	2	2		
Structural		6	8	1	1		
Mechanical		3	9	2	5		
Electrical		4	4	3	3		
Utilities		4	7		2		
Systems		4	3	5	3		
Specifications		1	3	2			2
Plan Review & Coordination		5					1
Section Design Coordination		1	11				
Environmental		1					
Materials		1					
Soils & Geology		1					2
Office Engineering		1	4	2			
Resident Engineer			1 As Req'd				
Dept. Supervisor	4					2	
TOTALS	4	42	69	22	23	2	5
II. ESTIMATING & PROGRAM CONTROL							
Scheduling		1	3	1	1		1
Estimating		1	10	2			
Billing							1 As Req'd
Program Control							1
Dept. Supervisor		1				1	1
TOTALS		3	13	3	1	1	3
III. ADMINISTRATIVE							
TOTALS	2*					12	
GRAND TOTALS	6	45	82	25	24	15	8

*Project Management

Exhibit 6-F

SECTION DESIGNER

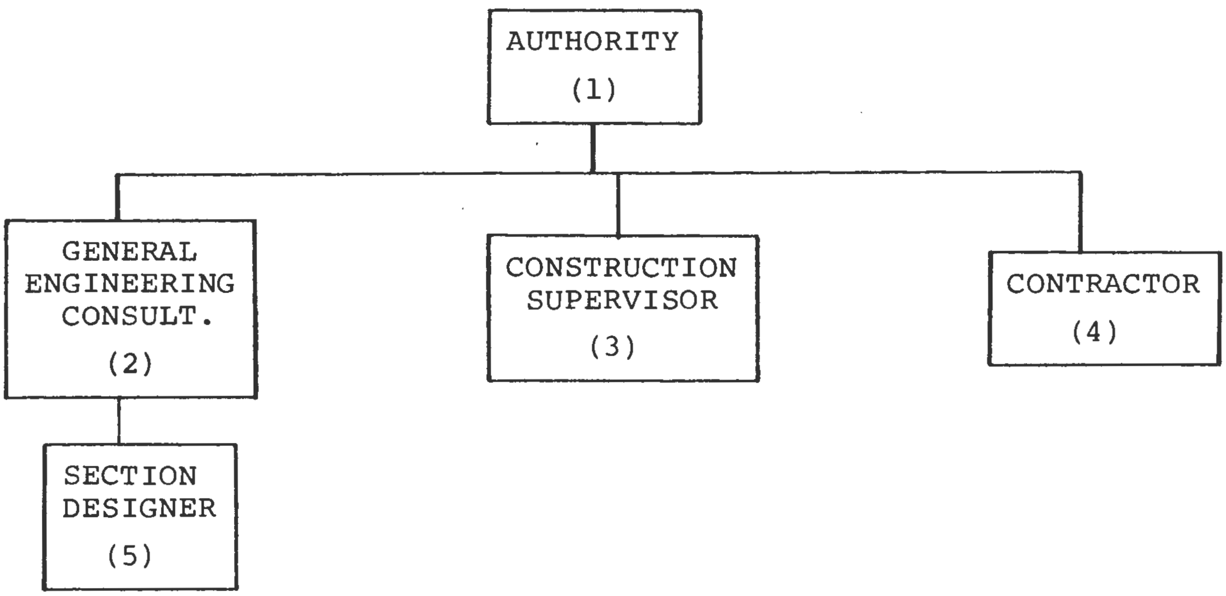
PROJECT PERSONNEL CLASSIFICATION

	Key Project		Non-Key Project			
	Managers	Group Leaders	Architects	Engineers	Technicians	Draftsmen
Project Management	1				0-1	
Tunnel Consult.		1		0-1		0-1
Civil Surveys R.O.W.		1			1-3	
Structural		1-2		2-8	1	2-4
Soils		1		0-2		
Architectural		1	1		0-2	
Landscape Architectural		1	0-1			
Mechanical		1		1-2	0-1	
Utilities		1			1-2	0-2
Electrical		1		1-2		0-1
Specifications		1			0-1	
Estimating		1			0-1	
TOTALS	1	11-12	1-2	4-15	3-12	2-8
GRAND TOTALS	12-13		10-37			

New organizational arrangements can create confusion, complexity and the opportunity for error. Interestingly, the contractors report that just this potential problem has led to such extra care in the formation of joint ventures that those organizations tend to be more profitable than do single-company projects. (This is discussed in Part V). For example, the insertion of a second layer of engineering firm adds to the steps involved in making a design or specification change. See Exhibit 6-G.

EXHIBIT 6-G

DESIGN CHANGES DURING CONSTRUCTION



CHANGE INITIATED BY	SEQUENCE
AUTHORITY	1-2-5-2-1-3 and 4
CONTRACTOR	4-3-1-2-5-2-1-3 and 4
CONSTRUCTION SUPERVISOR	3-1-2-5-2-1-3 and 4
GEN ENG CONSULTANT	2-5-2-1-3 and 4
SECTION DESIGNER	5-2-1-3 and 4

Engineers, contractors and consultants are critical of that arrangement. When changes or approval of shop drawings are requested by the construction contractor, the general engineering consultant must either decide the matter, feeling he knows enough about the change or shop drawing. This involves a risk of making the change on incomplete information.

Alternatively, the general engineering consultant can discuss the matter with the section designer and seek his advice on whether the change or shop drawing should be approved. This results in delays and additional costs arise due to an additional intermediate level of supervision. A better arrangement would be to use individual section designers to supervise and inspect work on sections that they designed. If the resident engineer on the job then requires assistance on a field problem he can quickly summon his own engineering staff. They worked on the design and are most likely to know why a particular operation was specified as shown, or why the materials specified should or should not be approved.

CONCLUSIONS

1. Big, complex projects have changed the engineer's role. Administration has begun to dominate jobs. Management distance has increased between the contractor's men in the tunnel and the person with the authority to approve major changes.

2. WMATA's organization form encouraged entry by engineering firms with minimal prior experience.

3. Most engineering firms balance their workload among a variety of kinds of work. There are few tunneling specialist firms.

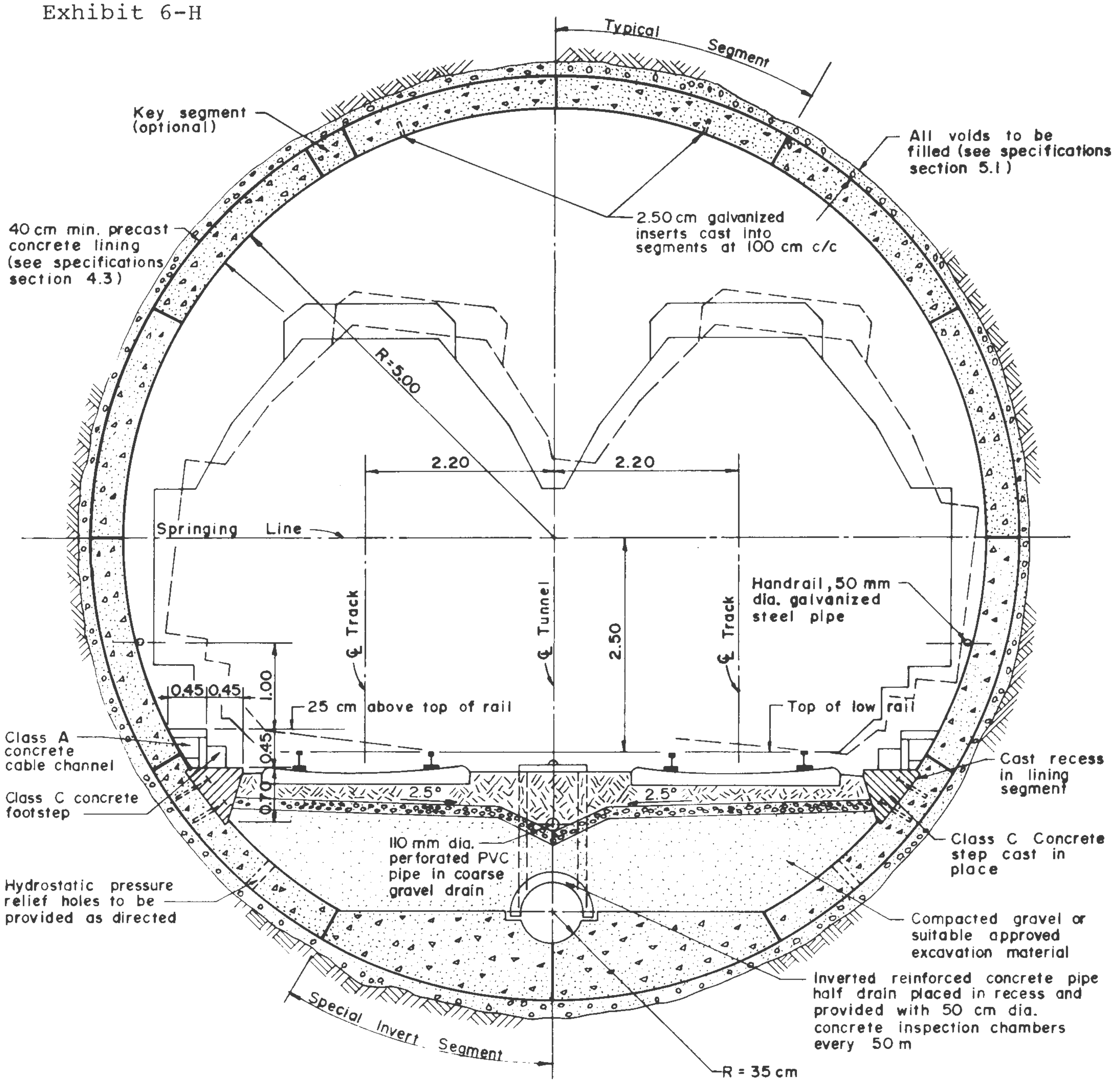
4. Many engineering firms are confident that they can handle either the design or management of major tunnel projects.

5. Most engineering firms have their major investment in senior staff. They are able to expand rapidly by hiring mid-level and junior staff, renting more space, and engaging expert consultants where needed.

6. As in other industries, there is a limit to the rate of manageable expansion of firms. During such periods people are frequently placed in positions exceeding their capability. This exposes the firm and the project to some risk.

A description of current tunnel engineering firms is in Chapter 9.

Exhibit 6-H



Typical Segment
Key segment (optional)
All voids to be filled (see specifications section 5.1)
40 cm min. precast concrete lining (see specifications section 4.3)
2.50 cm galvanized inserts cast into segments at 100 cm c/c
R=5.00
2.20
2.20
Springing Line
℄ Track
℄ Tunnel
2.50
℄ Track
Handrail, 50 mm dia. galvanized steel pipe
0.45
0.45
1.00
25 cm above top of rail
Top of low rail
Class A concrete cable channel
0.45
Cast recess in lining segment
Class C concrete footstep
0.70
2.5°
2.5°
110 mm dia. perforated PVC pipe in coarse gravel drain
Class C Concrete step cast in place
Hydrostatic pressure relief holes to be provided as directed
Compacted gravel or suitable approved excavation material
Inverted reinforced concrete pipe half drain placed in recess and provided with 50 cm dia. concrete inspection chambers every 50 m
Special Invert Segment
R = 35 cm

Chapter 7

TUNNEL CONTRACTORS

Contracting firms operating in the tunnel industry are of four general types. Some are divisions or subsidiaries of large multi-industry organizations. A second group of firms provides diversified heavy construction services to varied end-users, including tunnel owners. The third group is made up of people specializing in large excavation projects and underground work. Groups two and three are generally sizeable business: most are still owned by an individual, a family, or a management group, but some are public companies. The fourth group of contractors is made up of smaller local or regional firms which do tunnel work. Details on these firms are provided in Chapter 10 and in Appendices C and D.

At the project level, their organization for the job is much the same from firm to firm. On large jobs joint ventures are increasingly common. For example, The Chicago Addison Street Tunnel involved three bidders: two were joint ventures and each joint venture involved three firms. In enormous transit tunnel jobs like WMATA in Washington, where the entire project was split into smaller sections, it is more common for firms to work alone.

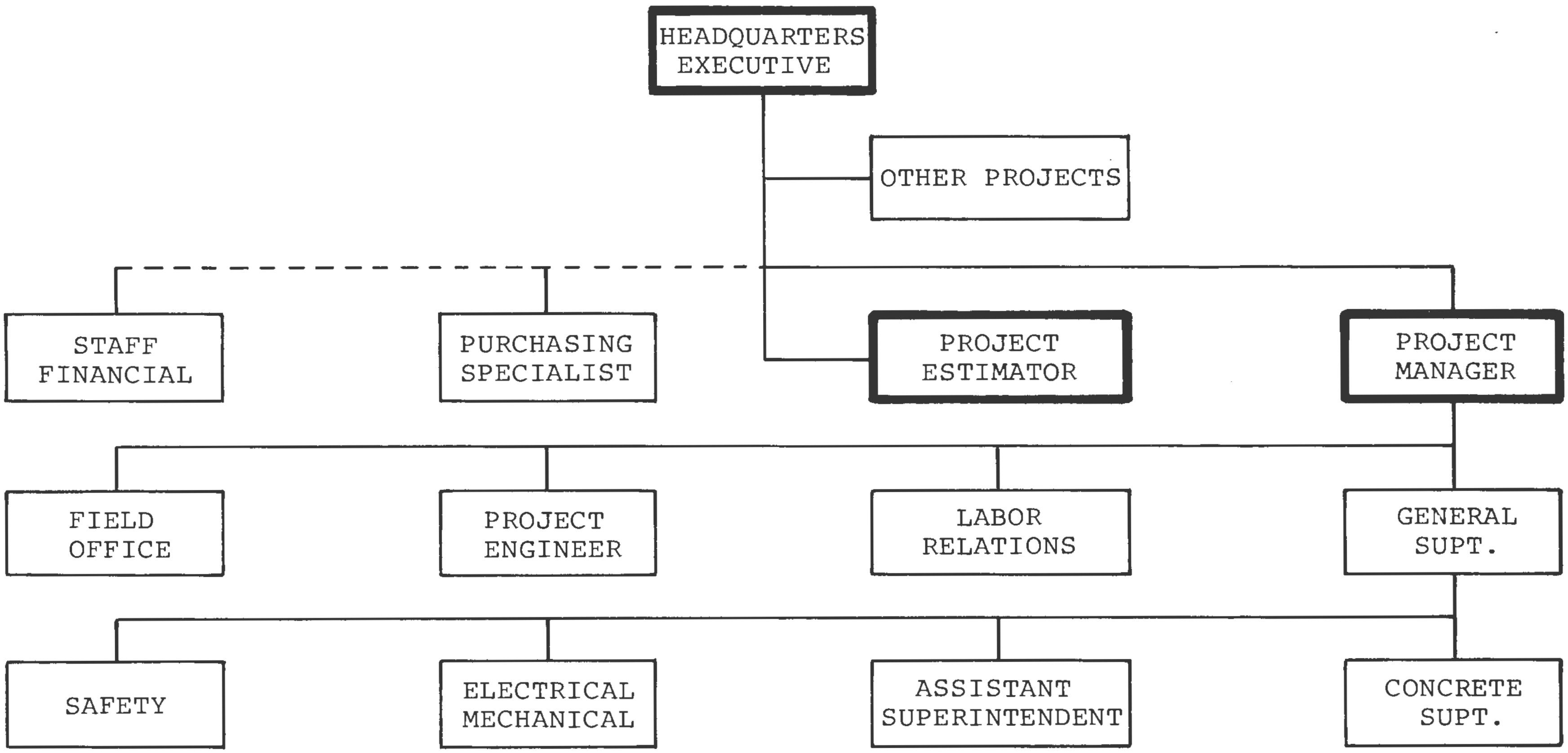
These firms attempt to maintain a diversified balance of work to provide fairly steady cash flow and reasonably stable employment. They also generally have to be involved in various work segments of the heavy construction industry because there are sharp peaks and valleys of activity. This is visible for tunneling in the data in Chapter 3 on Demand. It also applies in other types of heavy construction work. Small firms may have only one active project at a time and may have periods when the company is "between projects" and has to live on its capital.

KEY PERSONNEL IN TUNNEL CONTRACTING FIRMS

Contractors will not bid for jobs if they lack certain people to help run the project should it be awarded to them. Indeed, their bonding agents will not issue performance bonds if the necessary people, in whom the surety firm has confidence, are not either on the payroll or under agreement to join. The key people have this in common: they are not easy to replace.

In relation to a specific tunnel project, the executive responsible at company headquarters (usually a vice president or the president of a smaller firm) is the key person. The estimator, or head of the estimating team is a key office person, supported by finance and purchasing specialists. In the field, the project manager who will boss the job is the key person, supported by his project engineer, superintendents for each shift, and field specialists in purchasing, surveying, safety and labor relations. These are shown in Exhibit 7-A on the next page. All other people on the job are non-key.

KEY PEOPLE IN TUNNEL CONTRACTOR PROJECTS



▬ Key Project Personnel

ESTIMATING A TUNNEL JOB

As described in Chapter 4, the contractor's first decision is whether or not the firm is seriously interested in a particular project scheduled to be put out for bids. If the decision to prepare an estimate is made, it does not commit the firm to bid, but it does commit it to a considerable expenditure of talent, time and money.

On larger tunnel projects separate estimates may be made and their results compared. In joint ventures each of the joint-venture members generally prepares an estimate. The results may be compared against figures prepared by a professional estimator or consulting engineer. Estimates may be prepared manually or by computer. In the manual process the estimator sets down all computations; with a computer, production rates, crew sizes, wage rates and other basic factors are stored in the computer which produces a tabulated estimate. Often, an estimate is prepared both ways as a check.

Following are the steps taken in estimating a tunnel. All are interrelated. Continual review of the various steps is essential. Decisions made during the estimating process may require re-evaluation of steps completed previously.

FORM TEAM AND OBTAIN PLANS. Selection of the estimator for a tunnel project is actually the appointment of a team leader, since several people's efforts are required for weeks or months in order to properly prepare an estimate. As soon as plans or specifications are available, the firm obtains these from the owner, making a deposit payment. On a Fall 1975 project for bidding, the owner collected $710,000 in bid deposits from prospective bidders.

STUDY OF PLANS AND SPECIFICATIONS. The team studies these in some detail to gain an understanding of the total job; to identify potential changes or trouble spots based on its experience in other jobs; and to judge, generally, how well drawn the specifications are.

INSPECTION OF JOB SITE. The estimating team travels to the job site to observe local conditions and obtain current local information. They are particularly interested in these points:

Labor Rates	Local suppliers for initial job requirements
Access Roads	Site preparation requirements
Power Supply	Local subcontractors
Water Supply	Available work areas
Local Codes	Muck disposal areas and costs

RECHECK OF PLANS FOR SPECIAL REQUIREMENTS. With the site visit information and conclusions in hand, the team goes over the plan again to be certain nothing really important has been missed. Of particular concern are:

Prequalification requirements	Contractors license
Changed Conditions Clauses	Liquidated damages
Time extension limitations	Noise codes
Performance bond conditions	Billing Conditions
Payment bond conditions	Owner payments
Construction method limits	Work area adequacy
Water pollution restrictions	Blasting regulations
Labor union work rules	Traffic regulations

PREPARE CHECK LIST. From the specification, a reference list of all special requirements is made up for easy use. This will be an important judgment tool later where uncertainty decisions are made in the bid-no-bid decision and in pricing.

REVIEW SUBSURFACE INFORMATION. Reports of geological conditions relevant to the job are studied carefully. All other information which the team can obtain about ground conditions in the area of the job site is studied, discussed and assessed. Anyone who might know anything is interviewed.

DECIDE ON UNDERPINNING AND FOUNDATION SUPPORTS. In some soils, and in all urban transportation construction, the question of support of adjacent structures becomes an important one. For estimating purposes the contractor may be working with specified levels of support which the owner's engineer has included in the plans. Or the support may be optional, with the contractor required to fix damages resulting from construction of the tunnel. Some contractors have their people obtain options to buy the more doubtful buildings. The option cost plus demolition estimate provide a known expense exposure versus an uncertain one.

PLAN METHOD OF CONSTRUCTION. Some construction choices will be dictated by the owner's specifications and some by the soil conditions. Usually there is some room for alternative approaches within each job and the decision as to which way to do it must be made before costs can be estimated. One factor currently plaguing contractors in this aspect of estimating is supplier lead time for delivery of tunnel boring machines, commonly referred to as moles. Though the choice might be to use a mole for excavating, another method may have to be used because delivery of new moles takes too long (9-18 months).

DEVELOP INITIAL SCHEDULE. The general schedule of work for the scope of job and construction method chosen has to be developed. How long it will take to build the tunnel can have a dramatic effect on costs, as can any delays encountered after work begins.

SELECT EQUIPMENT. The types and numbers of units of general and special equipment required must be divided. General equipment includes items like dump trucks or fire extinguishers which are not unique to tunnels; special equipment includes drill jumbos, shields or muck cars, for example. Equipment selection is influenced by what the contractor now owns and has available, how much used equipment is around, and what the lead time is for delivery of equipment.

ESTABLISH CREW COMPOSITION. For each operation, the crew makeup has to be established to fit the contractor's work methods and any specified work rules which apply.

PREPARE QUANTITY TAKEOFFS. The actual quantities of each supply item or work task that will be involved in the project must be taken from the plans and specifications and arranged so the estimator can identify and cost every job aspect.

SOLICIT SUBCONTRACTOR AND MATERIALS PRICES. Each of the subcontractors potentially to be engaged must be approached, a prospective agreement developed and priced, and a deal reached which is firm contingent on the prime contractor's being successful in the bid. The same must be done with the materials and equipment suppliers. This can be a sensitive task as the bid being prepared is competitive and subcontractors and suppliers, not knowing who will win, may make contingency agreements with several contractors. An example of the detail provided by a special supplier is included in Appendix E, Supplier Support Documentation.

ASSIGN PRODUCTION RATES. When the estimator (or team) has a firm grip on what has to be done and how many people will be required to staff each crew or type equipment, the next critical consideration is how fast the work will be done. Many things affect this and the choices are important as these assumptions can have major effects on costs.

CALCULATE OPERATION COST BY PAY ITEM. Labor cost by direct, fringe, tax, insurance, or overtime premium item is calculated for each operation. This will show direct and indirect costs plus the ranges of decision for extra staffing versus payments of overtime premium pay.

OTHER ALLOWANCES. Estimates must be developed for overall costs of various types of insurance, payroll taxes, sales taxes, small tools, consumables, like office supplies, etc.

DEVELOP TOTAL DIRECT COSTS. With direct cost components identified and the crew composition, production speed, and quantities established, the estimator can develop direct costs in these categories:

1. Surface logistical requirements and costs.
2. Tunnel excavation costs.
3. Temporary support requirements and costs.
4. Tunnel lining labor costs.
5. Tunnel lining material costs.

DEVELOP INDIRECT COSTS. Most project estimators use one or more checklists for this since there is considerable detail. A Plant Cost checklist is included as Exhibit 7-B; Field Overhead Cost checklist is Exhibit 7-C; Insurance Cost checklist is Exhibit 7-D.

PREPARE CASH FLOW FORECAST. A complete forecast of project spending, based on the estimates of direct and indirect expense is prepared to show when cash will leave the company. As an offset, the expected dates and amounts of payments from the owners will be laid out on a spread sheet. (This process is illustrated in Section 12, Exhibit 12-A). The cash flow forecast cannot be completed until the job has been priced but it must be partially prepared so that financing needs can be identified. This results in borrowing, switching from purchases to leasing, or shifting funds in other ways.

SUMMARIZE TOTAL ESTIMATED COSTS. The combination of direct, indirect and estimated project financing costs, when summarized, is part of the basis for the bid-no-bid and pricing divisions discussed in Sections 12-14. Other cost factors are escalation, contingency and profit, and the absorption of corporate indirect costs.

CORPORATE OVERHEAD. Includes all indirect expenses not in the field overhead related to a given job or metropolitan area. (Sometimes field overhead can be shared among jobs if there is more than one job active in a metropolitan area away from the company's headquarters location.)

ESCALATION AND CONTINGENCY. In most instances the team will develop various factors or alternatives for handling the escalation of costs during a job. There will also be a full list of potential contingencies with their possible cost effects. These amounts (for escalation and contingency) are judgmental and will be reserved to the senior executives for decision.

ARRANGEMENT OF THE BID TO THE OWNERS' PROPOSAL FORMAT is the last task of the estimating team, if there will be a bid. Then there is the management decision, agreement by the bonding and financial people to support the bid, and submission of the bid to await an award.

EXHIBIT 7-B

CHECKLIST FOR PLANT COST ESTIMATING

PLANT INSTALLATION

Site preparation

Roads and bridges

Buildings

Water supply

Generating station

Sanitation arrangements

Air distribution

Electrical distribution

Steam distribution

Railroad sidings and switches

Wharfs and docks

Cableways and gantries

Concrete plant

Concrete delivery

Batch and mix

Refrigeration plant

Equipment installation

Freight costs for above items

GENERAL PLANT OPERATIONS

Automotive - cars and jeeps
Pick-ups and station wagon
Flat trucks
Ambulance
Air and water expenses
Generator operating costs
Roads & bridges operation
Electric operation
Equipment repair shop
Carpenter shop
Yarding and rigging
Bull gang

EXHIBIT 7-C

FIELD OVERHEAD COST ESTIMATING CHECKLIST

SUPERVISION

Project manager
Assistant manager
Administrative assistant

General superintendent
Asst. general superintendent
Carpenter superintendent

Excavation superintendent
Tunnel superintendent
Steel superintendent

Electrical superintendent
Mechanical superintendent
Quarry superintendent

Equipment superintendent
Concrete superintendent
Batch & cooling superintendent
Cure & clean-up superintendent

PURCHASING & WAREHOUSING

Purchasing agent
Chief Warehouseman (Bottom staff, etc.)

Receiving clerks
Administrative clerks
Expeditors

SECURITY - SAFETY EXPENSE

Director
Chief Guard
Guard
Watchmen

Safety clothing
Safety expense
First aid cost

Pre-employment physicals and doctor retainer
Fire equipment
Barricades and signs
Security expense

EXHIBIT 7-C (Cont'd) FIELD OVERHEAD COST ESTIMATING CHECKLIST

ADMINISTRATIVE

Office Manager
Accountant
Cost accountant

Personnel specialist
Labor relations spec.
Cost allocator

Paymaster
Timekeeper
Payroll clerk

Voucher clerk
Radio - telephone operator
Telephone operator
Typist

Administrative clerk
Secretaries

SAFETY AND FIRST AID

Safety engineer
Doctors
Nurses
First aid men

ENGINEERING

Project engineer
Field engineer
Office engineer

Cost engineer
Design engineer
Materials engineer

Layout engineer
Draftsmen
Printing machine operator

Party chiefs
Instrument men
Rodmen

WAREHOUSE EXPENSE

Warehouse stock loss
Misc. warehouse supplies

COMMUNICATIONS

Telephone & teletype
Radio

GENERAL EXPENSE

Land rental or purchase
Office rent
Move employees & families

Executive travel - this job
Entertainment & donations
Drinking water

Recreation
Home office charges
Sanitation & janitorial

Permits & fees
Utilities (light, heat & power)

PROFESSIONAL & ADMIN. EXPENSE

Legal - Audit
Office supplies & expense
Office furniture & equipment

Labor Relations expense
Bank charges
Project scheduling consultants

Consulting fees
Photographs & reproductions
Office equipment & supplies
Field equipment & supplies

Source: Tunnel Contractor

Exhibit 7-D INSURANCE AND TAX COST CHECKLIST

In estimating costs for a tunnel project the contractor will have to develop costs for these kinds of insurance unless the owner specifies different arrangements.

Compensation and Liability Insurance
(Per $100 of Insurance Payroll)

Contractual Liability
(Per $100 Contract Amount)

Builders Risk
(Per $100 of Contract)

Public Liability Property Damage

Dishonesty And Forgery Bond

Pressure Vessels & Boilers Insurance

Personal Property Taxes

Owner's Protective
(Per $100 Contract Amount)

Contractor's Protective
(Per $100 of Subcontractors)

Contractor's Equipment Insur.
(Per $100 of Value)

Fire And Theft

Hired Vehicles Contingent

Transportation Insurance

Local Taxes

BID COMPARISONS

When bids are opened by owners, the contractors all examine the bid items and compare them. The engineer's estimate is also available and there is substantial comment if a contractor's bid is much below the engineer's estimate. Such a low bid may indicate:

a. There is too little work coming up and the low bidder is cutting his price to insure that he gets the job.

b. The contractor is in financial difficulty and must have the next job to survive.

c. Poor bidding preparation or bad luck have led the contractor to leave money on the table (bid lower than necessary to win).

d. An error has been made and some cost item was forgotten.

The crucial importance of bidding knowhow was demonstrated by one heavy contractor who decided to enter tunneling. He assigned a team of several people to prepare estimates and bids on four jobs, with no intentions of submitting the bids. As each job was awarded, they studied all the details of all bids. After a year of work they submitted a well-thought out bid and won the job.

Exhibit 7-E (on the next page) shows actual bid data submitted by one contractor and two joint venture groups for a Chicago job. In examining these figures, please note the wide variations in unit prices offered for items 4A, 4B, 5A, 5E, 5F, 9B and 10.

EXHIBIT 7-E

COMPARISONS OF BIDS ON CHICAGO ADDISON STREET TO WILMETTE TUNNEL

Bids Received: October 7, 1975 Bids Opened: October 7, 1975 293 Advertisements Mailed

NAME OF BIDDER			J. F. SHEA CO. 4720 MONTGOMERY LA. BETHESDA, MD. 20014		KENNY CONSTR. PASCHEN CONSTR. S & M CONSTR.		S. A. HEALY CO. GREENFIELD CONST. GORDON H. BALL CO.	
Item	Description	Approx. Quantities and Units of Payments	Unit Price	Total Amount	Unit Price	Total Amount	Unit Price	Total Amount
1A	Mainshaft Excavation Addison Street	Lump Sum	10,000,000	10,000,000		1,500,000		9,000,000
1B	Mainshaft Excavation Howard Street	Lump Sum	10,000,000	10,000,000		19,500,000		9,000,000
4A	Tunnel Excavation 30" Diameter Tunnel	27,750 Linear Feet	1,000	27,750,000	700	19,425,000	468	12,987,000
4B	Tunnel Excavation 22' Diameter Tunnel	24,020 Linear Feet	750	18,015,000	557	13,379,140	375	9,007,500
5A	Drilling Grout Holes	66,400 Linear Feet	10	664,000	5	332,000	20	1,328,000
5B	Portland Cement for Grout	33,200 Cubic Ft.	4	132,800	4	132,800	4	132,800
5C	Sand for Grout	3,320 Cubic Ft.	3	9,960	1	3,320	2	6,640
5D	Fluidifier for Grout	3,320 Pounds	3	9,960	1	3,320	4	13,280
5E	Placement for Grout	132,800 Cu. Ft.	4	531,200	5.50	730,400	15	1,992,000

EXHIBIT 7-E (Continued)

COMPARISONS OF BIDS ON CHICAGO ADDISON STREET TO WILMETTE TUNNEL

NAME OF BIDDER			J. F. SHEA CO.		KENNY CONSTR. PASCHEN CONSTR. S & M CONSTR.		S. A. HEALY GREENFIELD CONSTR. GORDON H. BALL CO.	
Item	Description	Approx. Quantities & Units of Payments	Unit Price	Total Amount	Unit Price	Total Amount	Unit Price	Total Amount
5A	Connections to Grout Holes	5,100 Connections	40	204,000	25.00	127,500	100.00	510,000
6A	Excavation for 4' Diameter Drop Shafts	Lump Sum		2,000,000		800,000		2,000,000
6B	Excavation for 5'8" Diameter Drop Shaft	Lump Sum		2,000,000		900,000		4,000,000
6C	Excavation for 7'2" Diameter Drop Shaft	Lump Sum		4,000,000		2,000,000		5,000,000
6D	Excavation for 9' Diameter Drop Shaft	Lump Sum		1,500,000		450,000		2,700,000
6E	Excavation for 12' Diameter Drop Shaft	Lump Sum		3,000,000		1,600,000		9,300,000
6F	Excavation for 15' Diameter Drop Shaft	Lump Sum		4,000,000		1,800,000		8,283,000
9A	Rock Bolting	35,000 Linear Feet	20	700,000	9.50	332,500	20.00	700,000
9B	Rock Dowelling	30,000 Linear Feet	10	300,000	2.50	75,000	12.00	360,000
10	Rock Joint Treatment	1,500 Linear Feet	60	90,000	33.00	49,500	50.00	75,000
	TOTAL		84,906,920		63,140,480		76,398,220	

POST-AWARD CONTRACTOR ACTIVITIES

Despite continuing intentions to avoid frantic last minute work, nearly all contractors have a good bit of hurrying going on in their bidding process. Generally, the owner allows only a few weeks from the time plans are available, through a bidders meeting, to the bid submission dates. As a result, the contractor to whom the job is awarded has mixed feelings. The key people in the firm are happy to have the work, but they worry that their bid was lowest because they forgot something important.

Accordingly, the immediate post-bid activity is to review each critical area to reduce risk and try to improve the probability of rewards. A checklist is in Exhibit 7-F.

EXHIBIT 7-F

POST-AWARD RISK REDUCTION CHECKLIST

1. Prepare detailed site layouts to avoid interference among operations and provide proper accommodation for all.
2. Check muck removal system to be sure it exceeds the peak capacity capability of the excavation procedure.
3. Minimize sequential operations to limit breakdown impact.
4. Review each procedure to see if it can be simplified.
5. Review equipment to limit the pieces to be in use.
6. Provide for a fully adequate number of initial spare parts.
7. Consult again with suppliers, who will now be more open since they have one firm customer versus several prospects.

MOBILIZATION STAGE ACTIVITY

All of the post-award activity outlined in Exhibit 7-F goes on while the purchasing people are buying, leasing or refurbishing project heavy equipment; the labor people are arranging to fill the jobs which will use local people; shaft-sinkers and others with early-stage tasks are at work; and the staff support crews listed in Exhibit 7-F are organizing, installing and starting up their activities. In urban transportation construction projects, the owner and contractor may, at this stage, also have to deal with individuals or groups opposing the project. Groups may picket, seek injunctions to stop work, or otherwise pose a threat of disruption. The recent and growing custom of owners providing substantial mobilization cash to contractors is a muck welcomed addition to handling this phase.

PURCHASING

About one half of the money spent on most tunnels is for purchases of goods and special services; most is for the prosaic but necessary materials for excavation and lining of the tunnel. The scope of the purchasing generally is not fully appreciated by outsiders. For example, on only one section of the WMATA system in Washington, contractor purchasing people have to deal with 489 suppliers. These are shown in Exhibit 7-G by supply or service item, further divided into local or distant suppliers.

Though purchasing arrangements and prices have to be made in advance of bidding for the job, it is also necessary to keep a good bit of flexibility in the arrangement to make it possible to shift materials or amounts to meet changed conditions. At the same time, price-inflation has had an effect on the traditional purchasing practices, as has the changing ways of some owners. These are discussed in Chapters 8, 11 and 12.

MANAGING THE CONSTRUCTION

Tunnel contractor project managers have three sets of constraints to deal with which make their management task demanding. These are: the nature of the tunnel as a workplace; introduction of changes; and the controlling codes with which they must comply. Environmental limits imposed by the size and shape of the tunnel and the complex sequence of events necessary to excavation and associated work were described in Chapter 4. However, once the project is underway with excavation proceeding, the project boss must get his production rates for each operation up to the planned level and hold them at or above that level.

This means that the complex scheduling of construction and maintenance operations underground has to be held. All surface facilities, support for the tunnel, logistical and supply systems, have to keep moving smoothly. Details like the size of muck trains or the spacing of switches must be reviewed and inspected continuously. Rock tunnels are a bit more forgiving of error as they do not have to be lined as excavated. That has to be done in earth tunnels and it limits opportunity for local enlargement if needed.

Changes may be caused by unforeseen, geologically related events like incoming water, silt pockets, ground temperatures, fault zones, unexpected boulders or similar problems. Or the source of changes may be supply shortages or changes in the design instituted by the owner or the engineer. Examples of this abound in WMATA as a result of action by pressure groups. Contractors who were involved in installing elevators in subway stations to provide for handicapped persons to be able to enter the subway point out that, for the cost of the change, every prospective handicapped rider could have been given lifetime free taxi privileges.

EXHIBIT 7-G

SECTION SUPPLIES AND SUPPLIERS

(Example is from one section of WMATA - 489 Suppliers)

ITEM	Number of Suppliers Local Area*	Distant
Aggregates	10	0
Architectural	8	4
Bearing Assembly	2	6
Brick Paving	4	0
Building Contractors	9	0
Critical Path Scheduling	1	1
Cast Iron Liner	0	3
Cement	5	1
Concrete Redi Mix	9	0
Concrete Additives	1	2
Curb & Gutter Concrete	1	0
Corrosion Control	1	2
Dewatering	2	4
Drilling & Pre-Drilling	2	8
Electrical	11	2
Erosion	6	0
Excavation & Disposal	5	0
Explosives	0	4
Fence	4	0
Floating Slabs	3	3
Forms	1	9
Granite Curb	10	1
Instrumentation	1	7
Lime	0	2
Lumber	5	1
Mechanical Contractors	15	3
Miscellaneous Equipment & Supply	1	0
Miscellaneous Iron & Steel	13	3
Painting	4	6

*Local suppliers are those with telephones in phone area codes 202, 301 and 703.

ITEM	Number of Suppliers Local Area*	Distant
Paving	6	0
Concrete Piling	5	7
Pipe	17	5
Pipe Jacking	1	0
Plumbing	30	1
Prestressed Girders	10	8
Prestressing	5	3
Railroad Supplies	8	14
Reinforcing Bars	11	12
Rock Bolts	0	4
Roofing	1	1
Sandblasting & Stripe Removal	5	0
Slurry & Slurry Trench	0	3
Structural Steel	19	11
Tunnel Machines	0	7
Tunnel Steel & Liner	1	3
Underpinning	7	8
Waterproofing	7	3
Wrecking Demolition	3	3
Minority Contractors	22	1

Surrounding the project manager on a tunnel job is a web of agreements, specifications, rules and codes. His whole job is inspected by engineers representing the owner, by his company (which is exposed to serious risk if he fails) and by numerous public official inspectors. At the safety area he may be inspected by state or federal people operating under Occupational Safety & Health or Mine Safety Laws. His materials and workmanship must meet standards of the uniform building code; the steel construction industry; the concrete industry, electrical, building, railroad and fire codes; plus the state, county or municipal ordinances or codes. Further, he must comply with EPA and minority hiring agreements.

Clearly, running a tunnel project is far from the easiest way to make a living. That's one of the reasons why the head tunnel boss is such a scarce commodity and receives such emphasis in Chapter 15 on people.

CONCLUSIONS

1. Construction contractors in tunneling can generally do many types of heavy construction.
2. There are relatively small numbers of firms who are experienced in either hard rock or soft ground bored tunnels. Many construction contractors can handle the technical aspects of cut-and-cover jobs.
3. Estimating, bidding, and procurement preparations are very complex and must be accomplished in a short time. This encourages conventional approaches where one can have confidence based on prior experience.
4. Estimating the actual costs of a job is very difficult and contractors face a business-wrecking loss possibility on a large tunnel job. Contract clauses covering changes of conditions are spreading in use but only handle some troubles like labor cost escalations, materials or geological problems. With no such clause, or a poor one, the owner, engineer and contractor fall back to claims and lawsuits.
5. Key people presently employed, or who have agreed to be available,are a vital ingredient in a contractor's ability to bid. Equipment owned and available also is an important consideration.
6. A typical tunnel job requires extensive procurements from both local, generalized suppliers and national special equipment manufacturers. This offers the contractor flexibility in his job setup but also demands careful supervision of the logistics problem.
7. A contractor's prospective corporate cash flow (how badly he needs the work to support overhead and hold his crew together) has a major effect on his pricing of a bid.

Exhibit 7-H **Portal view of vehicular tunnel.**

Chapter 8

TUNNEL OWNER-OPERATORS

Most tunnels are owned and operated by public bodies. Rapid transit, motor vehicle, water and sewer tunnels are in this category. Railroad tunnels and those associated with power plants frequently are owned by capital stock companies. A summary description of the roles of owner-operators and the way they are organized is in Section 5 of this report.

If demand projections in Section 3 for the 1955-85 period prove correct, over 200 tunnels will have been completed in the continental United States in those three decades. Some of these are, of course, sections rather than independent tunnels, since the data are based on section contracts. Major tunnel owner-operators are shown in Exhibit 8-A, with their tunnels by end-use, construction status, and completion decade. A complete list of owners for 1955-85 is included in Exhibit 8-B, with details by tunnel included in Appendix A.

As noted in Section 5, the key functions of owner-operators of tunnels are (1) to continue operation of their existing system, whether it is for water, sewage, vehicles, trains, or rapid transit; (2) to oversee planning and construction of the tunnel and related facilities; (3) to obtain needed resources, principally authority to act plus money; and (4) to maintain support for the construction program among diverse constituencies with conflicting interests. In all cases this represents a substantial management task, but it is an especially awesome undertaking in urban transit construction.

HIGH RISK ON ALL FOUR FRONTS

The owner-operator of a new transit tunnel faces high management risk on all fronts. Operation of the existing system is usually partially disrupted by the construction. Too, the anticipation of change to come within the organization adds stresses within the work force and related constituencies. Arrival of the new system will be an opportunity for some but a problem for others. Similarly, the owner group faces potential problems and delays in construction due to a variety of technical or human situations.

Dealing with the federal agencies can be frustrating. As this is written, the Urban Mass Transit Administration of the U. S. Department of Transportation is seeking to limit its exposure to the ravages of construction cost inflation. UMTA's chosen alternative is to seek agreement that its contribution will be a fixed amount, in millions of dollars. This represents 80% of the planned cost, which has been UMTA's customary share. Commonly, the balance is made up of ten percent from the state and ten percent from the city, region or authority.

Exhibit 8-A MAJOR TUNNEL OWNER-OPERATORS IN THE U. S.

Major Owner-Operators	No. of tunnels by end use					No. tunnels by status			No. tunnels by decade of completion		
	Sewer	Water	Rapid Transit	Motor Vehicle	Other	Com-plete	Under Constr.	Planning Stage	1950-1959	1960-1969	1970-
Corps of Engineers	0	41	0	0	2 (RR)	35	8	0	10	24	3
BuRec	0	43	0	0	0	38	3	0	9	12	17
BART *	1	0	13	0	0	14	0	0	0	14	0
WMATA*	0	0	45	0	0	6	30	8	0	0	6
MWD/So. Cal.	0	9	0	0	0	7	2	0	0	4	3
City of Detroit	15	0	1	0	0	8	3	5	0	4	4
City of Chicago	10	0	0	0	0	10	0	0	2	8	0
Greater Chicago Met. Sanitary Dist.	14	0	0	0	0	5	3	5	0	4	1
SEPTA (Phila.)	0	0	3	0	1 (RR)	1	1	2	0	0	1
California Dept. Water Resources	0	7	0	0	1 (RR)	8	0	0	0	8	0
Milwaukee Sewer Comm.	5	0	0	0	0	3	1	1	0	0	3
Colo. Highway Dept.	0	0	0	4	0	2	1	1	0	1	1
NYC Bur. Water Supply	1	5	0	0	0	5	1	0	0	5	0
Rochester, N. Y. & Monroe Co. Pure Waters Agency	11	0	0	0	0	7	1	3	0	5	2

*Numbers denote number of tunnel contracts let.

UMTA's motivation is clear. It wants a cap on its contribution. Any federal agency (or state agency) must be responsive to its administration's objectives as well as the agency objectives. Holding to budget limits while managing dozens of commitments and seeking to provide continuity is a challenging exercise. So, the tactic of trying to deal with inflationary pressures, poor local management, or any lack of incentive to hold down costs by capping the major contribution source is understandable.

However, from the point of view of the owner-operator of a regional transit authority, such a tactic is unacceptable. If a project should encounter troubles in construction leading to a cost increase of ten percent, that would use up the contingency funds planned for the project in most cases. A series of small events like unexpected water, rocks, or a severe accident which is self-insured can do that. Further rises, due to labor or materials inflation might outrun the planned funds by, say, another 10% over a decade of work.

The important thing to note, from the viewpoint of the owner-operator, is that the last 10% increase virtually doubles the cost of the project to the local citizenry. In Philadelphia the Center City commuter tunnel is budgeted at $300 million, of which the local share is $30 million. A fixed-dollar contribution by other financial participants means a 10% overrun would make the local share $60 million.

DIFFICULTY IN MAINTAINING SUPPORT

Perhaps the most difficult of the four key owner functions is to maintain support for the project and the system over a long period of time, covering planning and construction. When another delay of any sort is introduced during either the planning or financing stages, opponents seize on the opening to try to force changes. Even after initial political acceptance, and passage of bond issues, the project can face serious attack and possible major modification before construction begins. Examples of this are:

1. Objections by businessmen to cut-and-cover disruptions in Atlanta and to the effects of this on nearby new buildings.

2. Proposals by local politicians for a light-rail, monorail style system instead of the planned 8.5 mile subway in Baltimore.

3. Revisions of UMTA support guidelines to make the agency's 80% contribution to Philadelphia's center city commuter tunnel a fixed-dollar amount, placing the full inflation burden on the city.

Exhibit 8-B OWNERS AND OPERATORS OF TUNNELS IN THE U. S.

AGENCY	TYPE	SEWER	WATER	R.T.	M.V.	OTHER
Austin Texas, Construction Mgmt. Dept.	M	X	X			
Bay Area Rapid Transit District	R			X		
California Dept. of Water Resources	S		X			
Chesapeake Bay Bridge & Tunnel Authority	S				X	
Chessie Systems Inc.	P					X
Chicago Dept. of Public Works	M	X	X	X		
Chicago Transit Authority	M			X		
Chicago Urban Transit Authority	S			X		
Colorado Highway Dept.	S				X	
Columbus Ohio, Dept. of Public Works	M	X	X			
Delaware River Port Authority	R			X		
Denver Board of Water Commissioners	M		X			
Denver Rapid Transit District	R			X		
Detroit Metro Water Dept.	M		X			
Eastbay Municipal Utility District (Calif.)	R	X	X			
Ft. Hood Texas, Dept. of Public Works	M	X	X			
Greater Chicago Metropolitan Sanitary District	R	X				
Greater Cleveland Transit Authority	R			X		
Honolulu Dept. of Transportation Services	M			X		
Houston Texas, Dept. of Public Works	M	X	X			
Idaho Power Co.	P					X
International Boundary & Water Commission	F					X
Maryland Mass Transit Administration	S			X		
Maryland Transportation Authority	S				X	
Massachusetts Bay Transportation Authority	R			X		
Massachusetts Turnpike Authority	S				X	
Metropolitan Atlanta Rapid Transit	R			X		
Metropolitan District Commission (Boston, Ma.)	R	X	X			
Metropolitan District Commission (Hartford, Ct.)	R		X			
Metropolitan Transit Commission (Minneapolis-St. Paul)	R			X		
Metropolitan Water District of Southern Calif.	R		X			
Milwaukee Sewer Commission	M	X				
Minneapolis Minn., Dept. of Public Works	M	X	X			
Monroe County (N.Y.) Pure Waters Agency	R	X				
Newark N.J., Transportation Office	M			X		
New Jersey Dept. of Transportation	S					X
New York City Board of Water Supply	M		X			
New York City Bureau of Water Pollution Control	M	X				
New York City Transit Authority	M			X		
New York Metropolitan Transit Authority	S			X		
New York Power Authority	S					X
Nevada Highway Dept.	S				X	
Niagara Frontier Transit Authority	R			X		
Niagara Mohawk Power Co.	P					X
Norfolk & Western R.R.	P					X
North Carolina Highway Dept.	S				X	
Oakland Drain Commission (Calif.)	R	X				
Omaha Nebraska, Dept. of Public Works	M	X				
Pacific Gas & Electric Co.	P					X
Pennsylvania Turnpike Authority	S				X	
Port Authority of New York & New Jersey	R			X	X	
Port Authority Transit (Pittsburgh, Pa.)	R			X		
Prairie Farm Rehabilitation Agency	F		X			
Rochester New York, Dept. of Public Works	M	X	X			
Rochester-Gennessee Rapid Transit Authority	R			X		
St. Louis Metropolitan Sewer District	M	X				
Sacramento Metropolitan Utility District	R	X	X			
San Francisco Water Dept.	M		X			
Seattle Washington Dept. of Public Works	M	X	X			
Southeastern Michigan Transportation Auth.	R			X		
Southeastern Pennsylvania Transportation Auth.	R			X		
Southern California Rapid Transit District	R			X		
Southgate Sanitation District (Colorado)	R	X				
Stanford University	P					X
U.S. Army, Corps of Engineers	F		X			X
U.S. Dept. of Interior, Bureau of Reclamation	F		X			X
U.S. Dept. of Interior, National Park Service	F				X	
Washington Metropolitan Area Transit Authority	R			X		
West Virginia Highway Dept.	S				X	

KEY

F = Federal Agency
S = State Agency
M = Municipal Agency
R = Regional Agency (controlled by several governmental units)
P = Private Enterprise
MV = Motor Vehicle Tunnels
RT = Rapid Transit Tunnels

TUNNEL ENGINEERING FIRMS

The engineering segment of the tunneling industry is made up of forty-one identifiable firms. They range from enormous construction and engineering organizations to specialty firms employing a half-dozen professionals, and can be classified into four groups:

- I Tunnel specialists
- II Firms with substantial tunneling involvement
- III Engineers active in the tunneling industry
- IV Firms with some history of tunneling work

EXHIBIT 9-A

TUNNEL END USE EXPERIENCE

PROJECT END USE	No. Firms with hard rock experience	No. Firms with soft ground experience	No. Firms experienced in both	Total No. of Firms
Rapid Transit	26	33	19	38
Vehicle	20	25	18	26
Water	20	25	16	30
Sewer	14	22	15	21
Other	3	6	6	5

The roles of these firms in tunnel projects vary widely and they are changing. Principal change influences have been the project organization decisions by owners of large transportation systems-under-construction and the blurring of the traditional definition of engineering firm.

Emergence of full-system simultaneous transportation construction projects has spurred the organization experiments and decisions. Building an entire system is a radically different challenge than adding a line to an existing system. San Francisco, Washington, Atlanta and Baltimore are full system projects. It is here that engineer and contractor roles changed. More conventional add-on examples are the Boston, New York, Philadelphia and Chicago rapid transit projects. These have used historical organization arrangements.

The shifts in roles of engineers from one major project to another were described in Section 6 on management of tunnel projects. Within the broader construction field the trend to architect-engineer, engineer-constructor, and other full service or special hybrid organizations is already well known.

EXHIBIT 9-B TUNNEL ENGINEERING FIRMS

Name of Firm	Headquarters	Classification For This Report
Amman & Whitney	New York, N.Y.	III
Bechtel Corp.	San Francisco, Cal.	II
Century Engineering	Towson, Md.	III
Daniels, Mann, Johnson & Mendenhall	Los Angeles, Cal.	II
DeLeuw Cather	Chicago, Ill.	II
Edwards & Kelcey	Newark, N.J.	II
Gannet, Fleming, Gorodry & Carpenter	Harrisburg, Pa.	III
Gibbs & Hill	New York, N.Y.	III
Greiner Engineering	Baltimore, Md.	III
Harza Engineering	Chicago, Ill.	II
Hayes, Seay-Mattern & Mattern	Roanoke, Va.	III
Hazelet & Erdal	Louisville, Ky.	III
Henningson, Durham & Richardson	Omaha, Neb.	III
Howard-Needles, Tammen & Bergendoff	Kansas City, Mo.	III
International Engineering	San Francisco, Cal.	III
Jacobs Associates	San Francisco, Cal.	I
Jenny Engineering Corp.	South Orange, N.J.	I
Kaiser Engineers	Oakland, Cal.	III
Keifer & Associates	Chicago, Ill.	II
Knorle, Bender, Stone	Baltimore, Md.	III
Lockwood-Kessler & Bartlett	Syosset, N.Y.	IV
McGaughy, Marshal & McMillan	Norfolk, Va.	III
MCA Engineering	Baltimore, Md.	III
Charles T. Main, Inc.	Boston, Mass.	III
C. E. Maguire	Waltham, Mass.	III
A. A. Mathews	Arcadia, Cal.	I
Murphy Engineering	Chicago, Ill.	IV
H. D. Nottingham & Associates	McLean, Va.	IV
Parsons-Brinkerhoff, Quade & Douglas	New York, N.Y.	II
Ralph M. Parsons	Pasadena, Cal.	III
Rummel, Klepper & Kahl	Baltimore, Md.	III
Sanders & Thomas	Pottstown, Pa.	III
Sverdrup & Parcel	St. Louis, Mo.	II
Tippetts, Abbett, McCarthy & Stratton	New York, N.Y.	III
Transit & Tunnel Consultants	Buffalo, N.Y.	I
Tudor Engineering	San Francisco, Cal.	III
URS/Madigan Praeger	New York, N.Y.	III
David Volkert & Associates	Washington, D.C.	III
Vosbeck, Vosbeck, Kendrick & Redinger	Alexandria, Va.	IV
Westenhoff & Novick	Chicago, Ill.	III
Wiley & Wilson	Lynchburg, Va.	III
Woodward, Clyde Consultants	San Jose, Cal.	I

NOTE: Classifications and associated information are detailed in Appendix B.

EXHIBIT 9-C

% OF FIRMS' BUSINESS IN TUNNELING

% OF BUSINESS	No. Firms with hard rock experience	No. Firms with soft ground experience	No. Firms experienced in both	Total No. of Firms
Under 10%	15	22	13	29
10-25	8	8	8	8
25-50	2	3	3	2
50-90	1	1	2	2
Over 90	1	1	1	1

IMPACT OF WMATA ORGANIZATION APPROACH

The sheer size of the Washington metropolitan area project, plus its organizational approach, have had a dramatic effect on the engineering segment of the tunneling industry. It created, or substantially enhanced, the tunneling capability of a couple of dozen engineering firms which, prior to WMATA, had had limited or no tunneling experience. The WMATA organizational approach requires three layers of engineering firms. The construction management firm and a general engineering consultant are supported by section engineers and station project engineers for each segment of the system (See Exhibit 9-D).

Representatives of all of the interviewed firms were confident of their ability to provide engineering services for about any tunnel project which can be conceived. Talking with engineers about their specialties and their firm's capabilities is very much like talking with lawyers and accountants on the same subject. The tenor of their remarks is that they can be anything that is required.

We were not able to conclude whether this meant that there is not much special about tunnel engineering (a majority view among opinions offered); whether, as in other professions, the definition of qualifications is highly elastic; or whether, armed with a contract, they were sure they could find the people they'd need to do the work.

COMPARATIVE INFORMATION

We were interested in comparing the forty-one firms (actually 48, but seven were omitted for reasons shown in Exhibit 9-F) and developed quantitative and qualitative questions.

Years in business	No. permanent tunnel staff
Years in tunnel work	No. tunnel people now employed
% of revenues from tunnel work	No. tunnel projects in given years
End use of tunnels involved	Types of tunnel experience
Role of the firm in projects	

EXHIBIT 9-D

TUNNEL ENGINEER FIRM CLASSIFICATIONS

GROUP	DESCRIPTION		NO. OF FIRMS	NO. WITH WMATA WORK
I	Tunnel Specialists. These firms restrict their practice solely to tunnel work or it is a major part of their total work and revenue.		5	3
II	Substantial Tunneling Involvement. These are major engineering firms or are smaller firms. What they have in common is substantial, on-going tunnel project work.		8	7
III	Active In The Industry. This category includes firms which have had several tunneling projects but don't maintain an extensive capability continuously.		25	19
IV	Some History Of Activity. Firms with one or two projects involving tunnels either now or in the firm's history.		4	2
V	Not Included.		7	0
	Now classified as constructors.	2		
	No tunnel experience or interest. Listed as engineer but all tunnel work is subcontracted.	2		
	Described their SF 251 information as "public relations - lies".	2		
	Refused to cooperate.	1		

Attempts to compare tunnel engineers quantitatively are not fully successful because of grey areas in:

a. Overlaps in project roles
b. Number of tunneling projects
c. Size and experience of tunnel staff
d. Impact of WMATA organization approach
e. Duration of tunnel capability

EXHIBIT 9-E NUMBER OF TUNNELING PROJECTS

NO. OF PROJECTS 1970-75	No. Firms with hard rock experience	No. Firms with soft ground experience	No. Firms experienced in both	Total No. of Firms
0	0	0	0	0
1- 10	19	28	20	34
10- 50	5	5	5	5
50-100	1	1	1	1
1965-1970				
0	3	4	2	6
1- 10	17	24	19	29
10- 50	4	5	4	4
50-100	2	2	2	2

There is a wide variance among tunnel projects. The type, size, end use, and geological conditions are all important variables. Knowing the number of tunnel projects a firm has won or completed helps. But it also helps to know whether it was a two-mile tunnel or a 500 foot job.

Clearly, from a financial viewpoint, classifying employees as "permanent tunnel staff" is based on assumptions about future business prospects, capital and cash flow. A number of firms, active in WMATA projects for some years, now think of their people as permanent and so describe them. However, many of these people will have to find other work if their firm's tunnel volume falls.

"Tunnel experience" is a gray area also. Some real specialists contend that many engineers working on section projects in large system construction both need and acquire very little specialized tunnel experience.

EXHIBIT 9-F PERMANENT TUNNELING STAFF

No. Persons permanent tunneling staff	No. Firms with hard rock experience	No. Firms with soft ground experience	No. Firms experienced in both	Total No. of Firms
0	10	17	10	24
1- 10	8	9	10	9
10- 25	4	3	6	4
25- 50	3	4	4	4
Over 100	1	1	1	1

EXHIBIT 9-G EXPERIENCED TUNNEL STAFF

No. Persons experienced in tunneling				
Under 10	5	11	5	13
10- 25	9	10	5	14
25- 50	5	7	5	7
50- 75	4	4	4	4
75-100	1	1	1	1
Over 100	2	2	2	2

EXHIBIT 9-H YEARS IN TUNNELING

No. Years in tunneling				
Under 10 yrs.	3	4	2	7
10- 25	13	18	16	22
25- 30	9	12	8	12
50- 75	1	1	1	1

DURATION OF TUNNEL CAPABILITY

The large majority of firms have a tunneling capability that has existed for at least 10 years. Only five firms have less than a five year involvement. In several of the firms with shorter tunneling experience individuals told us "I have been in tunneling for 20 years, but the firm has been involved for only the 5 years I have been with them." Several others have an on-going tunneling design capability going back decades but only recent or sporadic actual tunnel design work.

The detailed comparative information about the forty-one firms is included in Appendix B.

CONCLUSIONS

1. Rising activity in the tunnel industry has made it possible for additional engineering firms to expand into this segment of the heavy construction field. It has also enlarged the volume of work of firms already in the field.

2. Management considerations arising from this appear not to be unique to tunneling; rather they are common to engineering.

3. The increasing size of jobs has made joint ventures and mergers among firms more attractive.

4. There does not appear to be any serious shortage of people or capital among the engineering firms. Rather, their economic problems relate to scale, like most other professional service operations.

5. The cost increments affecting profitability and internal efficiency are related to size of the firm and support systems such as data processing, libraries, laboratories, and testing equipment.

6. Exposures to liability and the rising costs of errors and omissions insurance, discussed in Chapter 12, are a major concern.

7. The architect-engineer-builder field offers many combinations and possible permutations for business strategy.

8. For the next decade, all of the data and interviews suggest there will be plenty of work, enough new people to enter the firms, and adequate financing.

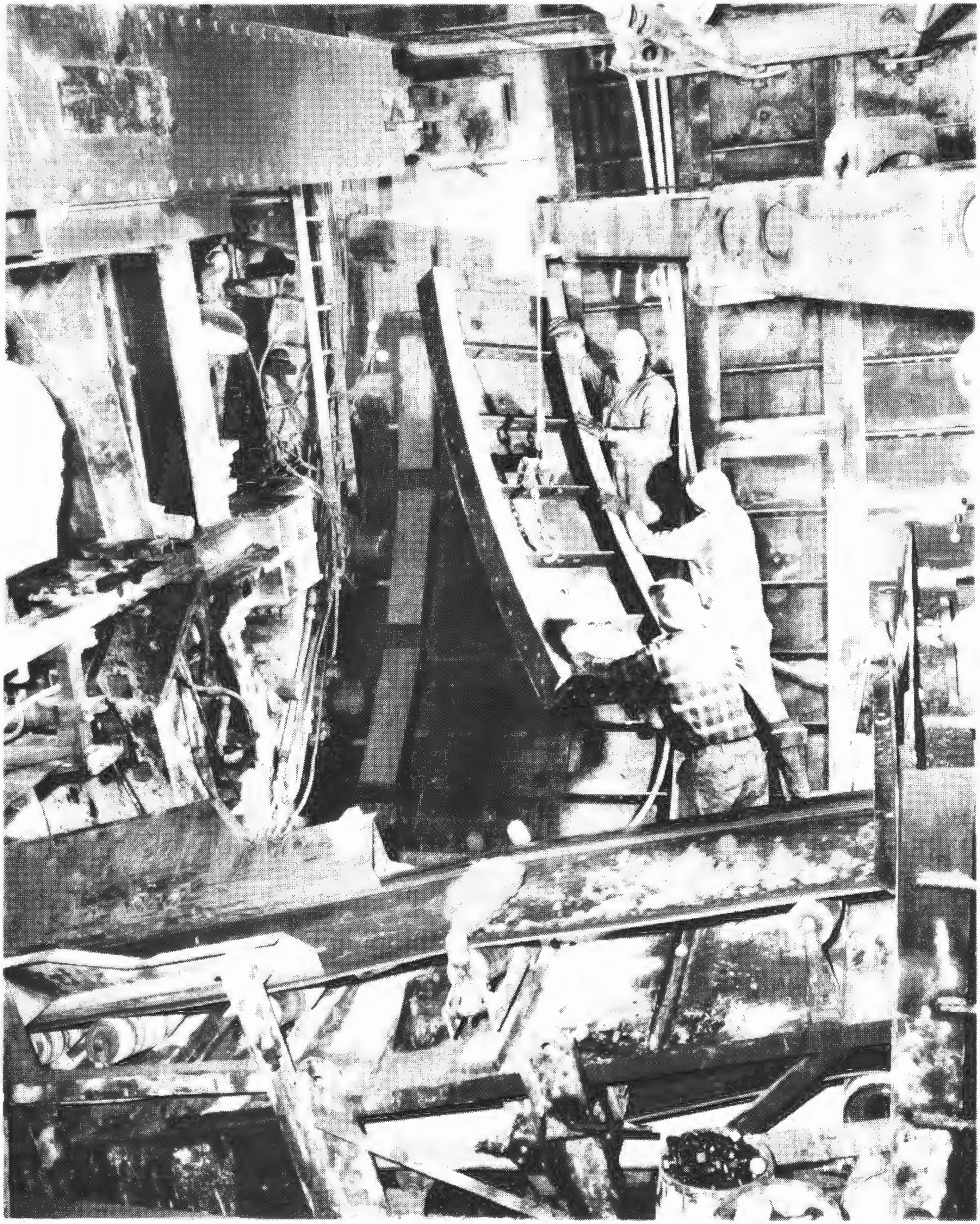


Exhibit 9-G **Erecting liner in a soft ground tunnel.**

Chapter 10

CONSTRUCTION CONTRACTORS IN TUNNELING

The firms which build tunnels are of four types: tunnel specialists, heavy constructors, conglomerates and tunnel related specialists. Tunnel Specialists concentrate on tunnels of all types. Heavy Constructors includes those firms who also do bridge, road and sewer work. Their tunnel work is an extension of their sewer work: open cut trenching.

EXHIBIT 10-A FIRMS WITH HARD ROCK TUNNEL EXPERIENCE - 18

Guy F. Atkinson Co.	Foley Bros., Inc.	Kaiser Construction
Gordon Ball, Inc.	Granite Construction	Lockheed Construction
Bechtel, Inc.	S. J. Groves & Sons	MacLean-Grove, Inc.
Brown & Root, Inc.	Gates & Fox	Morrison-Knudsen, Inc.
Dravo Corporation	S. A. Healy Company	Perini Corporation
Fenix & Scisson	Peter Kiewit Sons	Walsh Construction

Very large heavy construction firms do all kinds of building. Some have their own extensive engineering and design units as well as captive suppliers and other related subsidiary operations. They'll build ports, dams, tunnels, airports, etc. Important, but smaller, factors in this industry are the specialized shaft sinkers and those marine construction firms who can handle sunken-tube tunnels in harbors.

EXHIBIT 10-B SOFT GROUND TUNNEL CONTRACTORS - 39

American Structures	Greenfield Const. Co.	Mole Const. Co.
Armco Steel Corp.	S. J. Groves & Sons Co.	Morrison-Knudsen Co.
Gordon Ball Inc.	Grow Tunneling Corp.	Paschen Contractors
C.C. & T. Const. Co.	S. A. Healy Company	Perini Corporation
Capitol Tunneling	Intercounty Const.	Reliance Underground
Cooper Const. Co.	Jay Dee Const. Co.	S & M Constructors
DiMambro Const.	Kenny Const. Company	J. E. Seiben Inc.
Dravo Corporation	Peter Kiewit Sons Co.	J. F. Shea Company
Eastern Tunneling	Lockheed Const. Co.	Schiavoni Const.
Fattore Const. Co.	W. J. Lazinski Co.	Square Const. Co.
J. M. Foster Const.	MacLean-Grove Co.	Thalle Const. Co.
D. J. Franks	McHugh Const. Co.	Tomaro Const. Co.
Fruin-Colnon Corp.	Mancini Const. Co.	Traylor Bros. Co.

The full list of tunnel contractors of all types is included in Exhibit 10-C below. Every firm on the list is active in tunnel work or has a history of performance in tunnel building or is qualified and ready to do such work. Eighteen firms do hard rock work and forty-one do soft ground work.

An opportunistic approach, which is necessary in project based businesses like construction, translates a set of skills like side bank stabilization and trenching into cut-and-cover tunneling. To move into the center of town to work, and to maintain traffic overhead during the work is a major change for a rurally-oriented road or sewer builder but it can be done. (Entry of new firms to the industry is discussed in Chapter 16.)

EXHIBIT 10-C — TUNNEL CONTRACTORS IN THE U. S. - 74

CONTRACTOR	HEADQUARTERS LOCATION
American Structures, Inc.	Annapolis, Md.
Armco Steel Corp., Construction Div.	Middletown, Ohio
John Artukovich & Sons	Paramount, Calif.
Arundel Corp.	Baltimore, Md.
Guy F. Atkinson Co.	S. San Francisco, Cal.
Roger Au & Sons	Mansfield, Ohio
Gordon Ball Inc.	Danville, Calif.
Balport Construction Co.	Elmsford, N. Y.
Bechtel, Inc.	Oakland, Calif.
Brown & Root, Inc.	Houston, Texas
C. C. & T. Construction Co. (Subcontracting Only)	Luthersville, Md.
Capitol Tunneling Company	Columbus, Ohio
Andrew Catapano Co.	Glendale, N. Y.
Cayuga Construction Co.	New York City, N. Y.
Cementation Co. of America (Mine Shafts, Development & Grouting)	Brampton, Ont.
Cooper Construction Company	Mt. Clemmens, Mich.
Carl Decker Inc. (Also builds Moles & other equipment)	Detroit, Mich.
DiMambro Contractors, Inc.	Oak Park, Mich.
Dravo Corp.	Neville Island, Pittsburgh, Pa.
Fred Early Company	San Francisco, Calif.
Eastern Tunneling Corp.	Columbia, Md.
Fattore Construction Co.	Warren, Mich.

CONTRACTOR	HEADQUARTERS LOCATION
Fenix & Scisson Inc. (Mostly Mine Shafts)	Tulsa, Okla.
Fluor-Utah Corp. (All Mine Development now)	San Mateo, Calif.
Foley Bros. Inc.	St. Paul, Minn.
J. M. Foster Construction Co.	Gary, Indiana
D. J. Franks	Westminster, Md.
Frontier Constructors Inc.	Arvada, Nev.
Fruin-Colnon Corp.	St. Louis, Mo.
Don Gargaro Co.	Detroit, Mich.
Gates & Fox Co., Inc.	Loomis, Calif.
Granite Construction Co.	Watsonville, Ga.
Green Construction Co.	Des Moines, Iowa
Greenfield Construction Co.	Livonia, Mich.
S. J. Groves & Sons Co.	Minneapolis, Minn.
Grow Tunneling Corp.	New York, N. Y.
Gunther-Nash Mining & Construction Co.	St. Louis, Mo.
S. A. Healy Co.	McCook, Ill.
Intercounty Construction Corp.	Hyattsville, Md.
Jay Dee Construction Co.	Livonia, Mich.
Al Johnson Construction Co.	Minneapolis, Minn.
J. A. Jones Construction Co.	Charlotte, N. C.
Kassouf Construction Co.	Cleveland, Ohio
Kemper Construction Co.	Los Angeles, Calif.
Kenny Construction Co.	Wheeling, Ill.
Peter Kiewit Sons Co.	Omaha, Neb.
LaFera Contracting Co.	Newark, N. J.
C. J. Langenfelder & Sons	Baltimore, Md.
Lockheed Ship Building Construction Co.	Seattle, Wash.
W. J. Lazinski Co.	Milwaukee, Wisc.
MacLean-Grove Co.	New York, N. Y.
McHugh Construction Co.	Chicago, Ill.
Mancini Construction Co.	Warren, Mich.
Mergentime Corp. (The)	Flemington, N. J.
Michigan Sewer Construction Co.	Detroit, Mich.

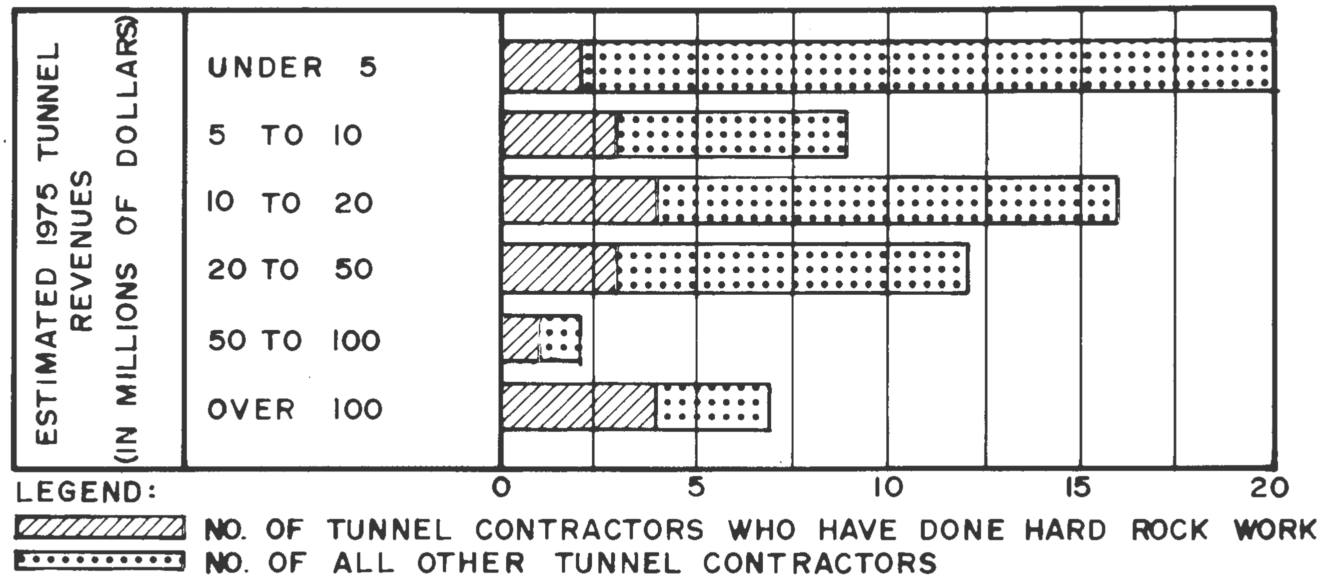
CONTRACTOR	HEADQUARTERS LOCATION
Mole Construction Co.	Romulus, Mich.
Morrison-Knudsen Co., Inc.	Boise, Idaho & Darien, Conn.
P & Z Construction Co.	Baldenburg, Md.
Paschen Contractors	Chicago, Ill.
Perini Corp.	Framingham, Mass.
Pioneer Corp. (Formerly Mountain States Construction Co.)	Charleston, W. Va.
Raymond International Inc. (Primarily Sunken Tubes)	Houston, Texas
Reliance Underground Construction Co.	Elk Grove, Ill.
S & M Constructors	Solon, Ohio
J. E. Seiben, Inc.	Leawood, Kansas
J. F. Shea Co.	Walnut, Calif. & Wash., D. C.
Slattery Associates (Highways, Bridges, Foundations)	Maspeth, N. Y.
Square Construction Co.	Baltimore, Md.
J. Rich Steers, Inc.	New York, N. Y.
Thalle Construction Co.	Briar Cliff Manor, N. Y.
Tomaro Contractors, Inc.	Cudahy, Wisc.
Traylor Bros., Inc.	Evansville, Ind.
Nello L. Teer Co.	Durham, N. C.
Walsh Construction Co.	Darien, Conn.

CONTRACTOR REVENUES

Nearly all of the contractors who build tunnels engage either in other heavy construction or specialize in underground construction including other projects than tunnels. Line-of-business data are not available so the numbers used here are those provided by the contractors themselves. A company with a five year average of $10 million per year in tunneling may have had one $50 million contract award or a steady flow of smaller jobs. However, within the five years there can be sharp swings in billings and cash flow.

Tunnel revenue information was obtained from 60 of the 65 identified contractors. Of these, 51 produce annual tunnel revenues under $50 million.

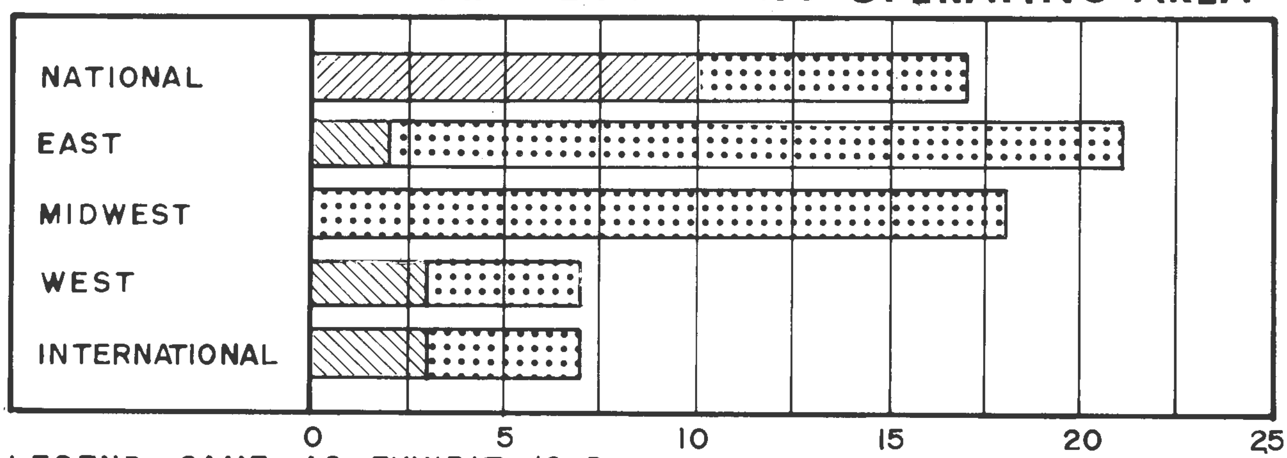
EXHIBIT 10-D **CONTRACTORS BY ESTIMATED TUNNEL REVENUE**



GEOGRAPHIC OPERATING AREAS

Some tunnel contractors operate worldwide, others any where in the United States, and others in specific regions.

EXHIBIT 10-E **PRINCIPAL GEOGRAPHIC OPERATING AREA**



LEGEND: SAME AS EXHIBIT 10-D

Prior to 1965, most contractors in the West were in hard rock; mid-western companies were in soft ground; and northeastern companies were in both (although many northeastern companies specialized in hard rock before 1960). Many eastern and virtually all midwest companies are soft ground specialists, and many of these confine themselves to a small geographic area.

All major hard rock contractors now work in soft ground as well. Some soft ground companies, particularly the larger ones, now bid on hard rock work, utilizing specialists hired on an ad hoc basis or forming joint ventures.

EXHIBIT 10-F

TUNNEL STAFFS OF CONTRACTORS

	Contractors who have done hard rock work	All other Tunnel Contractors	Total
1965	251	386	647
1975	537	1033	1470

The above figures were developed during face-to-face and telephone interviews with tunnel contractors. They should be qualified to include:

a. Difference in definition. This study probed the number of permanent or key employees related to their tunnel work or capability. This includes key job holders as defined in Chapter 7. It was suggested that anyone kept on part-pay during a slow work period be included.

However, definitions used by individual firms vary. They all include key people as we define them, but others include all the people they ship to a job from their headquarters. One firm staffs its own jobs down to and including walkers and would not accept a job it could not so staff, so they're included.

b. Underground construction firms, with large growth in mining and nuclear power plant work distort these figures if they are viewed as pure "tunnel staff". The most extreme example is Fenix & Scisson which went from thirty "underground" people in 1965 to 160 in 1975.

ASSESSING CONTRACTOR KEY TUNNEL POPULATION

Three firms show the largest growth in numbers of tunnel specialists, within the qualifying comments above.

EXHIBIT 10-G

TUNNEL STAFF GROWTH 1965-1975

	1965	1975	Growth	%
Sixty-five contractors	618	1380	762	123
Fenix & Scisson, Inc.	30	120	90	400*
Armco Steel Const. Co.	50	150	100	200
Bechtel Corporation	50	100	50	100

*Mostly nuclear-related work.

Some adjustments have been made to individual firm numbers which suggest that in 1965, using the personnel definitions in Chapter 7, there were about 400 tunnel specialists in contractor firms and that there are about 800 today. However, this must be labeled an "informed guesstimate". Further discussion of this is included in Chapter 15 under Manpower.

Because many contractors commented adversely on the productivity trends and their claimed relationships to union work rules, they were asked about union jobs. The following table indicates that union jobs still dominate. The only trend reported is definite growth in number of contractors who work "double-breasted" (using both union and open-shop work forces).

EXHIBIT 10-H

UNION AND OPEN-SHOP CONTRACTORS

	No. of Contractors who have done hard rock work	No. of all other Tunnel Contractors	Total
Union	15	37	52
Open	1	3	4
Both	1	9	10

OPERATING AND MANAGEMENT PROBLEMS

Presently, and for the next decade, there is as much work available for the tunnel contracting industry as there has ever been. As a result, the problems contractors face are different but no less serious than those they encountered in the Fifties. A trend toward larger projects is well established. Relationships among contractors, engineers and owners are being altered, and the risk-reward aspects of the business remain very difficult. These are discussed in Chapters 13-15.

EXHIBIT 10-I

FORMER ACTIVE INDUSTRY CONTRACTING FIRMS

The firms listed were active tunnel contractors in the past. As indicated, they are either, to the best of our knowledge, no longer in business or they are inactive as direct builders of tunnels.

Name of Contractor	Headquarters	Status
Bates & Robers	Chicago, Ill.	Still in contracting
Booth & Flinn	Pittsburgh, Pa.	Reported out of bus.
W. W. Boxley	Roanoke, Va.	Operates quarries
Tom Connolly	San Francisco, Cal.	No info available
James Coughlin	Boston, Mass.	Reported out of bus.
Geo. H. Flinn	N. Y., N. Y.	Reported out of bus.
Folk-Snare	N. Y., N. Y.	No info available
Frazier-Davis	St. Louis, Mo.	Now Gunther-Nash
General Const. Co.	Portland, Oregon	In Business
A. C. Guthrie	St. Paul, Minn.	Still in Business
Johnson Drake & Piper	N. Y., N. Y.	Reported out of bus.
Arthur A. Johnson	L. I., N. Y.	Bought by P. Kiewit
Patrick McGovern	N. Y., N. Y.	Reported out of bus.
Arthur McMullen	N. Y., N. Y.	Reported out of bus.
Silas Mason	Lexington, Ky.	Mfgr. of Munitions - see Mason & Hanger
L. E. Meyers	Chicago, Ill.	No info available
Thomas Nolan	Detroit, Mich.	Reported out of bus.
Northern States Construction	St. Paul, Minn.	Reported out of bus.
Parker, Graham & Sexton	Knoxville, Tenn.	Reported out of bus.
Rogers & Haggerty	N. Y., N. Y.	Reported out of bus.
Rosoff Tunnel Corp.	N. Y., N. Y.	Reported out of bus.
Sturm & Dillard	Columbus, Ohio	Reported out of bus.
United Concrete Pipe	Los Angeles, Cal.	No info available
Wenzel & Henoch	Milwaukee, Wisc.	No info available
J. G. White	N. Y., N. Y.	Building Construction
Winston Bros. Co.	Seattle, Wash.	Still in business

Chapter 11

SPECIALIZED SUPPLIERS

Suppliers to the tunnel building industry are in four groups: general equipment and supplies; special equipment and supplies; financial services and business services.

EQUIPMENT AND SUPPLIES

General equipment and supply items are those considered for many industries which can be used without modification in tunnel building. General equipment includes things like dump trucks, air compressors, payloaders, hand tools or office trailers. General supplies include items like concrete, timber or office supplies. Usually there is adequate supply and competition. In recent years there have been shortage problems with some steel shapes and with plywood. There may be future problems with gasoline or diesel fuels.

Special equipment items are unique to tunnels and to related heavy construction like mines or underground power plants. (These are listed in Exhibit 11-1.) The market for these specialized items is relatively small and not especially attractive to large companies. It tends to be served by specialized suppliers. When large firms participate in this market, it is usually to extend use of a product which they also sell in other markets. Tunnel construction itself is not a sufficient market to support the costs of product development normally associated with large company efforts.

Interviews with suppliers established the facts reported above. A summary of equipment and special supply items and of the companies that furnish them is included in Exhibit 11-2. Those suppliers who concentrate in this market act as sources of technical information and informal communication. Contractors tend to spread their business around to assure access to this information and so that the suppliers will provide the occasional quotation on a single small item the contractor needs.

The principal supply problems stem from delivery delays. Except for temporary shortages of plywood and steel forms noted above, the only persistent difficulty is in the long lead times associated with moles (tunnel boring machines). When a major job is divided into sections, each contractor handles procurement for his own job. There are reports that some owners are considering ordering the mole for the job and furnishing it to the contractor finally selected to cut that delay. Several engineers (but no contractors) have suggested that some supply items be purchased and provided as government furnished items.

Exhibit 11- A **EQUIPMENT USED IN BUILDING TUNNELS**

ITEM	Soft Ground	Rock Tunnels	Metal Mines	Coal Mines
SHAFTS				
Sinking Frame	D	D	D	D
Sinking Hoists	S	S	S	S
Shaft Jumbo	O	D	D	D
Steel Ribs - Roof Bolts - Shot Crete	S	S	S	S
Steel Forms	D	O	S	S
HAULAGE				
Mine Cars	S	S	S	S
Car Dumpers	S	S	S	S
Rails, Turnouts, etc.	S	S	S	S
LHD (Load-Haul-Dump)	S	S	S	Battery
Belt Conveyors	O	O	O	S
LOCOMOTIVES - Battery	S	S	S	S
LOCOMOTIVES - Diesel	?	S	S	NO!
MUCK HOIST				
Headframe	D	D	D	D
Mine Hoist	S	S	S	S
Cage-Skip-Bins	S	S	S	S
Measuring Pocket	S	S	S	S
Inclined Shafts			S	S
BREAKING ROCK				
Drill Jumbos	D	D	D	O
Drills, Booms & Drill Steel	S	S	S	S
Explosives	S	S	S	Permissable
Air Compressors - High	S	S	S	S
LOADING MUCK				
Mucking Machines	O	S	S	S
Belt Conveyors	S	O	O	S
SOFT GROUND				
Tunnel Shields	D			
Erector Arm	D			
Hydraulic Jacks	S			
Back Hoe	D			
Pea Shooter	S	S		

KEY
D = Dedictated: Special S = Standard O = Probably Not Required ? = Questionable

Exhibit 11-A (Cont.) **EQUIPMENT USED IN BUILDING TUNNELS**

ITEM	Soft Ground	Rock Tunnels	Metal Mines	Coal Mines
GROUND SUPPORT				
Segments: Iron or Steel	D			
Segments: Pressed Steel Liner Plate	S			
Segments: Pre-Cast	D			
Ribs-and-Wood Lags	S	S		
Steel Ribs		S	S	S
Roof Bolts		S	S	S
Shot Crete		S	S	S
CONCRETE LINING				
Steel Forms	D	D		
Concrete Pump or Gun	S	S		
Agitator Cars	S	S		
Concrete Cars	S	S		
Pneumatic Grouters	S	S		
Grout Mixer & Pump	S	S		
Mixing or Batch Plant	S	S		
SUB-AQUEOUS				
Air Locks - Muck	D			
Air Locks - Man or Escape	D			
Medical Lock	D			
Low-Pressure Air Compressor	D			
TUNNEL BORING MACHINE				
"Moles" *	D *	D *		
Coal Cutters				S

* A Tunnel must be at least 1-1/2 miles in length before a Mole becomes cost competitive because of the high initial cost.

KEY
D = Dedicated: Special S = Standard O = Probably Not Required ? = Questionable

MOLES

At one time or another since the end of World War II, at least seven firms have offered for sale various models of mole (the popular industry term for tunnel boring machines). Here is their status, as of January 1976.

CAL-WELD. Made large TBMs. Has dropped out of the business.

CARL GRAYS. Builds small moles for clay. Popular with Great Lakes area contractors. S & M (owners of Jarva) goes to Carl Grays for its small mole requirements.

DRESSER INDUSTRIES. Made one mole for the Navaho tunnel. There were operating problems requiring expenditure of considerable added funds and the company chose to drop the product.

JARVA MACHINE CO., Salon, Ohio (216-248-0166) is long established in the mole business and is currently building a 30' mole for a deep tunnel in Chicago.

LAWRENCE MOLE. The first product was developed in Alaska about 1950 for coal mines. A second-generation machine was introduced in 1959 and worked very well in soft rocks. It did not work well on the New York City tunnel between Brooklyn and Staten Island because of hard rock encountered. After 750' the machine was taken off the job. In 1966, Ingersoll-Rand purchased the then-troubled Lawrence Company to add to its product lines. They currently are reported hard at work on vertical raise borers but have no near-range plans to develop or market a tunnel mole.

ROBBINS MOLE, Seattle, Washington (206-767-7150) is the sales leader in this country and reports doing considerable export business to Europe, Japan and Australia. Their January 1976 delivery lead time on new machines is from eight to twelve months, depending on the size of the machine. The company's original boring machine product was brought out for use in coal mines in 1947. The first tunnel mole was introduced in 1952.

TERRA-FORM FOOTING CO., Clinton, Michigan (517-456-4161) builds moles for use in clay. Their lead time for new machines is four to six months. In 1975, they built three machines ranging from 4-1/2' to 15-1/2' and they now (1976) have in production a 12-1/2' machine for Navaho to be used in soft sandstone. (Often called Scott moles after their builder, Loran Scott.)

There are several manufacturers in Europe. Only one of their machines (a mini-tunneler) is known to be in the U. S., and it is not in use. Overseas manufacturers do market in the U. S., but their prices and delivery delays exceed those of domestic sources.

In Exhibit 11-2 (Specialized Manufacturers) the major explosives firms are included, although their product is not restricted to use in tunnel work. They provide unique technical services as part of the sale.

ITEMS - SHAFT	MANUFACTURERS
Sinking Frame, Shaft Jumbo, Steel Forms	Card Car Company, Elgood-Mayo, Ray Moran
ITEMS - HAULAGE	
Mine Cars	Card Car Company, Elgood-Mayo, Ray Moran
ITEMS - LOCOMOTIVES	
Battery, Diesel	Elgood-Mayo, Jeffrey, Mancha, National Mine, Plymouth
ITEMS - MUCK HOIST	
Headframe, Mine Hoist	Coeur-d-Alene, Elgood-Mayo, Nordberg, Wallman-Seavers-Morgan
ITEMS - BREAKING ROCK	
Drill Jumbos, Drills, Booms & Drill Steel, Air Compressors-High	Atlas-Copcos, Chicago Pneumatic, Gardner-Denver, Ingersoll-Rand, Joy Manufacturing
ITEMS	
Explosives	duPont, Hercules, ICI America
ITEM - LOADING MUCK	
Mucking Machines	Conway, Eimco
ITEM - SOFT GROUND	
Tunnel Shields, Erector Arm, Back Hoe	Elgood-Mayo, Memco, Milwaukee Boiler
ITEM - GROUND SUPPORT	
Segments: Iron or Steel, Segments: Pressed Steel Liner Plate, Segments: Pre-Cast, Ribs-and-Wood Lags, Steel Ribs, Roof Bolts, Shot Crete	Armco Steel, Commercial, Republic Steel, Bethlehem Steel, U. S. Steel, San-San

ITEM - CONCRETE LINING	MANUFACTURERS
Steel Forms, Concrete Pump or Gun, Agitator Card, Concrete Cars, Pneumatic Grouters, Grout Mixer & Pump, Mixing or Batch Plant	Blaw-Knox, Econo-Forms, Elgood-Mayo, Ewing Record
ITEM - SUB-AQUEOUS	
Air Locks-Muck, Air Locks-Man or Escape, Medical Lock	Elgood-Mayo, Memco, Milwaukee Boiler
ITEM - AIR COMPRESSORS (General and Low Pressure)	Chicago Pneumatic, Gardner-Denver, Ingersoll-Rand

FINANCIAL SERVICES

A crucial raw material for tunnel builders is money. Though one legendary firm handles very large jobs wholly on a self-financed basis, most need to borrow or have other forms of help. The principal sources are:

- Retained earnings and equity investment capital
- Progress payments by owners or other contractors
- Project financing or term loans from banks
- Leasing of equipment from third parties
- Fast collections and slow payments to others

MAJOR SOURCES OF MONEY

Progress payments and bank financing are the big sources of working capital to tunnel contractors. The need for cash flow is what leads to much of the unbalanced bidding that goes on. (Unbalanced bidding is explained in Chapter 12.)

Leasing is a growing money source. It enables contractors to have the use of equipment without having to purchase it outright or finance it and show debt on their balance sheets. Commercial firms, bank-related lessors, captive sister firms and others with which the contractor is associated are used.

The practice of being a "slow pay" is highly developed in the industry, but professional cash management techniques are growing and this is becoming more difficult.

BANKS VERY ACTIVE IN HEAVY CONSTRUCTION

For lending in the $10-20,000,000 range

Most active: Morgan Guaranty, Bank of America, 1st of Chicago
Also active: Chase Manhattan

For lending in the $2-10,000,000 range

Continental Illinois-Chicago, First National Bank of Boston, First Pennsylvania-Philadelphia, Hartford National Bank, Republic National-Dallas, Riggs Bank-Washington, D. C., State Bank of Albany, N. Y.

For lending in the under $2,000,000 range

Local banks with sufficient lending capacity provide most loans in the lower ranges.

BONDING

The management of risks in tunnel projects requires prior arrangements to prevent losses if possible and to determine who will bear any losses experienced. Bonding and insurance companies are among the important specialized suppliers involved here. For this study, the focus is limited to the role of bonding companies.

Bonds (or surety arrangements) are required either by owners or by financing sources to guarantee both completion of the work (performance bonds) and payment of all of the subcontractors, suppliers and others involved (payment bonds). Generally contractors are required to post a performance bond with their bids for 100% of the bid price. Payment bond requirements vary but have a $2.5 million limit at present.

The prime task of the surety firm (bonding company) is prequalification of contractors for project owners. The general public thinks the surety's function is to pay off the owner in case of non-performance of the work. However, success for a bonding company is to avoid certifying as qualified any individual or organization not likely to perform. The owner will take money as settlement for non-performance if there's no other choice. But what owners want is performance: on budget, on time.

To make these judgments about qualifications for a given job the surety firm must know both the business and the contractor well.

This leads to long-term relationships. They are like those between clients and other suppliers of specialized, professional services like accounting, consulting or legal work. The bonding company has a great deal of control over the bidding ability of a small contractor; much less so for larger firms.

Surety firms participating in heavy construction work are divided into two groups, reflecting price differences. The "bureau" companies use an agreed set of rates that has been established using the industry's long-established practices of working through associations known as rating bureaus. These rates are higher than those used by companies that do not participate in the rating arrangement (at the $20,000,000) point the price difference between the traditional bureau firms and the independent "non-bureau" firms pretty much disappears.

The leading bonding firms in terms of customers and coverage are three bureau member firms (Aetna Casualty, Travelers and U. S. F. & G.) and three non-bureau firms (Federal, INA and Seaboard).

EXHIBIT 11-C

RATES FOR CONTRACTOR BONDS

Level of Coverage	Bureau Rate per $1,000	Non-Bureau Rate per $1,000
Up to $ 100,000.	$10.00	$7.50
Next 2,400,000.	6.50	5.20
Next 2,500,000.	5.25	4.50
Next 2,500,000.	5.00	4.40
Over 7,500,000.	4.70	4.20

Non-bureau discount schedules range from a high of 25% off to a low of 10% off. Average discounts are in the 15-17% range.

Also mentioned as prominent in construction surety related to transportation and tunneling were: American General, Fidelity & Deposit, Firemen's Fund, Hartford A & I, Maryland Casualty, Reliance and the St. Paul Companies. Most of the surety companies are affiliates of much larger finance and insurance groups of the same name. In some cases the parent or sister companies have unrelated names. Here are some examples (the parent or sister firm is in parentheses): Federal (Chubb); Firemen's Fund (American Express); and Seaboard Surety (a subsidiary of Home Insurance Company which is, in turn, controlled by City Investing Company).

The major insurance and financial firms active in heavy construction surety work also are among the world's leading lending organizations. However, there is generally no financing provided to a contractor by his surety firm.

BONDING CAPACITY

The limit on bonding capacity of any one surety for a given project is set at ten percent of its capital and surplus. With the increase in size of jobs, and accompanying bond requirements, this has stretched tight the capacity of sureties. For example, a firm with a limit of $9.5 million faced with a request for coverage of $15.0 million by a firm it had qualified, had to pool the resources of three of its sister firms (subsidiaries of the same parent) to take the business.

Because so much heavy construction, and virtually all tunneling, is owned or financed by governmental agencies, the U. S. Treadury is involved in establishing surety bonding limits. The U. S. Treasury Department publishes a list of companies that are acceptable as sureties on federal bonds. (See Appen ix F).

The list shows company names and addresses, states in which the firms are properly licensed and in compliance, and their underwriting limitations. The limit is net on any one risk, not on total business. Each July this list is revised and published in the Federal Register (Surety Companies Acceptable on Federal Bonds).

BUSINESS SERVICES

Like most other businesses, tunnel contractors find that they are using more outside services each year and the trend is up. Some of these services are to help them manage complex projects. Use of computers in purchasing, scheduling and similar applications is growing. Other services relate to make-or-buy productivity choices, like the use of rented portable toilets. Still others are the by-product of new needs, of which guards with dogs is an example.

CONCLUSIONS

1. General equipment suppliers supply to the entire construction industry. Their potential market is quite large.
2. The market for some special equipment suppliers is small and erratic. This discourages investment in R & D, since the probable payoff is not sufficient.
3. Availability of operating cash and of performance bonds is essential to a contractor. Bonding companies have considerable influence on small contractor bidding.
4. Availability of working capital is not a problem to an experienced, healthy firm, although the interest rate is very high.
5. The surety firm has as its prime task the prequalification of contractors for project owners.

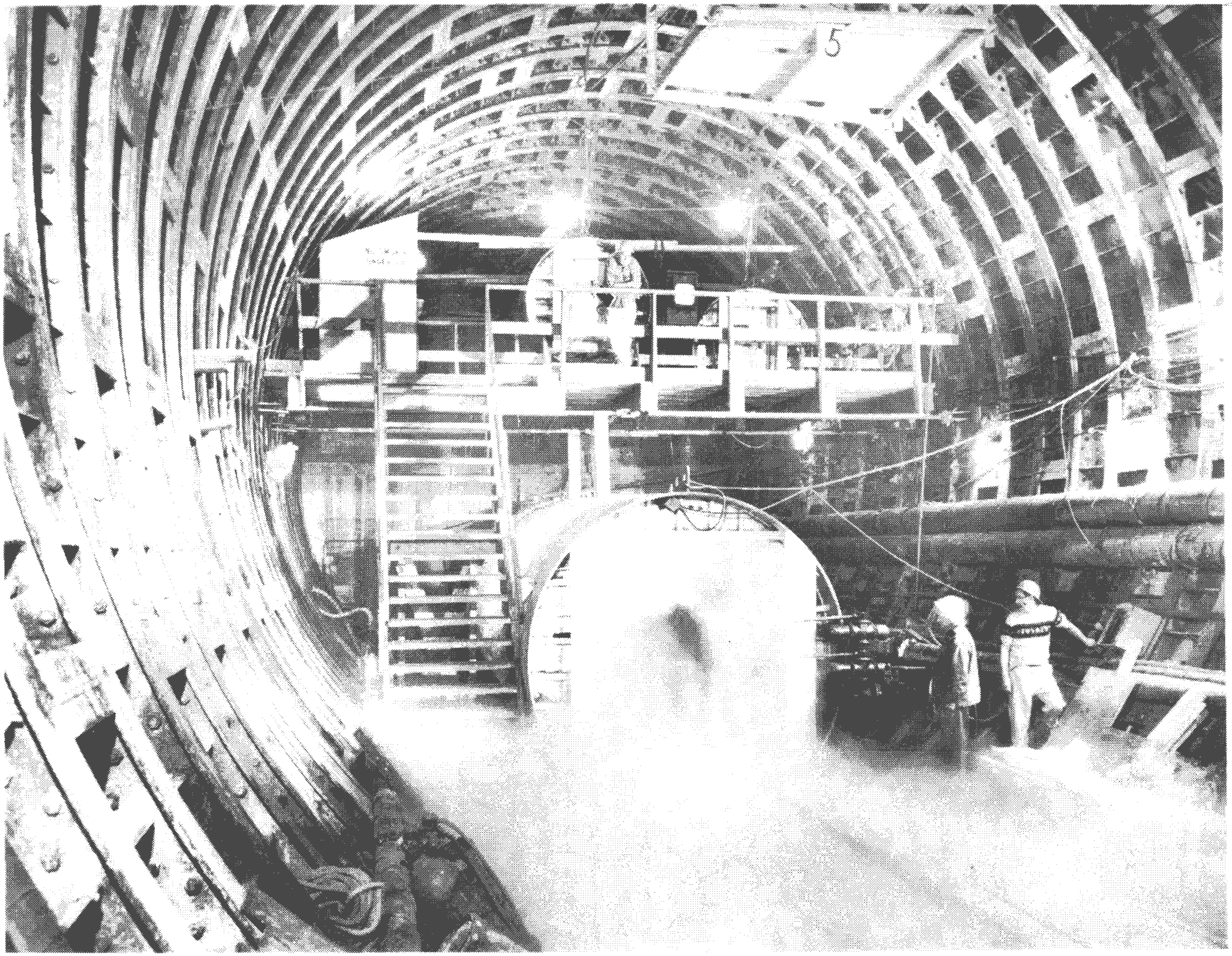


Exhibit 11-D

View of the outside of bulkhead. The man lock is in the upper right, the emergency lock upper center and the muck lock lower center.

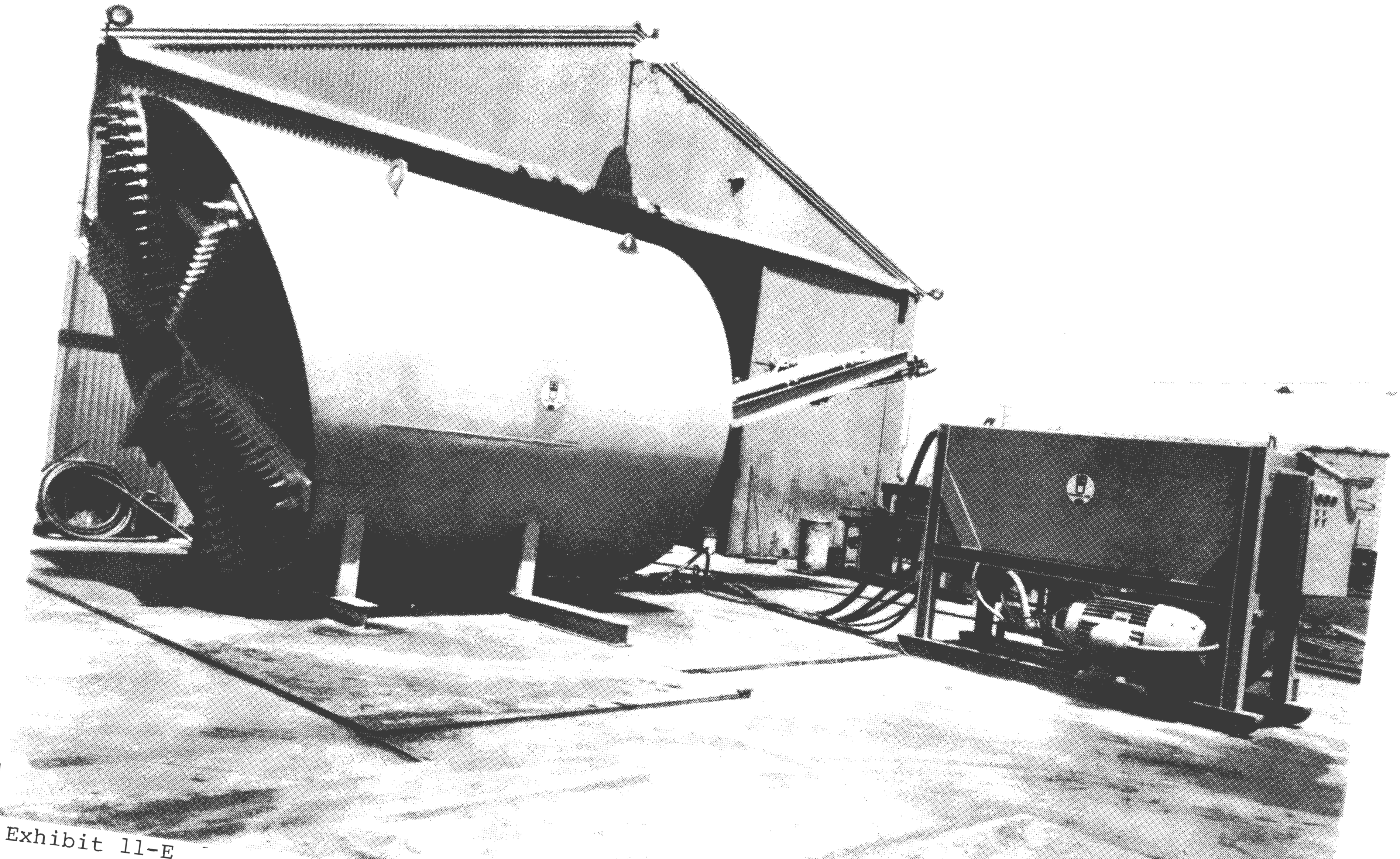


Exhibit 11-E

A soft ground tunnel boring machine or mole.

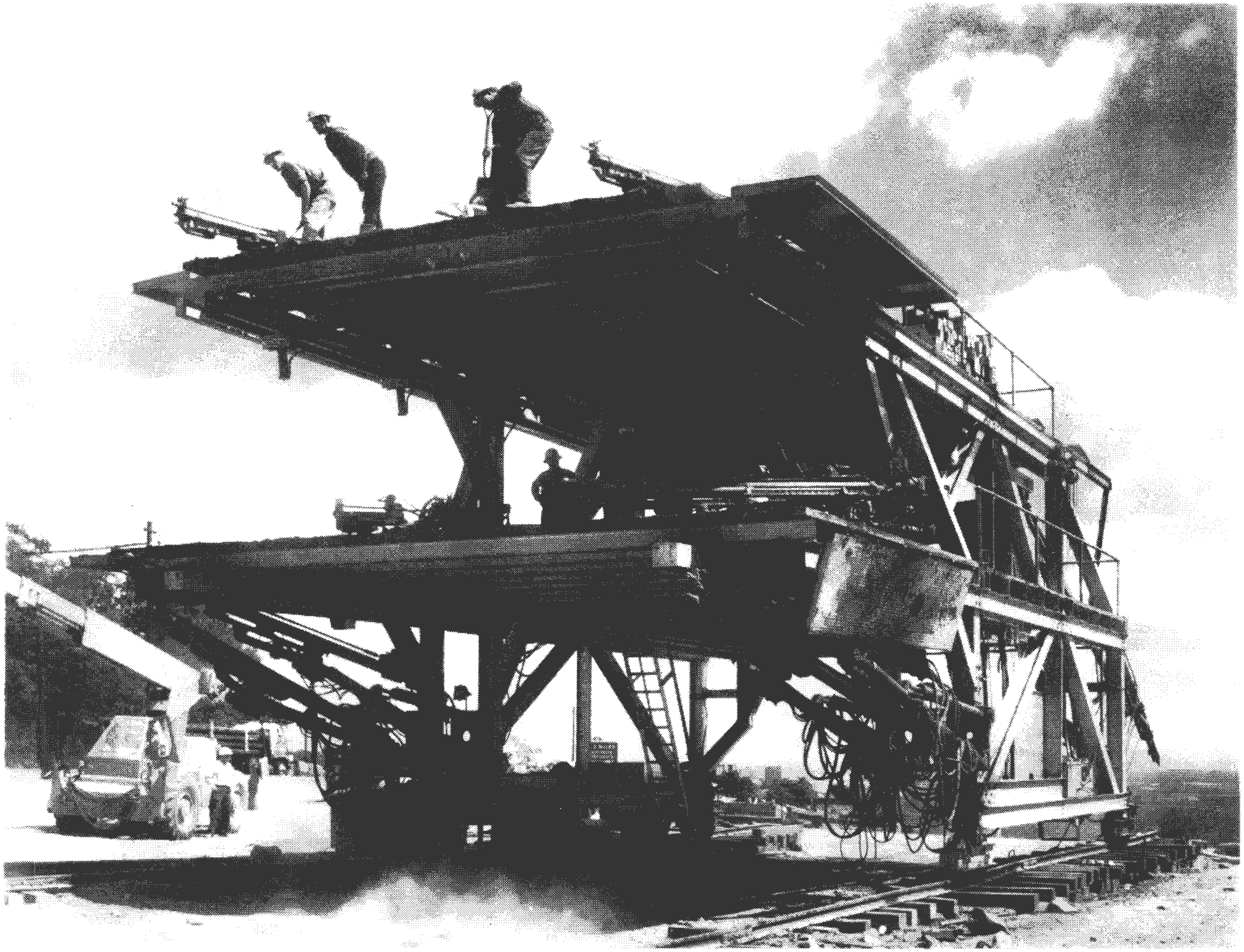


Exhibit 11-F **Drill Jumbo**

Chapter 12

BIDDING, BONDING & CONTRACT CONDITIONS

For tunnel contractors, competitive bidding is a way of life. That is the purchasing system currently required for almost all public agencies. Pressure is building for changes in this approach but no major breakthrough appears to be close to occuring. The long lead time in the major projects and the fact that virtually all tunnel construction now is publicly financed, means that contractors know about proposed work well in advance of the time that the project is officially advertised.

Three classes of decision are made:

A marketing and business strategy decision

Technical decisions and assessments

A bid-no bid business risk decision

The approaches to the business risk decision used by ten firms are discussed in Chapter 13.

MARKETING AND BUSINESS STRATEGY DECISIONS

Bid development is an expensive process. It takes a lot of the time of the most talented people in the business and there is also out-of-pocket expense for travel, communication, and related expense. When a developing prospective bid opportunity becomes known the marketing questions are: Do we want this business during the time the job probably will be active? Do we have the money and the people if we get it?

A company seeking to change its mix either toward or away from tunneling will have a market objective. So, too, will one which wishes to extend into, or withdraw from, the geographic area where the job will be. Business strategy considerations will involve the prospective impact of this project on the rest of the business and how having, or not having, that work will affect other corporate objectives. These sometimes include getting into joint ventures or working with specific people or firms.

A firm might not even bid on a job offering normal expected profits. (Actual corporate strategies are discussed in Chapter 13.) Let's look at a simple analysis a management might make. The planned tunnel project offers an expected profit with some degree of uncertainty. To even prepare a bid requires a sizable investment, and to handle the job, if it is awarded, will require a substantially larger financial commitment.

Other things being equal, the contractor won't consider the job unless the rate of return on his investment is equal to or greater than the rate for alternative jobs. These other choices, for most firms are either other tunnels or heavy construction jobs and may be either domestic or international. If the rate of return on the job being considered is greater than that on other choices, the contractor still might decide not to bid on the basis of this job's perceived greater uncertainty.

Construction firms which have survived and prospered develop a conservative approach. They will not bid, or will bid high, if they feel there's a serious risk of a loss which could cripple or bankrupt the firm. In tunneling, uncertainty is higher than in other types of heavy construction, both because of geology and the inability to easily correct or adjust operations, due to the constraints of tunnel driving.

So, if the cost of bidding the job will be high and the firm's recent bid success rate has been low, and if the firm does not have a serious potential cash flow problem, the bid opportunity frequently will be by-passed.

TECHNICAL DECISIONS AND ASSESSMENTS

The professional and technical judgments begin with the information available about the project and its objectives. After a job is advertised there is substantial detail available from the owners. Estimating decisions have to be made about each cost detail to build up field labor, materials, equipment and services costs. These will be affected by the way the owner handles such items. For example, some owners are beginning to furnish more items themselves. Others are specifying the unit costs for certain supply items in advance. (See also Chapter 7)

If a fixed-price bid is required, even with labor and materials escalation clauses, unforeseen subsurface conditions can create havoc and enormous losses. Risk considerations aside, the subsurface conditions also affect equipment, labor and time requirements. For example, if water is encountered unexpectedly there is a delay while the dewatering specialists dry the area. Additional pumps or different equipment or supplies may have to be purchased or rented. Labor time is lost.

A crucial set of technical decisions involves geological data. Good geological data is often expensive to acquire and generally not available in large quantities. Even when it is available, it must be interpreted by experts and their judgment sometimes is fallible. There is increasing pressure from contractors to have all of the owner's geological data made available to bidders. The argument advanced is that this would reduce the probability of encountering surprises and ameliorate the adversary climate that so often prevails.

"We ran into shale unexpectedly. The core samples had been taken improperly and showed clay. It turned out that the geologists' field men used a new power auger to drill for the core samples. The power auger ground the shale and brought it up looking like clay."

Preparing a bid doesn't commit the contractor to submit it. In fact, contractors sometimes have their office people prepare bids largely for practice or training. Once the cost estimate is prepared, great attention is focused on potential trouble areas: water, soil, labor problems or anything that has to be considered in the risk premium part of the bid pricing. If the technical and operating people are satisfied, their recommendations and data are forwarded to management for administrative, strategic, and pricing decisions.

PROJECTING THE CASH EFFECT OF A CONTRACT

The estimating process was described in Chapter 7. When the best estimate of costs to undertake and to complete a job has been made, some judgments and analysis about office overhead, profit required, and risks associated with the job have to be made. As part of this task, a projection of cash effects of the contract is an essential management practice. All labor and materials payments, equipment use charges, subcontractor payments, supply and service purchases, and overhead charges have to be laid out on a spread sheet.

Estimates of customer billings, payments, retentions, etc., also have to be made. This is a project version of a regular corporate cash flow projection. The cumulative cash effect of the job at each time period has to be estimated. Properly done, this shows how much cash is needed, and at what periods. This is essential for good financial planning and cash management. A three month segment of a project's cash flow is shown in Exhibit 12-A.

Billings to the owner are made monthly (in this example) on the basis of percentage of completion of the job and this is subject to verification by the engineer or the owner's inspectors. Usually this is computed by comparing cash costs for the period (and cumulatively to date) with the agreed total estimated cost. In the example in Exhibit 12-A (a small job for a tunnel contractor) the cash invested by Week 12 will reach $185,000. This assumes a good cost estimate and an award on all of the terms planned.

Does the contractor have enough money to finance this? If not, can he borrow it? At what cost? In the 1970's money costs of 12-18% for project financing are common and higher

Exhibit 12-A

PROJECT CASH FLOW FORECAST

(FIRST THREE MONTHS)

Week	Direct Labor	Materials	Equipment Use	Subcontracts	Supplies & Services	Overhead Charges	Planned Billings	Net Cash Investment
1	2,500					3,750		6,250
2	3,750					6,250		16,250
3	5,000					5,000		26,250
4	6,250					4,000		36,500
5	10,000	10,000	7,500	75,000	5,000	4,000	(146,500)	1,500
6	10,000					3,500		15,000
7	15,000	70,000	22,500		6,250	3,500		132,250
8	15,000					3,500		150,750
9	15,000	20,000	25,000	100,000	7,500	3,500	(317,000)	4,750
10	17,500					3,000		25,250
11	20,000	80,000	25,000		8,750	3,000		162,000
12	20,000					3,000		185,000
13	10,000	50,000	20,000	100,000	7,500	3,000	(417,000)	(41,500)

NOTE: This indicates when the money is expected to be paid out. It reflects payroll dates, normal supply credit terms, etc. Numbers in parentheses indicate receipts or net positive balances of cash. The cash problems caused by late payments by owners are apparent.

costs are not unknown. Has the cost of such borrowing been included in the bid price? It is a legitimate cost but might make the contractor's price too high to win the job.

The firm may tie up its own money without a return in order to get the job. A proper bid should include the cost of money on the firm's own funds. That is, the same return it would earn if on deposit with full safety, plus the market risk factor. Contractor surplus funds on deposit in 1975 could earn about 8% without risk. Project borrowing, if available, would cost about 17%. Thus the market risk premium is 9%. A contractor who ties up his money without including that 17% cost is, in effect, cutting his price.

Another alternative money source is the owner. Contractors, some engineers, and others interested in the industry are urging that owners provide more of the cash flow requirements. Some owners with large continuing construction programs have begun to provide more mobilization money, reduce retentions, etc. Still another source of money is to get a partner. As the size of jobs has increased and outrun contractor resources, the absolute number of joint ventures has increased.

So, the contracting firm considering its cash needs has these options:

1. Use its own working capital to finance the job (with or without a return on the funds equal to market rate.)

2. Borrow the money from a bank or other source.

3. Obtain advances (mobilization, etc.) from the owner.

4. Joint venture with another contracting firm.

5. Obtain funds from the owner by unbalancing the bid.

UNBALANCED BIDS

This last option involves so structuring the bid as to bring in money in excess of the amounts being spent and create a positive cash flow, or a lessened negative cash flow.

In Exhibit 12-A the contractor, billing on an estimated percentage of completion method, requires $185,000 in working capital for the project cash flow at its high point for the three-month period. This is derived from a time-array of costs which originally were estimated from work items in the specifications. For example, let's assume there are five work items (normally there are many more). Exhibit 12-B shows the work items, profit and bid price. This would be before the decisions about uncertainty, competition, etc., which might further alter the bid price in either direction.

Exhibit 12-B WORK ITEM PRICES (COST ESTIMATE)

Work Item	Estimated Cost	Estimated Profit	Unadjusted Bid Price
A	140,000	14,000	154,000
B	110,000	11,000	121,000
C	60,000	6,000	66,000
D	115,000	11,500	126,500
E	50,000	5,000	55,000
TOTAL	475,000	47,500	522,500

Unbalancing is accomplished by moving some costs or allowable billing items ahead in time. It involves manipulating several variables. In Exhibit 12-A the work items were broken into components such as labor, materials and equipment and spread by week of payment. Profits and risk premiums are included in that display.

To unbalance the bid adjustments are made in work items (12-B), then are tried for effect on cash flow projections (12-A) until the desired combination, or best available, is reached. Exhibit 12-C shows these computations in part. It is based on taking the profit for work items A through E ($47,500) and attributing it all to items A and B. The allocation used is to add $25,000 in profit to Item A, $22,500 to item B, and bid items C, D, and E with no profit. Total bid effect is the same, ignoring other considerations.

Exhibit 12-C CASH GENERATED FROM UNBALANCED BID

Work Item	Percentage Completion	Balanced Bid Price	Unbalanced Bid Price	Increase In Cash From Unbalance
A	75%	115,500	134,250	18,750
B	25%	30,250	35,875	5,625
C	10%	6,600	6,000	(600)
D	5%	6,325	5,750	(575)
E	7.5%	4,125	3,750	(375)
	TOTAL	162,800	185,625	22,825

This exercise takes a few hours. The cost of money for $23,000 for three months is over $1,000, while the cost of an estimator to unbalance the bid is probably $50 for the time spent. It's an excellent return on the investment for the contractor. A growing body of opinion opposes unbalanced bids but the reality of cash flow costs and pressures suggests they'll be with us for some time to come. Other factors of bid-no bid decisions are discussed in Chapter 13.

RELATIONSHIP OF BIDS TO PROFIT HISTORY

When a tunnel job to be bid is similar to other work recently performed, the contractors' informal but active network is a factor in bid preparation. The high rate of transfer of people among firms means that everybody has friends working for other firms. Secrets are hard to keep. So, an informed opinion can be developed as to whether a contractor is doing well on a given job. If he is, the bids on a similar job will reflect this and will incorporate all that was learned from the bid openings of the earlier job.

Veteran tunnel men say that you can tell that a job is like another one that has been profitable when you see a very narrow spread of bid prices. Here's an example from the Metropolitan Sanitary District of Greater Chicago for rock tunnels and shafts. Bids were opened January 6, 1976.

Engineer's estimate	$18,000,000
Bidder No. 1	21,371,607
Bidder No. 2	21,420,345
Bidder No. 3	21,888,113
Bidder No. 4	21,916,275

If a contractor is losing money on a job the early signals are conversations about the need to modify the contract due to changed conditions. If that isn't fruitful, claims usually follow and may lead to actual litigation.

ENGINEERING LIABILITY

The contracting firm is highly sensitive to the fact that a key part of the normal bidding process is actually the transfer of risk from the owner to the contractor. This transfer is surrounded by various kinds of insurance coverage, performance bonds and payment bonds. Also in the risk picture, to a lesser degree, is the engineering firm and all consulting and specialty engineers. Errors and omissions insurance coverage used to be optional.

Now the engineering firms face a dilemma. Most can't choose to be "naked on the risk", i. e., without errors and omissions insurance. Owners generally require such coverage. At the same time, E&O coverage is increasingly difficult to obtain and its costs are escalating. In December 1975, E&O premiums were equal to 4% of engineering hourly billing rates in the firms checked.

A general fear surrounds professional liability insurance. The experiences of insurance carriers and state regulators with medical, legal and accounting firm losses have led them to be wary of architects, engineers and consultants. Anyone handling the design, inspection or supervision of a heavy construction project is in a risky business. However, tunnel engineers tend to believe that the troubles with Boston's John Hancock building have as much to do with E&O costs as does the 1975 tunnel failure in upstate New York. This is because most carriers don't discriminate among types of design work.

Principal professional liability insurance carriers are withdrawing from the field, putting through enormous rate increases, and stiffening requirements for acceptance as covered risks. In the BART project in San Francisco, engineers' errors and omissions coverage was provided as part of a full project "wrapup" insurance program developed and paid for by the project owner.

PERFORMANCE AND PAYMENT BONDS

The importance of the surety function was demonstrated anew in 1975 when there was only one bidder for a major tunnel project in the northeastern United States. The others who had been expected to bid could not obtain bonds. Decisions as to whether or not a contractor is qualified to perform a given job are important to four groups:

OWNERS - who want assurance of performance that is made by an independent third party.

CONTRACTORS - who are dependent on bonds to qualify as eligible to bid. No bond, no work.

FINANCIERS - who need an independent check on firm qualifications and probabilities that things will go well on the project that they are financing, plus a contingency cover if things don't go as planned.

OFFICIALS - public sector executives need to be able to avoid political pressures for qualification of the unqualified.

Surety firms maintain close contact with contractors for whom they provide bonds. As a bid opportunity becomes known they determine how well the contractor can perform. The more important factors in their decision are the contractors net quick assets, the proposed project management team, relationship of the experience of the people involved and the type of project, general operating environment experience of the contractor, anticipated duration of the project, and any social legislation objectives involved.

The so-called acid test of a firm's liquidity and general soundness is the ratio of its net quick assets to its current liabilities. It includes the total of cash, marketable securities and accounts receivable, ignoring all other assets.

Exhibit 12-D NET QUICK ASSETS OF TUNNEL CONTRACTOR

A Measure of Liquidity ($000 omitted)	1974	1973
Quick Assets (Cash, Securities & Receivables)	111,933	89,998
Current Liabilities	104,927	91,274
Quick Ratio (Assets - Liabilities)	1.07	.99

*** Source: Annual Report of Dravo Corporation for 1974.**

After the question "Do they have the money?" (which is answered in part by evaluation of net quick assets) comes the question "Do they have the people?" Important qualitative judgments must be made as to how well and how fast individuals are developing, and how devoted they are to this work or this team. The key people for the contracting firm are the estimator, project manager, engineers and superintendents, and purchasing specialists. Others usually can be hired. The ability to assemble and field this team is a crucial part of the contractor's ability to perform.

Most contractors are cautious and their conservatism is reinforced by the surety managers. When a sewer contractor says he wants to bid on a cut-and-cover transit tunnel, the surety looks carefully at the people <u>and</u> the project. He wants to be sure that the contractor is not taking too large a step beyond his technical experience or his work-environment experience. Most bonding people are relatively comfortable when a competent pipeline or sewer-building contractor decides to bid a cut-and-cover tunnel.

They note that the skills of excavations, utility removal, sidebank stabilizations, and general restoration are much the same for both types of job. However, they put a lot of weight on differences in environment in which the job will be built, i. e., urban vs. rural.

One surety specialist gave this example: one of his customers is a road builder who works in rural Georgia. For years he has had a successful record with roads, sewers, and small bridges in the country, including sections of interstate highways, main and secondary roads. "He wanted to bid a downtown section of MARTA in Atlanta, including a cut-and-cover tunnel. There's no way we'd go along with that. He's a successful country boy but doesn't understand cities. He can build the thing but not with the complications of city work." The longer the duration of the job, the greater the exposure to problems with people, materials, costs and other factors. A native tendency for surety people to favor short projects has been magnified by the inflation of the Seventies.

Added complexities of contractor prequalification are due to legislative and regulatory changes aimed at social objectives. Specific references were made, by people interviewed, to equal employment quotas set for specific jobs. While contractors are trying to meet the letter and the spirit of the law, their actions have the unintended side effect of reducing competition by excluding out-of-towners.

Another problem is that jobs are getting bigger while bonding capacity is shrinking. Even after inflation adjustments, surety people say job size is growing. (They didn't restrict their comments to tunnel work, but included other heavy construction, mentioning that sewage treatment plants can now cost close to $100,000,000.) Industry capacity has shrunk. On any company's bond commitment the limit per project is 10% of its equity and reserves. Several years of inflation, investment reverses, and poor loss experience have eroded the industry's capital.

Exhibit 12-E SHRINK IN BONDING CAPACITY

Example Company	1974 Capacity	1975 Capacity
American Casualty (Reading)	$5,084	$3,159
American Employers Ins. Co.	6,290	3,665
American & Foreign Ins. Co.	1,734	793

Source: Federal Registers, Circular 570, 1974 and 1975.

PERFORMANCE BONDS PROVIDE NEEDLESSLY HIGH COVERAGE TODAY.

This is the unanimous assertion of surety people. They contend that performance bonds covering 50% of a project's estimated cost would be enough, noting that their worst case actual exposure under 100% coverage is about a 20% loss.

How much of this position is due to the capacity problems noted above? Their responses brought out these points:

a. Premiums for coverage at 50% of estimated project cost are the same as for 100% coverage.

b. Reductions to 50% would indeed improve the capacity situation of insurance carriers.

c. In case of a loss of over 50% they expect the carrier would pay it anyway so the government won't be tempted to operate without surety firms.

d. Their worst case loss is 20% of the face amount of coverage.

Historically, when a general contractor failed financially on a job his subcontractors and suppliers did not get paid. For some this caused severe hardship or bankruptcy. The practice of awarding jobs to low bidders sometimes increases this risk. As a contingency plan, the practice of requiring general contractors to provide a bond for payments up to $2,500,000 arose. This added to contractor cost but eliminated most of the need for bad debt reserves by suppliers. (These reserves add 2-3% to prices.)

In numerous projects the costs of installed or operating construction equipment exceed $2,500,000. Therefore, the surety industry people believe it would be better to have the payment bonds guarantee 50% of the cost. They think the premium will be about the same either way.

CONTRACT CONDITIONS AND PRACTICE

An adversary environment, with enormous amounts of time spent trying to outfox the other fellow, frequently prevails. Claims, litigation, arbitration, and bankruptcies remain common. Owners are angry when they discover or suspect that the contractors are unbalancing their bids, playing games with equipment, or doing other things to improve cash flow. Requests for data in connection with this study had to be declined by WMATA officials due to pending litigation.

Contractors are angry when they encounter unforeseen conditions (subsurface) and the owner expects them to bear all the extra cost. No matter what the contract says, the contractor will try to recover it. Engineers, faced with erosion of their traditional role as the owner's representative, find themselves between the owner and the contractor and sometimes regarded by both as the devil's agent.

Major federal agencies have been working with some success to move away from the adversary environment and toward the team cooperation that projects as large as tunnel building require. The Federal Differing Site Conditions clause provides for the owner to assume costs associated with subsurface problems that couldn't be foreseen. Progress is being made in providing mobilization money at times and in quantities that relieve contractors of financial pressures. Some contractors and engineers had commendatory things to say during our interviews about these changes and cited WMATA, BuRec and the Corps of Engineers as among those providing arrangements regarded as fair.

Of increasing concern is the fixed-price contract. This concern seems to be heavily related to inflation. Also of concern in bidding decisions is the relatively low level of experience of certain state or municipal-owner officials. Where their construction volume is low they can't acquire experience.

Among common contract provisions which contractors now face are:

> Modified definitions of changed conditions.
>
> Bids stated in cost per linear foot (Schedule A) and unit cost (Schedule B). Owners are specifying costs on some items such as steel or concrete.
>
> Escalation clauses intended to cope with inflation or changes in labor or materials costs during the project.
>
> Buying preferences for small business, local business, minority firms, etc.
>
> Modified ways of settling disagreements. There is a trend to substitute arbitration for litigation.

In developing the bid and considering operating conditions on the job the contractor must also assess the possible changes, delays or costs which might arise from: affirmative action rules, community relations activity, environmental rule compliance (noise, dust, mud, air quality), health regulations, labor work practices, minority employee groups, operating hour limits, safety regulations, security against theft and vandalism, and any other conditions which may be imposed contractually or in practice by the owner or which might be enforced by regulatory or pressure groups.

REWARD OFFSET RISKS IN SOME CASES

The chronic fears of contracting executives that they will overlook something crucial which might wreck the company, especially in a fixed-price contract, are occasionally offset by circumstances which combine good management and luck to provide a bonanza for the company. Within the last few years there has been an example of this that is worth describing.

A subaqueous tunnel involving an approach to the water, an underwater segment, and an approach on the other side was specified by the engineers as requiring compressed air operation. The contractors bid it on those conditions. After work began it became apparent that there was no need for compressed air work in the approaches, though there would be under the main body of water.

The financial impact of this discovery was extraordinary for the contractor. Many support costs were eliminated. The permissible hours of labor-per-worker-per-shift was double the amount in free air that it is in compressed air. The job could move much more quickly with associated savings in overhead costs. Everyone involved was delighted because of the removal of hazardous work conditions and the other benefits of a free air job over compressed air.

However, it created a political problem for the engineer. Everything was legal and correct, but there would be a loud howl if the press learned of the contractor's bonanza. The engineer insisted that the contractor install one lock and keep a little air pressure in it. The contractor happily complied.

CONCLUSIONS

1. A construction contracting firm makes a decision to bid either this job or other alternatives. It is not limited to tunneling, or to certain types of tunnels.

2. Bidding a large tunnel job is a difficult, costly step. Contractor capacity to prepare bids is limited.

3. A contractor includes sufficient risk premium in his bids. If he prices at the margin (close to costs), a small number of bad jobs will ruin him.

4. Geological data is costly to acquire and generally not available in large quantities. Even when it is available, its validity is uncertain.

5. Some owners have not been willing to release full geological information to bidders. This increases the riskiness of the job. The contractor must either increase his risk premium in the bid or hope for favorable negotiating or litigation if difficulties occur.

6. The timing of cash flow on a job can be as important as the final profit margin.

CONCLUSIONS (cont'd.)

7. Contractors have become used to absorbing risk through insurance and bonds. The engineering firm has seen a significant increase in its risk recently, as demonstrated by the practical requirement for errors and omissions insurance.

8. The bonding decision largely depends on the firm (financially), the key men (specific experience), and the job (overall project circumstances).

9. In urban tunnels, success depends more on cost management than on technical ability.

10. Tunnel jobs, as other heavy construction jobs, are increasing in size (fixed dollars).

11. Performance bond coverage requirements are needlessly high.

12. In the worst of projects, an adversary climate develops, where minor changes cannot be reconciled, litigation is common, and the owner's engineering consultant loses the confidence of both sides.

13. The fixed price contract incurs problems when unexpected soil conditions or rising supply prices occur.

Chapter 13

DECISION MAKING BY TUNNEL CONTRACTORS

Contractors willing to bid for tunnel work must accept:

a. Industry risks specifically related to tunnel work, which were outlined in Chapter 4.

b. Job risk, unique to the job being bid, which was outlined in Chapter 12.

c. Financial risks like loss of money and reputation.

Twenty-three companies were specifically contacted about decision making and financial analysis. Fifteen were in-depth contacts. Of these, ten were selected as representative of the three kinds of tunnel contractors: (a) private companies (small and large), (b) public companies (small and large), and (c) conglomerates with subsidiaries in heavy construction including tunneling.

Decision making factors in these ten companies are discussed in this section and financial comparisons are included in Chapter 14.

Exhibit 13-A shows decision levels and weighted factors involved in decisions to bid. Factors influencing profitability of the ten companies are shown in Exhibit 13-D.

THE PRIVATE COMPANIES

The level of authority required to bid a tunnel job is highest in these companies. The chief operating officer is always involved in the final bid. Decision making in the smaller company is oriented around the entrepreneur who founded or runs the company. Even in larger private companies, decision making is usually centered around members of the founder's family or descendants who usually occupy most of the executive positions.

In the smaller private companies specializing in tunnel work, the need for business is an often dominant factor. In the larger private companies this is replaced by the mix-of-business requirement which prohibits a company, by choice, from accepting more than a specific percentage of tunnel work. Because of the centralized ownership of these companies within a family or a small group of private shareholders, risk is considered as a personal thing and these companies are generally conservative in their commitments to bid.

The decision makers in both smaller and larger private companies frequently have considerable actual experience working on tunnels. They know first hand the kinds of problems which might be encountered. As one small private company president said, "When everything else is equal, I'll go with my nose."

THE PUBLIC COMPANIES

Decision making in smaller public companies is generally made at the highest levels, with the final decision made by the Board of Directors and/or the chief operating officer. The most profitable smaller public companies rigorously review all bid proposals. As the companies get larger, some responsibility is delegated, but major decisions to bid are still generally made at the chief operating officer and executive committee (or Board of Directors) level.

A decision to bid was described by one company Vice President where Board involvement was critical as follows: "The Board expects complete position papers, including the final proposed bid, internal expectations, critiques of the bid by others not involved in its preparation, an analysis of cash flow, capital commitment and financial return, a synopsis of other work done for the customer, and a complete evaluation of manpower available to supervise and staff the job. It's not uncommon for our board to table to a subsequent meeting a proposal for bid modification so additional information can be obtained."

All the public companies were originally private family businesses, and share in the sense of personal risk in decision making. Qualified manpower here provides good cost controls.

In public companies, the mix of business becomes a more significant factor. Some companies are unwilling to allow more than 15 to 20% of their volume to come from tunnel work because of the high financial risk. In addition, some of these companies are unwilling to take on more than one or two jobs at a time, because of the availability of qualified manpower. Some companies refuse to bid until they have identified supervisors for a job.

THE CONGLOMERATE

A conglomerate with a tunnel division has a lower level of decision making because of both corporate size and diversity. Decisions are usually made by chief operating officers of the subsidiary concerned or by division vice presidents or general managers.

The need-for-business and mix-of-business factors are less dominant in conglomerates than in the private and public tunnel construction companies. In a typical large conglomerate, the potential for revenue scarcely outweighs the risks involved and is not a critical decision factor. In at least one case, a need to keep some conglomerate firm employees with tunnel experience busy was expressed as the principal reason for getting involved in tunnel work.

Some tunnel divisions attached to conglomerates are well managed, with much the same autonomy and operating philosophy they had when they were smaller private companies. Others are parts of divisions which lost their identity in larger general areas of the conglomerate.

One major conglomerate with corporate sales in excess of $3 billion had tunnel revenues of less than $10 million "in a good year." Its commitment to the industry is marginal and "were it not for that fact that we have some equipment and some men who are enthusiastic about working in this area (and we don't know where we would put the men if we shut down the division), we wouldn't be involved in tunnel work at all."

One of its executives said: "We have a full time inside accounting staff that can't tell you, I'm sure, what our overall revenues and net profit from tunnels really are. It's such a small line item, with at best a break-even contribution to profitability, that we really don't pay much attention to it. Why the area of corporate responsibility it is included in is two levels below the point at which we break out revenue categories for our reports to the Securities and Exchange Commission."

A second conglomerate with a much higher degree of dependence on construction and engineering viewed tunnel work differently. "After all, about 75% of our revenues come from engineering and contracting, so we obviously want to know what's happening here. We prioritize all potential contracting projects we consider bidding and do substantial risk analysis."

"When the job risk is high, we consider joint venturing. When we're not sure we have the right people, but see a friendly competitor who does have the right people, we consider joint venturing. When the risk is extremely high, and we don't have the people or a partner, we do not bid, or if we do, we bid it extremely high."

"Even then we might get the job and come close to losing our shirts. Building twenty feet under the earth, there are always plenty of surprises, even with the best geological studies available."

A third conglomerate viewed its participation quite differently. Its tunnel revenues range from 1 to 5% of overall corporate revenues, with profitability contribution ranging from -6.3% in one year to a recent result of 4.9%. "We acquired a smaller private company specializing in tunnel work that had a good track record. We knew it was a risky business."

"We didn't expect it to lose $10 million in one accounting year. Since then we've tightened up bidding, cost accounting, and progress reporting. Decisions are made at a higher level. We thought we could expand more quickly than actually was possible. We couldn't find the right people to supervise the projects, and we got burnt."

Exhibit 13-A DECISION MAKING BY TUNNEL CONTRACTORS

	PRIVATE				PUBLIC			CONGLOMERATE		
	#1	#2	#3	#4	#1	#2	#3	#1	#2	#3
Level of Decision to Bid										
- Board of Directors	10	10	8		10			7		
- Corporate CEO/COO	10	10	10	10	10			8		
- Subsidiary CEO/COO								10		8
- Division V.P.			10	10	10			10	4	10
- Division Manager									10	10
Bidding Criteria										
- Need for Business	8	8	6	6						
- Mix of Business			10	8	10					
(not to exceed __%)			20%	20%	20%					
- Joint Venture Invitation	7		8	6	8			8		
- Availability of People										
. to Manage Job	7	5	9	8	10			9		8
. to Work Job	5		7	6	8			7		5
- Availability of Equipment										
. in Company	5	8	7		3				7	
. outside of Company	7									
- Ability to do Job	10	7	10	8	10			8	4	8
- Cash Flow Projections	9	8	8	8	9			9		6
- Capital Availability to Finance Job	9	8	8	8	9			9		5
- Location										
. in regular marketing area	9	8	4	6	9			7	5	7
. in area where work is currently underway	9	8	4	7	9					
- Need to Keep Employees Working	2								8	
- Geologic Info. Available	6	3	6	6	9			7		7
- Risk Analysis	8	7	8	7	10			9	6	8

SCALE: Weight assigned range 1-10 (High)

"Experience is everything in tunnel work, and there just aren't many tunnel experts. We all have a man or two who's worked under so and so on a tunnel job, but that's not the kind of supervision that is going to save time and money, and have the job come in under bid."

"He's got to know the work, and those who work for him have to know the work, and even those in the next level of supervision if possible. When our Board of Directors had to put in over $15 million to keep the company alive and in the contracting business, they told us our jobs were all on the line and they weren't going to pour money into somebody else's tunnel."

JOINT VENTURE ORGANIZATIONS

In our discussions with management of all three kinds of companies joint ventures almost always were endorsed enthusiastically. It seems to be an effective way to share risk and risk analysis. As one company executive Vice President expressed it,

> "We look at joint ventures as an ideal combination because we seem to be able to make money on them. Maybe it's because a joint venture requires that two Boards of Directors ask a lot of questions. Maybe it's because two independent auditors look at how things are done. Maybe it's because we both are more conscious of wasting our partner's money."

Exhibit 13-B

JOINT VENTURE COMPARISONS

Factor	Single Contractor	Joint Venture
Ability to handle larger job	Varies	Very good
Organization planning	Varies	Very good
Risk analysis of job	One team	Two teams
Review by accountants	Sometimes	Always
Review by attorneys	Sometimes	Always
Review by directors	Usually	Always
Share of job risk	Full	Partial
Job staffing	Complete	Partial
Job financing	Complete	Partial
Profit probability	Good	Excellent

Source: Cresheim Company Interviews, 1975.

The Associated General Contractors of America, Washington-based industry association for all contractors (builders, heavy and highway), issued in November 1975 guidelines for its members to use in considering and in forming joint ventures. AGC suggests principal contractor objectives are to limit liability, supply needed know-how, reduce in-house costs, maximize income from the proposed project, or improve the firm's ability to compete.

Although AGC's guidelines do not weight the relative reasons for interest in joint venturing, interviews with contractors suggest that risk and competition are the prime motives, with access to know-how, or resources following. Smaller firms also note that joint-venturing with a large well-regarded firm enhances the reputation of the smaller firm. Competitive considerations include: preparation of a better developed bid, access to an unfamiliar geographic market (partner supplies local contacts and know-how); and reduction in competition. The expanded bonding capacity is vital as job sizes increase.

Tunnel joint ventures tend to be among tunnel contractors but AGC notes that possible combinations include:

general contractor and architect-engineer

general contractor and equipment-supplier

general contractor and traditional subcontractors

general contractor and developer (real property)

This suggests for the tunnel industry the fascinating possibility of joint ventures including manufacturers of tunnel boring machines.

EXHIBIT 13-C

CHECKLIST FOR JOINT VENTURES

AGC suggests contractors follow this checklist in forming joint ventures.

1. Date venture is established
2. Names & addresses of venturers
3. Name of joint venture
4. Description of project
5. Definition of party interests
6. Monetary or other consideration
7. Termination if losing bid
8. Bid deposit and bonding
9. Performance bond details
10. Insurance coverage details
11. Management of the venture
12. Share of profits and losses
13. Working capital agreement
14. Cost of construction
15. Equipment rentals
16. Bank account details
17. Bookkeeping procedures
18. External audit
19. Costs prior to contract
20. Distribution of profit-loss
21. Bankruptcy of venturers
22. Limit on venture projects
23. Non-assignment of interest
24. Arbitration of disputes
25. Not a legal partnership
26. Termination other than 7
27. Governing laws
28. Execution by officers
29. Notarizations

Source: AGC Joint Venture Guidelines

Exhibit 13-D PROFITABILITY FACTORS OF TUNNEL CONTRACTORS

	PRIVATE				PUBLIC			CONGLOMERATE		
	#1	#2	#3	#4	#1	#2	#3	#1	#2	#3
Factors Determining Profitability										
Level of Control of Job										
COO - Div. Pres.	10		7	7	9			5		
Div. V.P.		8	9	8	10			10		8
Div. Manager			9	8	10			10		8
Project Manager	10	9	9	9	10			9	10	10
Section Manager	8	10	10	10	10				7	8
Use of Equipment - Efficient	8	8	8	6	8			8	5	8
Control over Expenses	9	8	9	8	9			8	6	8
Good Cash Flow	9	8	9	7	8			6	5	8
Availability of Supervisor	7	6	8	7	9			8	7	8
Availability of Labor	7	6	6	6	7			6	5	7
Good Geologic Information	6	4	8	8	9			8	5	8

Scale of 1 to 10 with

10 = Highly Relevant or Committed

1 = Minimal Relevance or Commitment

CONCLUSIONS

1. The decision to bid a tunnel job goes beyond the engineering staff to various levels of corporate management. In larger firms a job requires the approval of several levels of management who are removed from tunneling *per se*. This places more emphasis on the profitability and riskiness of each job. Less emphasis is on personal experience or professional pride in tunneling.

2. Some companies are unwilling to bid tunnel jobs unless they can supply all supervisory staff from their own people.

3. The need for work can influence a contractor's decision to bid as well as the markup within a bid. When a company has sufficient work, it will either avoid new bids or it will bid high.

4. Since tunneling competes directly with other heavy construction, the relative amount of other work available -- such as sewers, highways, bridges, harbors, and nuclear plants -- will directly affect the attractiveness of tunnel jobs.

5. Many firms within the industry have put a limit on the amount of tunnel work they are willing to undertake. The limit may involve the mix of business (generally a limit of 15 to 20% of total volume) or the availability of qualified people to run the job.

6. There is a definite relationship between the organizational level of decision making on bids for tunnel work, the organizational level of job supervision, and the profitability of a tunnel job.

7. The firms who were surveyed considered control over expenses to be a more important factor than good geological information in the profitability of a job. This is generally a financial staff view with construction professionals giving better geological information equal weight with expense controls. However, in conglomerates (multi-industry firms) the financial staff tends to have more power.

8. Joint ventures have become a well accepted method of handling the large jobs. They appear to offer better cost controls than single firm efforts. Their effect on price competition in bidding has not been determined yet.

Chapter 14

PROFITS, LOSSES, COSTS AND CAPITAL

In January 1976 Pittsburgh's Dravo Corporation announced that it was writing off as a loss its investment of ten million dollars in the Water Tunnel Constructors joint venture. The problem-plagued tunnel job from Yonkers in Westchester County down to New York City had been suspended for more than a year when the Dravo announcement was made.

Of the six joint venture firms, two have announced massive writeoffs, two have gone out of business, and two have not been heard from publicly. By coincidence the Dravo writeoff on this project is equal to all the after tax profits of all Dravo business groups for all of the year 1974. One tunnel project did all that damage to six experienced companies.

So the same sort of bonanza of good luck that resulted when a compressed air job could be worked in free air (see Section 12) can backlash with brutal force. And the general opinion (Section 13) that joint ventures are better managed and more profitable than single firm jobs is subject to exception. In 1974 total liabilities of $526,598,000 were outstanding for the 1,840 construction firms of all types which went out of business. Dun & Bradstreet also reports that through July 1975 an additional 1,473 contractors were bankrupt or out of business leaving another $473,820,000 in liabilities outstanding. These figures, of course, include all types of construction, not just tunnel-driving.

Profits for tunnel contractors are a by-product of management skills, good people, and some luck. The nature of the business dictates that much of the probability of profit is a result of the bid-no bid decision or of errors built into the bid. After estimating project costs, overhead, and desired profit, contractors add a contingency cost to cover the risks they perceive. Finally, an adjustment up or down is made based on an estimate of what it will take to get the job and how badly the firm wants it.

It is here that a major influence on profits is felt. Errors, omissions and emotional involvements all play a part in the outcome. One well-known tunnel contractor got an award for his $2,500,000 bid and at the bid opening it was apparent that something was wrong. All the other bids were several million dollars higher. It turned out that his people had estimated one of the twin tunnels specified and had forgotten to multiply the result by two. Despite extensive reviews, this error slipped through.

Some of the larger contractors use complex computer aids for estimating and bid preparation. However, in our investigations, everyone using the computer also prepared a manual estimate. The possibility of error and the cost of such errors is so great that no contractor will rely on a computer. They use them for check estimates only and to store and reproduce large amounts of boiler-plate and repetitive data. There is also extensive use of computers for scheduling, purchasing and accounting.

Repeatedly we have been told that competent key people are a crucial difference between a profit and a loss. This is discussed in more detail in Section 15. However, the value of this resource is illustrated by another incident. At a bid opening, the second bid of $15,000,000 was substantially higher than the low bid of $13,500,000. Competitors' initial reactions were that the low bidder would lose his shirt. On second thought they concluded that he probably would either break even or have a small profit or loss.

There were two principal considerations in this conclusion:

a. The particular project boss involved was worth about a million dollars on a job like that one,

b. They were reasonably certain the winning contractor owned all the equipment from a prior job. The value of fully depreciated equipment is discussed later.

TUNNELING IS AN INDUSTRY WITH FEW ORDERS EACH YEAR

The conventional businessman, with a flow of orders every month, can't understand the pressures on a tunnel contractor who may have from one to a half dozen orders (awards of business) for a full year.

These contractors are closer in flow-of-business patterns to the aircraft or armaments manufacturers. At the beginning of this study we wondered, as did others, whether there might come a time in the transportation industry when construction people would be responding to owners like the car builders.

For example, in February 1976 Atlanta's MARTA had delayed from February 12 to March 17 the scheduled opening of bids for its program of 100 rapid transit cars. Rohr Industries, builder of transit cars for BART and WMATA complained of "increasingly unreasonable risks" and said it wouldn't bid. Boeing Vertol, builder of light rail vehicles for San Francisco and Boston, wasn't bidding and cited "unacceptable risks". Pullman-Standard, completing a car order for New York, won't bid and General Steel's St. Louis Car division withdrew from the business. General Electric Company's "final decision hasn't been made". Bidding systems don't function as planned with only one bidder.

Could this situation repeat itself on the construction side? After all, the cars are only a small part of a transit system's cost. The construction accounts for 75% or more of the cost of most systems. Our conclusion is that there is no danger of a similar problem despite the similarity of major projects, orders, enormous risks, etc., between these businesses. The differences are in the mix of business, mobility, development investment and rate of technological advance.

This phenomenon of few new orders (awards) for tunnels in a given year is a main explanation as to why most such construction firms have other specialties. Most are in several lines of work within the heavy construction field and can employ their people, equipment and overhead support systems on various types of work in addition to tunnels. Also, unlike the car builders, the tunnel people have a portable manufacturing facility. They maintain few fixed facilities and mobilize on-site for each project.

Tunnel contractors don't spend money on research or development as they can't amortize that investment over a number of jobs or gain a competitive advantage that can be held for some time. They don't push technological change since it increases their risks without markedly increasing their rewards (see Section 16). Profit improvement through cost reduction doesn't provide the same opportunity to a tunnel contractor that it does to a goods maker. Ford Motor Company executives used to point out that a saving of $1.00 per car in costs, applied to all their cars, amounts to $3,000,000 a year. These economics don't apply in tunnels.

MANAGEMENT SKILLS

Running a tunnel building job properly calls for leadership, technical knowhow, a sense of timing and momentum, and a firm set of controls. If a contractor lacks these, even a good bid won't make him profitable. An example of this is the veteran tunnel project boss who decided to go into business for himself and won a hard-rock job.

One of the time-consuming and costly tasks in tunnel excavation is returning to a previously blasted area to remove "tights". These are areas where rock protrudes from the wall and the required clear diameter isn't achieved or, if it is, the protruding "tight" will result in the concrete lining being thinner than planned.

The new contractor's operating experience had demonstrated conclusively that good progress in feet-per-day usually led to good operating results. Accordingly he instructed his people to blast away and move as fast as they could.

The contractor's people excavated three miles of tunnel in record time and with thorough professionalism. As a result of completing this job the contractor went broke and is now a project boss again for another contractor. What he had failed to take into account was that the enthusiastic blasting by his people had resulted in "overbreak" of two feet. That is, his twelve-foot diameter tunnel required a space fourteen feet wide so the one-foot concrete lining on both sides could be installed. His people had two feet of overbreak. They had blasted it sixteen feet wide, avoiding all the need to go back and clean up "tights".

However, his contract was for a twelve foot tunnel and minimum one foot concrete liner on all sides. So, he had to pour more than twice as much concrete, use extra labor to do it, and got the job off schedule. The resulting $600,000 loss cleaned him out. An old tunnel-builder's rule-of-thumb is "10% overbreak increases concrete needs by 50%".

The work environment of a tunnel is such that any loss of schedule becomes a remorseless domino-effect problem. For example, in the overbreak problem cited above, the contractor's plan called for 100 feet of lining per day to be poured. The first two shifts of people working would set up the forms and the third shift would pour. When it became necessary to pour twice as much concrete to fill the cavity that was too large for the specifications, the third shift crew could only do eighty feet per day.

This got the whole job out of synchronization. The short-fall of twenty feet per day dominoed along the 15,000 feet of tunnel, creating havoc with the interlocked schedules of the various crews. Labor and material costs escalated; overhead remained the same, and the difference came out of profit.

A building contractor or road builder who runs into a problem can have someone work on it while the main force moves on with the job. The builder's crews can be on another side of the building or on another floor. The road crews can work a half-mile ahead. Tunnel contractors must work around their repair or rework crews, twenty or more feet underground, in a space twelve to thirty feet wide that's filled with workers and equipment. Errors and trouble are much more costly.

CONTROLS

Other contributors to poor profits or to losses are gaps in controls. Instructions To Auditors, an internal publication of a national accounting firm, warns auditors to look for:

1. Failure to periodically evaluate contract profitability on a realistic basis.
2. Inadequate control over estimating and bidding on new contracts.
3. Inadequate contract cost records.
4. Weakness in billing procedures.
5. Inadequate control of construction equipment.
6. Lack of adequate cost records on equipment.
7. Poor control of job site payroll.
8. Poor control of disbursements.

All of the firms we interviewed in depth have fairly tight control systems, though there have been gaps which led to hugh losses on some projects. The professionally managed firms protect themselves with checkpoints, systems and reviews. The family controlled firms have limits beyond which all key family members must be involved as a control.

NEED FOR FINANCIAL MANAGEMENT SKILLS

The management executive in any construction firm has to be aware of the interactions of time, cash, costs and risk. His variable costs are generally tied to project field costs. His administrative or overhead costs have a high percentage of fixed or period cost. With fixed costs related heavily to time periods, while variable costs relate to job performance and revenues, the operating skill is to keep enough jobs moving in each time period to prevent the fixed costs from eating up the job profits.

On the financial side, the highest skills are to turn the fixed costs into variables, as discussed below, and to maximize cash flow. This is what makes unbalanced bidding an every day occurrence and leads contractors to insist on amortizing their fixed equipment costs on a single job, so they'll be variable costs the next time around.

In the process-plant side of heavy construction, contractors have improved their profits and reduced their risk by pulling out of fixed-price work. They have an advantage over their tunnel-building brethren in usually having patented processes to license as part of the project. One firm's president says of process jobs, "with the end of fixed-price contracts, the risk-reward ratio of the business has altered". Their return on investment for construction is about 85%, using about 15% of the firm's capital and providing 28% of its profits. A number of the heavy constructors build process plants, and heavy jobs like tunnels.

IMPORTANCE OF EQUIPMENT DEPRECIATION

Contract costs include depreciation expense for equipment used on the job (or lease expense with the lessor providing for depreciation in his price). Most contractors attempt to depreciate equipment over the life of a job unless it's a short job. Two or three year depreciation schedules are considered desirable. In cases where fully depreciated equipment is owned, it can be redepreciated against another contract. This can result in extra income, provide a cushion for risk losses, or put a contractor in a position to submit a lower bid while retaining a normal profit.

Thus, control of fully depreciated equipment gives contractors a power position competitively. It also accomplishes the vital task of turning a huge fixed cost (equipment purchase) into a variable cost and profit source. This result sometimes is accomplished by sale of the asset to a related or unrelated company for lease-back. The rationale behind this was that "if a company didn't have equipment, they'd have to go out and buy or lease it, in which case an expense for its cost would be charged against the contract".

The use of fully depreciated equipment allows a contractor to leverage assets and maximize profitability. He has the opportunity to build into his bidding the cost of equipment that will actually incur minimal costs (maintenance and damages). The most profitable company visited, with a return on sales in the range of 9%, shows only about 10% of its total assets commited to fixed assets. However, further examination showed that depreciation already taken on those assets is an additional 34% of total assets. This indicates an equipment availability and commitment in the upper percentage range of total assets of the ten companies studied.

PROFITS AND LOSSES AMONG JOBS

The only specific profit or loss histories available on a range of jobs was for an eastern U. S. building contractor. This is included as Exhibit 14-A to illustrate the swings in profit and loss with which contractors routinely contend, even when well managed.

Exhibit 14-A PROFIT STATUS OF JOBS UNDER CONSTRUCTION

Job No.	Original Contract Amount*	Revised Contract Amount	Original Profit Estimate	Current Profit Estimate	Percent of Job Complete
1	5,225	6,987	96.3	275.	88%
2	6,648	7,645	429.7	365.	90%
3	3,740	4,015	150.	215.	100%
4	2,300	1,815	100.	100.	100%
5	10,745	11,073	400.	-557	48%
6	1,341	1,339	30.2	-7	100%
7	1,922	1,685	65	-14.7	100%
8	10,935	10,936	1,000.	12.9	44%
9	2,046	3,693	47.5	47	100%
10	4,777	5,357	145.	-53	85%
11	834	832	47	47	100%
12	3,594	3,658	150	150	84%
13	3,493	349	19	25.5	99%
14	6,695	6,806	175	245	70%
15	3,500	3,500	140	140	22%
16	6,227	6,227	225	255	1%
17	1,932	1,227	100	100	1%
18	3,547	3,547	82.5	100.5	23%

***($000 omitted) Data based on an eastern U.S. building contractor.**

TEN COMPANIES EXAMINED

The same ten companies examined earlier were studied to compare their financial ratios, strength and profitability. The use of ratios in the accompanying table, instead of gross dollar amounts, makes valid comparisons easier. For example, the ratio of Cash and Marketable Securities to Current Assets shows that the samller private companies, Private #1 and #2, have significantly higher ratios (.667 and .220) than the larger private companies, the public companies and the conglomerates.

We conclude that they tend to keep more cash on hand because of the difficulty of obtaining short term loans, and because of their smaller cash flow.

Exhibit 14-B COMPARATIVE FINANCIAL RATIOS

	PRIVATE				PUBLIC			CONGLOMERATE		
	#1	#2	#3	#4	#1	#2	#3	#1	#2	#3
Current Assets/Total Assets	.896	.543	.644	.824	.444	.557	.540	.373	.782	.491
Current Liabilities/Total Liabilities	.229	.252	.363	.364	.338	.305	.356	.265	.475	.276
Current Assets/Current Liabilities	3.900	2.153	1.712	2.266	1.314	1.106	1.516	1.409	1.646	1.778
Cash + Mkt. Sec. to Current Assets	.667	.220	.157	.023	.190	.057	.030	.067	.096	.125
A/R to Current Assets	.333	.779	.688	.517	.490	.534	.667	.552	.137	.516
Inv/WIP to Current Assets	-	-	.047	.264	.293	.238	.189	.259	.699	.359
Equipment + FA/Total Assets	.103	.331	.326	.155	.499	.194	.401	.275	.157	.386
Equipment + FA/Long Term Debt	-	-	1.321	.647	5.692	.974	1.616	.780	.364	3.001
Equipment + FA/Net Worth	.134	.443	1.234	.618	.989	.659	1.175	.872	9.706	.689
Current Assets/Net Worth	1.164	.727	2.439	3.293	.881	1.923	1.583	1.183	48.215	.877
A/R to Long Term Debt	-	-	1.797	1.750	2.484	1.520	1.452	.584	6.600	1.969
NET WORTH	B	A	B	C	C	C	D	D	C	E
TOTAL REVENUES	B	A	C	D	D	E	E	E	F	F
% Revenues - Tunnels	95%	95%	20%	20%	18%			1.5%	.03%	7%
Profitability - % of Revenues	9%	(-3%)	6%	.6%	3.8%	1.405%	1.984%	5.8%	.007%	4.719%

NET WORTH AND REVENUE RANGE CATEGORIES:

A - 0 - 3,000,000
B - 3,000,000 to 10,000,000
C - 10,000,000 to 100,000,000
D - 100,000,000 to 500,000,000
E - 500,000,000 to 1 Billion
F - 1 Billion to 5 Billion

Meaningful comparisons between various companies meant that "generally accepted accounting principles" acquired several interpretations. The most consistent use of accounting principles was found in joint venture companies, since the joint venture agreement was often reviewed by two separate public accounting firms.

They tend to be more consistent with respect to the work undertaken by the parties to the agreement, the method used by each in charging contract costs to the venture, the method of accounting for contract profits and losses, division of the profits and losses between the participants and other areas of financial control.

A small private contractor using a specific method of depreciation of an asset might affect 10% total net profit, while a large conglomerate using the same method for the exact same asset might show a net effect on earnings of less than .0001%. The public accounting firms were more stringent with small private and public companies than they appear to be with large public companies. Their tendency not to require the larger firms to disclose or clarify certain information on the grounds that was not "materially significant" compounded our problem in developing consistent comparisons.

HIGHER LEVEL CONTROL HELPS PROFITS

Profitability frequently can be related to the level of decision making and the criteria of decision making (as shown in Exhibit 14-B). Also of interest:

1. The two small private companies in addition to having a high Cash to Current Asset ratio are also free of long term debt.

2. In all but one company, a combination of the ratio of Fixed Assets & Accounts Receivable to Long Term Debt is better than 2:1.

3. In all ten companies, net worth is relatively liquid. In 7 out of 10 cases the ratio of Current Assets to Net Worth is better than 1:1. In the three cases where it is below 1:1, none are lower than 7:10.

4. Those companies with higher Accounts Receivable to Long Term Debt record their revenues and profitability differently (presumably for stock market purposes) which probably results in a longer collection period of the work-in-process inventory billed, and billed accounts receivable which are not yet due.

CONCLUSIONS

1. Most of the companies have access to large pools of capital when required. Financial availability of capital to undertake tunnel work is generally not a problem, and in those cases where it might be, a joint venture is created to handle the job. Mobilization clauses also minimize the need for capital.

2. Increasing financial strength, even for the smallest companies, appears to be a partial result of probing from auditors and bonding companies, who are requiring more detailed, comparable historical data before issuing a bond.

3. Higher levels of decision making on whether to bid a job, and in supervising it, are directly related to the ultimate profitability of tunnel contractors.

4. The demand that contractors face is for a small number of very large jobs each year. This, plus the inherent risk in the industry, means that the contractor can't apply all of the cost management approaches that most manufacturers can.

5. Despite careful screening during the bidding phase, the profitability of a job contains a large degree of uncertainty. The rigid work cycle followed in a tunnel job will magnify any work description that occurs.

6. Inclusion of an exceptional project manager is thought to strongly affect profitability, probably because of his control over daily costs and rate-of-progress, and his ability to attract talented staff members.

7. Most of the firms have been in business for over twenty years. Entry into the industry is not easy for new companies, with many failing after one or two jobs. Most of the firms are old firms dating back to the late 19th and early 20th century. Survival in the industry calls for well established, financially strong companies, with continuity of experienced people.

8. The number of projects available to bid may not affect the number of projects bid by the companies. With manpower availability and competence a critical factor and with the desire to limit tunnel work to a specific percentage of total volume, increasing demand may not be absorbed by qualified contractors.

9. R & D is impractical for individual contractors because they can't gain enough competitive advantage and they can't recoup enough profit for their investment.

10. A sophisticated construction contracting firm is able to use its investment in major equipment to great financial advantage.

11. There is a tendency for the smaller private companies to want to "go public" or to be acquired by a conglomerate. Of the small public companies contacted, most indicated that they felt either alternative strengthened a company's ability to take on additional work in tunneling and heavy construction. Estate taxes are the big force here.

Chapter 15

PEOPLE IN THE TUNNEL INDUSTRY

Tunnel industry people are a colorful lot. They've developed a camaradarie like that frequently visible among groups of people in other high-risk occupations (bridge-builders, fighter pilots, stage and screen actors, and elected politicians). Most learn how to balance the risks and rewards of the career. Among such occupational groups, history shows that there is a substantial exodus from this work as people get older. By the time an individual is in his thirties, the risk-reward relationship and the effects of the job on family life cause many to choose other work.

Those who remain in tunnel or other heavy construction work after their first decade of employment have a high tendency to stay with it all the way. The level of satisfaction of personal needs for achievement, power, affiliation, recognition, money, etc., is, for them, superior to, or at least no worse than other alternatives. This is in the face of a continuous exposure to serious injury or death risks while in the field. The rule-of-thumb in 1975 for tunnel builders is still two deaths per mile of job.

Like the other high-risk occupation groups, tunnel people have their own terms for each other. Career tunnel specialists are referred to as "tunnel stiffs". The widely used term "sand hogs" originally referred to the people working at or near the tunnel facings in compressed air excavation work.

The high mobility of the work (moving from project to project) further tends to bind the people to the industry rather than to the community in which they happen to be housed. Much of their social life is industry-related. Major events in a project are traditionally celebrated with a party. One example is the "holing through" affairs held when a tunnel is broken through at its distant end.

Communication among people in tunneling is maintained via business, social and professional organizations and an important part is played by suppliers. At the management and professional levels three organizations have emerged which are essentially social groups but provide an opportunity for informal contacts, recruiting, establishment of joint ventures, and the maintenance of tribal customs. Largest and oldest of these is The Moles, a 648 member group founded in New York in 1938. Its winter dinners and summer clambakes are widely known and well attended.

Though The Moles originally intended to have a professional-social organization, the evolution has been business-social. Contractors, consulting engineers, insurance and supply executives, owners and public officials are the participants at these gatherings. Midwestern activity is centered in Chicago with a similar organization called The Groundhogs, which dates from about 1940. On the West Coast this function is served by The Beavers, which group was organized after World War II. Between meetings, industry people rely on newsletters like that published by Gardner-Denver's Jack Burke and the bidding information bulletins published by Hercules, Inc.

PROFESSIONAL ORGANIZATIONS AND PUBLICATIONS

Engineers in tunnel work for the most part rely on ASCE (The American Society of Civil Engineers) for professional representation and leadership. A lesser number are members of the American Institute of Mining Engineers (AIME) reflecting collateral interests. These two organizations jointly sponsor the Rapid Excavation & Tunneling Conferences. ASCE's Underground Construction Research Council has both hard rock and soft ground activities.

Continuing and ad hoc groups are common in tunneling as in other fields. Presently being organized is the American Underground Association which has announced plans to publish a journal similar to the best known and widely respected British periodical Tunnels and Tunnelling. Established groups include the International Tunneling Association, U. S. National Committee on Tunneling Technology, UCRC, and Transportation Research Board.

The people who design and build tunnels can be classified by type of work and general motivation. They are engineering professionals, heavy construction professionals, tunnel specialists, and craftsmen or laborers. Engineering professionals working in tunnels may be employees of design, inspection or management firms or of contractors. Their general specialty is civil engineering. After their early career years they will usually progress into office engineering, field supervision, or a definite specialty area.

Heavy construction professionals include engineers, managers, craft specialists, and laborers who have chosen heavy construction as their work and main income source. Over the several decades of a career they will have worked on a variety of projects including some tunnels. The shifts from job to job sometimes reflect the basic need for steady work and sometimes are more related to the distance one is willing to go to be on a job. Many of these jobs are in international locations. This group tends to be employed by large, diversified, heavy construction firms or to have a key spot in a smaller firm.

Tunnel specialists are those engineers, builders, craftsmen and laborers who prefer tunnel work to all other forms of employment. To obtain their chosen type of work they will move to a distant location, suffer personal inconvenience or hardship, endure fairly long layoffs between jobs while kept on partial pay, etc. Generally, they work for tunnel specialty contracting firms; to a lesser degree for tunnel specialty engineers. The fourth group - craftsmen and laborers working on tunnels - is made up of people who prefer a given locality for lifetime residence. They will take any work their skills qualify them for: tunnels, dams, roads, buildings or plant maintenance. A significant number of them have job mobility limits because of their union membership and local labor contract conditions.

NUMBER OF TUNNEL SPECIALISTS

About 700 tunnel specialists are reported by the forty-one engineering firms surveyed. Since there is every indication that these firms are generous in definitions of capability, there are probably 200 real tunnel design and inspection specialists in the United States. At the other extreme, nearly 2,000 people are employed on tunnel projects by engineers and construction managers. However, the majority are doing general engineering that happens to be on a tunnel project.

Contractors interviewed reported nearly 1500 people on their tunnel staffs in 1975, which was more than double the 647 reported as on their staffs in 1965. However, there are large differences in definition of "tunnel staff" which were not controllable by the project investigators. Also, the 1965 numbers were provided in 1975, in most cases, from memory rather than from company records. Contractors report 537 of these people as rock tunnel specialists versus 251 in 1965. Rock tunnel people reportedly have (roughly) doubled in number while soft ground specialists showed a reported 150% increase. This appears valid since so much of the current work is cut-and-cover tunnel construction.

QUALIFICATIONS AND EXPERIENCE

Those people who will hold the key jobs (defined below) increasingly have more formal education. The preferred background is a B. S. in civil engineering, or an approximate equivalent. Industry engineering and contracting firms prefer that the young graduate obtain some field experience before going on to advanced education. Engineering faculty people generally advise continuous graduate education after the receipt of the bachelor's degree.

On the contractor side of the business, additional qualifications for young engineers who wish to advance in the project management area involve management and leadership skills. Financial management and cost control procedures are very important and are learned in junior project jobs and in work on estimates and bid preparation.

Today's boss commands a relatively orderly work force and the project manager for a large firm, if he is under 40, probably has a master's degree as well as extensive field experience and industry contacts. He still is likely to be physically large, as were the tunnel bosses of the last generation. They had less formal education and a lot rougher work force to manage. Many had to carry guns and one man, now in his fifties, recalls a job where nearly all of his laborers were ex-convicts.

EXHIBIT 15-A

KEY TUNNEL INDUSTRY PERSONNEL

ENGINEERING FIRM		CONSTRUCTION CONTRACTOR	
Office	Project	Office	Project
Vice-President	Proj. Mgr.	Vice-President	Project Mgr.
Chief Engineer	Proj. Engr.	Chief Estimator	Project Engr.
Group Leaders	Resident Engr.	Purchasing	Genl. Supt.
		Financial	Asst. Supts.

Source: Cresheim Company Interviews, 1975.

For all of these key people, experience is much more important than is formal education. This experience has to involve a rising level of responsibility and accomplishment and takes a long time to acquire. Even in an industry which has enjoyed considerable growth in the last fifteen years, it is rare to find a project manager who is less than forty years old. Most are in the age range 45-65.

As a young executive acquires accomplishments and success, he also attracts the attention of others who would like to have him help on their projects or of juniors who would like to work for him. The high industry mobility makes this characteristic an asset for the tunnel executive. If he is offered the opportunity to manage a job and can put together a management team of people largely known to him, that job has a substantial tactical advantage. This fact is consciously reflected in bidding and bonding decisions.

An initial concern in this project was whether or not the recent explosive growth in mining (especially of coal) would draw off manpower needed in tunnel work, or whether an increase in tunnel construction would impair the energy programs. Apparently there is no need for concern there. Tunnel people are civil engineers and their labor market is heavy construction, including process plant construction which is very active now and is expected to be for some years hence. Mining people work in a different environment. For example, a seven foot diameter tunnel is regarded as quite small, whereas coal tunnels may be only 30" to 48" high. Only nine engineering and contracting firms of 146 interviewed reported hiring graduates of recognized schools of mining engineering.

COMPENSATION

The key people on the tunnel projects are well paid. Their salaries, fringe benefits and bonuses are competitive with those in other heavy construction work. At the lower levels, engineering salaries are based on going market rates for supply and demand. For supervisory people, the upward push of union wages is a key factor in their pay adjustments.

At senior levels compensation relates to the value of one's contribution. For the large firm (publicly owned) executives there are good bonuses and eligibility for stock options. In the smaller firms, executives usually are owners or have incentive compensation arrangements.

The only manpower constraint visible at this time or in the near future is that it is not easy to quickly expand the number of project managers and key personnel. Responsibility for a large tunnel project is a truly awesome assignment, and one not easily handed along to anyone. Once a project manager has won his spurs, he will be able to work as long as there is work. Presently there are at least three project managers in their seventies at work. Two of them are actually overseeing younger men who haven't fully proved themselves. And, in 1975, one project manager in active charge of a job in the northeastern U. S. was ninety-two years old.

SOURCES OF KEY PEOPLE AND INDUSTRY EDUCATION

Engineers come from a wide variety of schools (see Appendix G). At the craft levels, most entry is through apprenticeship programs. The pattern of acquisition of people by firms or of jobs by people is best described as opportunistic. Few of the firms have organized recruiting programs. Informal networks of contacts, "walk-ins", word-of-mouth and pure chance are the most common descriptions that were given on how this aspect of the industry operates.

University education is fairly severely criticized by practitioners and vigorously defended by the faculty members. It appears that the faculty direction is toward more graduate education and the practitioners agree with this but prefer it after field experience and probably as part of engineering continuing education. The several special area committees of the engineering societies which are involved in underground construction maintain liaison and a lobbying effort with the appropriate faculty members.

Apprenticeship programs generally are operated by regional or local industry advancement groups. These are joint contractor-union committees with permanent staffs. Their functions include apprenticeship training (cooperatively with the Bureau of Apprentice Training, U. S. Dept. of Labor), management and supervisory development (generally continuing education), provision of assistance to vocational-technical and secondary schools, and industry public relations work. These projects are financed by payroll levies which vary from area to area. Two or three cents per hour for all labor payrolls is a fairly common funding arrangement.

Within allied industries, like suppliers of equipment and services, there are also people who become tunnel specialists. This is also true of owner staffs and these needs provide opportunity for job mobility, or to settle down geographically, or to advance in a different direction while remaining in one's chosen industry.

Exhibit 15-B

IMPORTANT FACTORS IN KEY PERSONNEL PERFORMANCE

ENGINEERING FIRMS IN TUNNELING WORK

KEY JOB	DESIRED RESULTS	REQUIREMENTS & RELATIONSHIPS	MEASUREMENTS
Vice Pres.	Maximize profit and enhance firm's name.	Prime mover on sales efforts Handle contact with senior Client people. Technical degree & P.E. license. Convivial. Reports to chief executive.	Gross Sales Net profits Repeat business. Lack of problems.
Chief Engr.	Drawings & specifications technically okay. Expenses in control.	Have sufficient and appropriate staff. Official signer and sealer of drawings. Technical degree & P.E. license. Executive ability to manage diverse tech group. Reports to company Vice-Pres.	No manpower shortages. No cost overruns due to overstaffing. No errors or omissions on drawings or specifications.
Dept. Head or Group Leader	Proper design criteria standards and procedures. Correct drawings & specs for his discipline.	Review drawings & specs. Assign engineers, technicians or draftsmen to projects. Train people. Handle special problems. Highly qualified in field. Degree and P.E. license usually.	No technical problems. No manpower shortages on projects. No errors or omissions.
Proj. Mgr.	Complete project on time & budget	Obtain scope of work changes Attend all job meetings & owner meetings. 10 yrs field exper. as engineer or supt. in underground construction. Ability to manage diverse people. Technical or business background. Contract, cost & labor knowhow vital. Reports to V. P.	% completion vs. time. % completion vs. $ Client satisfaction.
Proj. Engr.	Design completed on time and within budget.	Drawings to conform to needs Manhour & budget schedules. Progress reports. Transmittal of shop drawings. Technical liaison with owner & contractor. B.S. in civil or mining engineering. P.E. license, local registration. Cost, contract & negotiating knowledge. Reports to chief engineer and to project manager. Directs engineers & technicians.	% design completion vs. time and money minimum misunderstandings from drawings and specifications. Has control of design effort.
Res. Engr.	Construction conforms to drawings and specs.	Assured drawings and specs followed <u>during</u> construction. Responsible for measurement of material quantities to be paid for on unit price basis. Monitors contractor progress, detailed construction know how is mandatory. Knowledge of design procedures. Reports to Project Manager. Manages engineers and inspectors	Proper performance of final product. Fair unit price to contractor. No structural or other failures during construction.

CHANGES IN MANAGEMENT EMPHASIS

Exhibit 15-B illustrates the degree to which management skills emerge as more important to key people in engineering firms than their technical skills in many aspects of their work. This has long been true for large jobs or large firms. The big change in recent years has been that, while the management art itself is more complex, and the jobs have increased greatly in size, even smaller firms get caught up in complex management tasks through their roles as subcontractors or joint venturers.

In construction contractor firms, the major changes at the project management and company key executive level have to do with increased management skills. Planning and estimating are more complex because of the size of the jobs and the web of relationships. Requirements for sophisticated financial skills, a real understanding of the intricacies of cash flow, escalation clauses, and the like, continue to grow.

Presently the same uncomfortable blend of old style and new, of art and science, which characterizes manufacturing firm managements is also present in heavy construction firms. As one tunnel firm vice-president describes it, "When my whiz kids finish up with their computers, I still have to sit in my office and decide how much to add to a bid to allow for risk and how much to subtract for competition." Thus, the long-experience judgment development cycle will continue. No evidence exists that this can be shortened substantially.

THE PROJECT MANAGER IS <u>THE</u> KEY MAN

Among all the key people listed, the project manager is <u>the</u> key man after a job has been obtained. All available evidence suggests that the good project managers will continue to be in limited supply and relatively mobile. Having such people is critical to a firm's ability to bid a job and complete it successfully so that the project manager group is the most sensitive to any increases in demand in the industry.

Usually after five to ten years of experience, engineers begin to make their key career directional decision as to whether they will be technical or management people in the industry. Of course, the job requirements are such that the decision may be made for them by their employers.

Those who elect to follow the management route can benefit in today's environment from a strong continuing education program but, for project managers, this has to occur before they take on the consuming task of a large, lengthy project. A year of graduate school with management and technical content would be well timed for the management oriented engineer in his thirties. Limited program opportunities exist, but the financing of school for a year for a 34 year old with a family to support, remains a formidable problem.

CONCLUSIONS

1. Technical people in the tunneling industry form a strong identification with it. The good ones are known and are sought after for major jobs. Recognition comes about only as a result of successful on-site management.

2. There is job transfer between firms and exchange of technical information at a personal, rather than a corporate, level.

3. The key positions under President all require a long apprenticeship on the job. Academic or general business experience is relatively less important. Running a tunnel job successfully requires leadership, technical expertise, a sense of timing, and good cost controls. Many of these skills are peculiar to the individual or are acquired on-the-job.

4. At the present time, the normal construction engineer career ladder consists of (1) Entry, requiring a B. S. at most, (2) Technical Management, requiring an M. S. at most but usually based on successful job performance, and (3) Financial Management, requiring no new degrees but instead gradual experience in cost control and financial planning as a Project Manager.

5. Non-key personnel can be selected from practically any group of engineering graduates. A good general background is all that is required for entry.

6. There is no capacity constraint foreseeable in tunnel construction due to manpower supply or demand. Sufficient people exist to staff the key jobs though there is always a need for better project managers as jobs grow larger. In the non-key jobs it is possible to have shortages due to competing non-tunnel projects in the local area. (Example: New York City and the World Trade Center project.)

Chapter 16

Risk And Resources

INNOVATION, TECHNOLOGICAL CHANGE, ENTRY AND DEPARTURE

The tunneling industry is accused from time to time of being unreceptive to innovation or to technological change. We don't think the industry is unreceptive, but its slow acceptance rate appears to be related to risk-reward relationships.

In those aspects of tunnel construction where there is little risk, any normal reward seems to lead to innovation. The usual stimuli are improved productivity, the saving of time, or increased profit. If we take a seventy-five year view (since the turn of the century), we see many changes: concrete has replaced brick and stone in materials; drill jumbos and tunnel-boring machines have improved excavation; locomotives and trucks have replaced animals for hauling; front-end loaders have replaced shovels; computers now aid timekeepers; and much more is known about geology, costs, labor safety, etc.

This rate of change is nowhere near as dramatic as that in aviation or data processing, for example. We believe that the risk-reward relationship mentioned above is the controlling factor. Any owner, engineer or builder associated with a tunnel is bound to feel some kinship with the Romans building aqueducts or with Julius Caesar and his much earlier version of the Interstate Highways. A tunnel is not a throw-away product like a building built to last for thirty years. With apologies to the DeBeers diamond people: a tunnel is forever.

Nearly every tunnel built in the United States in the twentieth century is still in use, as are many of the unlined tunnels built in the nineteenth century. There is every reason to believe that most of them will be in use a century from now. They are built to last. If they fail, the design engineer is discredited professionally forever, and the contractor will be ruined financially. That means a "wait and see" predisposition affecting anything impinging on a high-risk aspect of the tunnel.

Steel is known to corrode so conservative tunnel builders are wary of steel reinforcing in concrete. How long will it last? It can't be inspected from inside the concrete. One can take a small risk with something that is easily inspected. Concrete can crack or leak water so there has been a strong tendency to stay with metal linings for rapid transit tunnels involving electricity in the third rails. A computer estimate might overlook something big, result in a major bidding error, and wreck the company. So when computers are used, a manual bid usually is also prepared.

Thus, risks clearly remove some incentives to innovate. At the same time, the nature of the industry limits the rewards available to an innovator. A contractor developing a new construction method usually can't get enough protection of the idea for a long enough time to gain a windfall profit of the capital-gains magnitude that inspires inventors. Equipment advances, which might be protected by patents, affect too small a market to enrich anyone. Engineering ideas become general property fairly quickly.

INNOVATION FROM OUTSIDE THE INDUSTRY

It is an accepted axiom among management consultants that most change in an industry or organization is imposed by market forces. Much of the change that has occurred in the tunnel industry involving productivity or new technology fits that rule-of-thumb. People with equipment or services to sell quickly learn of the vast size of the construction industry. Many of those goods and services suitable for general heavy construction firms have an economic appeal to firms involved in tunnel construction. Two large companies supplying special products to the tunnel industry were interviewed. In both cases, the percentage of their sales of products was relatively small in the tunnel industry (less than 2% and 5% respectively). One company manufactures mining and tunnel contracting machinery, while the other manufactures drilling equipment, including a number of expendable products. In the latter case, there is a great deal of interchangeability of sales with the petroleum drilling industry, and products were being designed primarily for the petroleum industry, rather than the tunnel industry.

In the case of the supplier manufacturing tunnel boring equipment, it is apparent that tunneling is a small segment of total business, with little growth expectation. Relative profitability as compared with other products was lower, and the number of units produced is very low and cyclical. As a result, the representative of that manufacturer indicated he "saw no need for a company like us in the industry, since we're not close enough to it to make technological breakthroughs in new equipment unless they are brought to us." Generally, the breakthroughs come from smaller manufacturers, who are on the scene and may be involved in the job from other perspectives, like engineering.

The profitability of sales ranged from 10 to 13.5% pretax, with manufacturing costs rising over the last five years from 60 to 67%. Both companies declined to break down specific industry profitability.

There is a limited flow of ideas and suggestions from the universities except in areas of materials. When an idea has some appeal the inertia of the high risk-low reward usually prevents the contractor from embracing a major experiment. It seems to require either funding by a public agency as a demonstration project or sponsorship by an owner willing to assume the risk in lieu of the contractor. Two examples on the technology side support this view.

One technique advanced for soft ground excavation has been to freeze the soil during excavation, using a network of brine-filled pipes. It was anticipated that this would make possible a free-air job rather than a compressed-air job. It was also felt that this application would be successful for the long-term for underground storage sites in locations with marginal soils. One contractor using frozen ground in New York City to prevent use of compressed air was bankrupted when brine pipes burst, saturated the soil, and flooded the job. A New Jersey public utility built a large underground LNG gas storage facility using frozen ground but had to abandon it after three years because of seepage. (There are instances of successful use of this technique.)

A persistent mystery is the known American resistance to the use in rapid transit tunnels of precast concrete linings. These are widely used in water transmission tunnels. Further, they have been used for over thirty years in tunnels of London Transport. Why are they not used here? Extensive checking and following-down of leads to decision makers led to the conclusion that there is no incentive for owners, engineers or contractors to use this, even though it would be cheaper. The owner has a relatively fixed budget and can't use funds saved here for other purposes. Engineers, facing increasing errors and omissions hazards have no offsetting reward for specifying concrete. Contractors have to bid on what is specified. In nearly every case they may not introduce bids for alternate designs or materials.

The British deserve no credit as innovators on this one. They used concrete because they were unable to get steel immediately after World War II. However, change may occur in the U. S. as there is a plan to fund a demonstration section of Baltimore's rapid transit tunnels with a short length of precast concrete lining. That extra funding and risk assumption may start the innovation stream's flow.

Two additional factors appear to contribute to the lags in development of new techniques. Information dissemination is slow. Though there are meetings and publications and much job mobility, domestic firms (engineers and contractors) have little contact with foreign firms. Second, in an aspect of tunnel work where there <u>has</u> been a history of acceptance of change (tunnel boring machines) the delays in delivery are so long that numerous jobs on which moles might have been used are driven with long-standing drill-and-blast techniques. This is an example of a need for institutional innovation, which is discussed below.

CHANGES IN TUNNELING TECHNOLOGY

As part of the study of technological change, a three time-point review of industry practice was conducted. These aspects were reviewed to see what the practices were in 1925, 1950 and 1975: Drilling, explosives, hauling, lining, mucking, shields, and use of compressed air.

DRILLING. On the Moffat Tunnel in 1927 the chuck tenders had to put in a new piece of drill steel every time they had drilled two feet of hole. A piece of drill steel would drill two linear feet of rock before it had to be sent to the blacksmith's shop to be resharpened and retempered. On the Moffat Tunnel, they used drill columns and were drilling eight foot holes. The chuck tender put in the starter drill and the miner hand-cranked it into the hole. It was then cranked out of the hole, the four foot steel inserted, and the hole drilled another two feet. Thus, it took four pieces of steel to drill an eight foot hole. Since there were twenty-four holes in the face, ninety-six pieces of steel had to be sent out to the blacksmith's shop for resharpening.

Tungsten carbide was invented in Germany about 1922, brought to the United States about 1938, and was first used in machine shops for cutting steel. About 1942, it was introduced to rock drilling, first being used on boring machines for drilling oil wells. Probably in 1947, it was introduced to rock drills used in tunneling. Since a piece of drill steel with a carbide tip will drill about 1500 feet, thus eliminating the blacksmith's shop, it wasn't long before it was widely used.

With this new drill rod, the drill manufacturers quickly developed drill cradles with long strokes which could, in one setting, drill a hole 10 feet, 12 feet or even 16 feet. These were then mounted on hydraulic booms and thus the mechanized "drill jumbo", as we know it today, made its first appearance.

Tungsten carbide teeth made the tunnel boring machine possible and the history of that dates from the late Forties, with early machines initially built to aid coal mine productivity. TBMs in tunnels date from the early 1950s and their growth in use, as previously noted, is impeded by long delivery delays more than anything.

EXPLOSIVES. Black powder, used in nineteenth century tunnel construction, was superseded by dynamite about 1895. There has been a steady improvement in the efficiency of explosives but the last days of dynamite are nearing, after a seventy-five year dominance. Water gels are being phased in rapidly as its replacement. They are safer in handling, transportation and storage. They are low in gas. Performance can be varied by the use of additives and handling is much improved. For example, cartridges of gels of 1" diameter to 4-1/2" diameter can be shot into the drilled hole with an air gun. Or, it can be pumped into large holes if purchased in bulk.

HAULAGE. In 1923, on the Holland Tunnel, all the muck had to be hauled up hill. Battery locomotives were used right at the face, but from about 200 feet back from the face to the air locks, trolley locomotives were used. This meant that there was a 240 volt trolley wire about seven feet above the rail. This was a real hazard to the sandhogs working back in the tunnel using long wrenches or crowbars.

In 1925, in a Chicago tunnel, progress was fifteen feet per day, with two shifts devoted to mining and one shift to concreting the day's drive. Mules were used for haulage and that was common on all small tunnels of that day. Even on larger tunnels, where they used a locomotive, a mule was used to switch the empty car up to the face. A mule would become very efficient in this type of work and would stand aside to let a rolling car pass.

Railroad tunnels in the Thirties used steam locomotives for haulage during construction. On one job on which Bob Mayo worked in West Virginia in 1932, the tunnel objective was to double track a railroad main line. The coal smoke was unbearable. In an effort to deal with this, a gasoline locomotive was introduced. Without any scrubber, it emitted pure carbon monoxide. The people on the job made it known that they preferred coal smoke to carbon monoxide.

Today, battery locomotives are still used in small tunnels but on large jobs, diesel locomotives, equipped with BuMines approved scrubbers, are the common locomotion. These require additional ventilation of the tunnel, of course. On shorter tunnels, there is also extensive use of rubber-tired vehicles.

MUCKING. In small tunnels this was all done by hand until 1925. The exception was railroad tunnels through rock where the standard steam shovel was adapted by operating it by compressed air. About 1925, the Conway Mucker was developed for work in small tunnels. It was too expensive for most jobs. Hand mucking in a small rock tunnel was hard work. The muck was shot down onto steel plates known as "slick plates" where a gang of men shoveled it into cars. These were generally small and low cars.

About 1930, the EIMCO mucker was introduced. This was a small, low-cost and efficient muck operating by compressed air. It is still on the market and popular for both small and medium sized tunnels.

Today the muck produced from a mole (tunnel boring machine) is fed to a conveyor belt or to a train of cars. Where a mole is not in use, payloaders and conveyor systems and trains of mine cars are most common. However, soft sticky clay may require hand mucking. It is too sticky for the machine. A continuing operating problem is the interdependence of systems. The drilling cannot go faster than the mucking or the whole job will get out of synchronization.

SHIELDS. There have been no major improvements in shields in the 1925-75 period. There have been productivity improvements since modern high-pressure hydraulics permit use of jacks with smaller diameters. Shields are now all-welded.

TUNNEL LINING. There has been considerable conversion to concrete linings in tunnels for other than rapid transit uses, as discussed earlier. However, much of the San Francisco and Washington rapid transit systems was built with the same tunnel linings which were used in 1950, in 1925 and in 1900 for transit tunnels.

EXHIBIT 16-A

COMPARATIVE TUNNEL TECHNOLOGY USE

	1925	1950	1975
Drilling	Drill steel & blacksmiths	Drill Jumbos	Machines (moles)
Explosives	Dynamite	Improved Dynamite	Water Gels
Haulage Large Tunnels	Battery locos Trolleys	Battery locos Trolleys	Diesel locos Rubber tired
Haulage Small Tunnels	Mules	Battery locos	Battery locos Rubber tired
Mucking	Hand shovel	Mucking Machine & Train	Payloader & train Conveyor & train
Lining In Transit Tunnels	Cast Iron O'Rourke block	Cast Iron	Precast concrete segments, Cast Iron Fabricated Steel Pressed Steel Plates Ribs & Wood Lagging
Shields	Non-welded Large jacks	Non-welded Large jacks	Digger shield (backhoe), all welded High pressure hydraulics Smaller jacks

Source: Fifty Years of Tunneling, R. S. Mayo, unpublished manuscript.

USE OF COMPRESSED AIR. Mining by compressed air may have gone backwards. In 1925, tunnel bosses said that there was absolutely no danger in working under compressed air at pressures less than 15 psi. Many jobs used compressed air in those days even when it was not essential. The air served to support the ground and thus made the job safer. However, today's safety and labor regulations require very short work shifts and a medical lock (with medical lock attendant) even when the pressures are only 3 psi or 4 psi.

As a result of these high labor costs, owners and contractors look for every alternative to avoid the use of compressed air, even when it would be the safest method. Some of the alternatives used are: dewatering, chemical grout, and freezing. However, as with other things, the pendulum may begin to swing the other way again. At a fall 1975 conference in Milwaukee, Dr. Eric Kindwall, a distinguished specialist in Hyperbaric Medicine, commented that there was absolutely no danger in working in compressed air at pressures less than 12 psi (pounds per square inch).

CONTRACTOR INTEREST IS IN CHANGES IN CONTRACTING PRACTICES

American scholars, scientists, executives and bureaucrats tend to be somewhat enamoured with gadgetry and advanced systems, perhaps because of the solid record of success in certain sectors. The tunnel industry people, on the other hand, put much more stress on the need for economic innovation. Appendix F summarizes their comments on, among other things, research and development (innovation and technology) for the industry. Of 66 contractor executives who expressed wishes, 19 put greatest weight on changed conditions clauses for contracts and 18 wanted changes in the way geologic information is handled by owners and engineers. Full disclosure was as important to them as techniques for getting better geological data.

Technological innovation was important but somewhat lower. Sixteen contractors want better teeth for their moles; thirteen would like to find a way to combine primary and secondary tunnel linings. Clearly, many of the people interested in the advance of the industry have been focused on technology, which is a second level need, rather than on restructuring the economic relationships among tunnel project participants, which is a vital first level need.

ENTRY TO THE TUNNELING INDUSTRY

Contrary to the expectations of most observers with whom we talked at the outset of our study, there are few serious barriers to a determined entrant to the tunneling industry. Forty-one established firms have been active in tunnel work for more than ten years; 31 of them for over twenty years. However, eleven have come into the business during the last ten years. Here are the ways most commonly used.

JOINT VENTURE. An experienced contractor finds the key people needed to run a tunnel job and bids on the work with them as a joint venture. He provides the staff, support, equipment, and working capital. They provide specialized know-how and some working capital. Example: DiMambro-Majestic.

HIRE THE SPECIALISTS NEEDED. The key people required can be employed "on spec" to provide an in-house capability. This enables the firm to prepare a credible bid, obtain the bonding company's support, and go after some business.

SEEK SELECTIVE ENTRY. A number of sewer contractors bid on, and won, cut-and-cover jobs in MARTA and WMATA rapid transit projects though they had no prior tunnel-building experience as firms. The required skills are very similar. See examples in Appendix A.

ACQUIRE ANOTHER FIRM. An easy way to enter the industry is to acquire an existing firm which is ready to consider an acquisition or merger for its own objectives. See examples in Appendix C in the column Corporate Affiliations.

OBTAIN HELP FROM A SUPPLIER. The Insanna Corporation of Ohio is the leading example of this route. It obtained a job with the condition that a certain mole would be used. The skilled operators of the mole were furnished under contract by the manufacturer. (Unfortunately the firm went into reorganization).

Though these five entries to the tunneling industry have been identified, and all have been used in the last five years, the statement above that there are few serious barriers to entry cannot be taken literally. This is not a business which can be entered by a fellow just out of the Army with the help of a loan from the Small Business Administration. On the other hand, it is a far cry from trying to start a television network, a breakfast cereal company or automobile manufacturing.

DEPARTURE FROM THE INDUSTRY

Most departures involve disaster, either physical or financial or both. The major current example is the joint venture Water Tunnel Contractors, a six-firm team in New York. As a result of the stopping of that job, two firms have ceased operations, two larger diversified firms have taken writeoffs that are sizeable and two are licking their wounds.

On Page 10-8 is a list of old, well-known firms that have either gone out of business or have voluntarily left the industry. There are other, lesser-known firms which have disappeared, of course. Some withdrew because the work in their area dried up and they didn't want to expand geographically. Some were drawn into other things and have been fully occupied with them (Mason & Hanger), while others remain in construction, but avoid tunnels (J. G. White, A. C. Guthrie). Financial failure and lack of provision for management succession appear to be the leading factors for loss of firms from the industry.

CONCLUSIONS

1. The profit incentives in tunneling do not encourage broad innovation by individual owners, engineers, or contractors.

2. There is little or no incentive to take a risk on an unknown supply item or procedure. The reward, if any, is small, but the costs associated with failure are known and feared.

3. The market for most specialized suppliers is too small and too unstable to encourage innovation.

4. Contractors are highly concerned with institutional relationship.

5. Basic tunneling technology in the U. S. has changed relatively little in the last generation: examples -- TBM's, ground stabilization, and high pressure hydraulics.

6. New entry is feasible in the industry but the rate of failures is high.

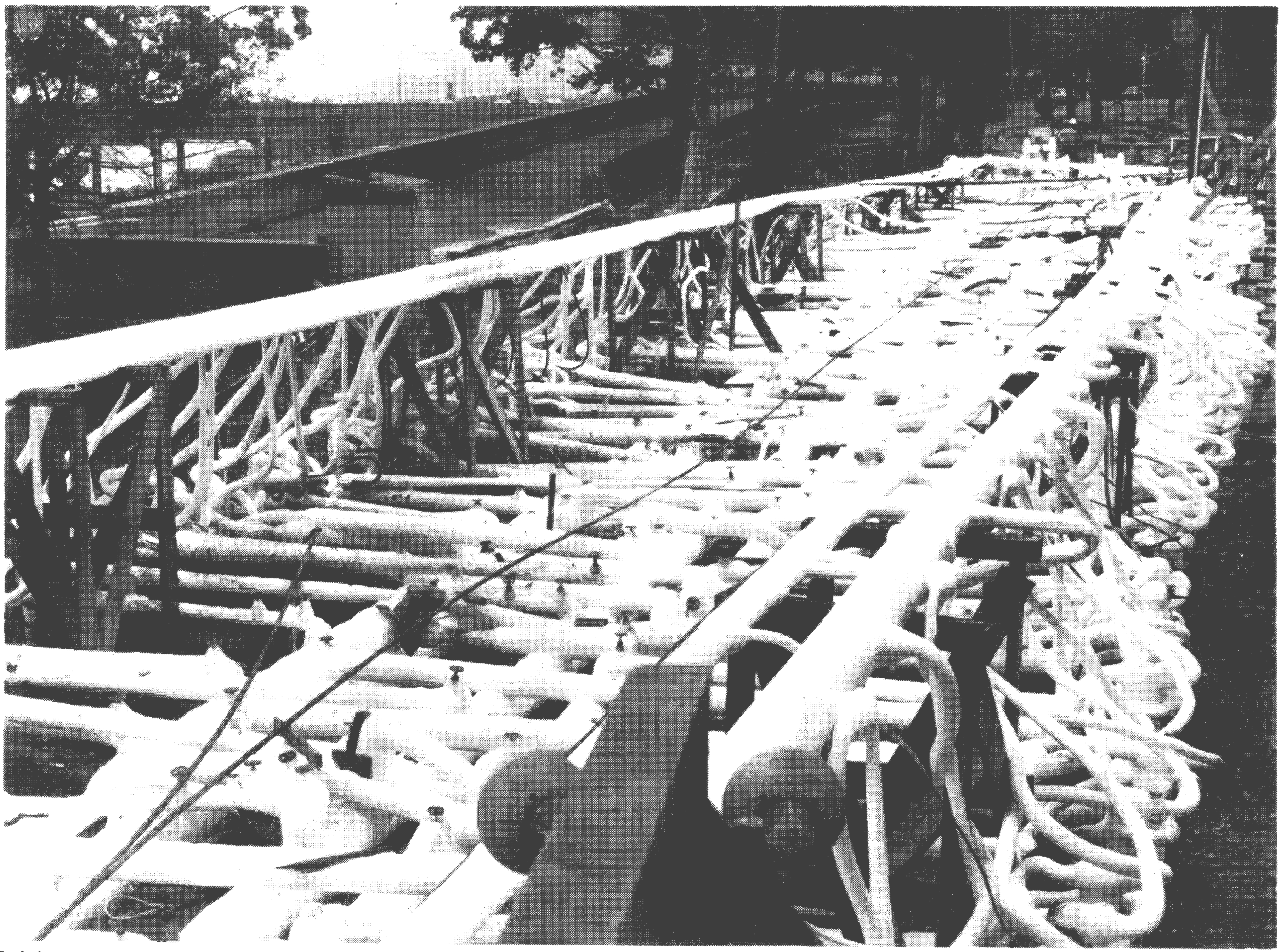


Exhibit 16-B Ground freezing for soil stabilization.

Chapter 17

CONCLUSIONS AND RECOMMENDATIONS

This report has developed a new viewpoint on the industry's problems and opportunities. This approach, coupled with normal specific technical studies, can lead to improved policy for the industry. Many factors which influence capacity and risk-taking in the tunneling industry have been identified, including operating and financial relationships that are not easily visible. These range from financing arrangements by owners to decision making at various levels of multi-industry companies.

We consider the U. S. Department of Transportation's main objective in tunneling to be the reduction of costs so that underground construction can remain an acceptable option for transportation planners.

The promising cost reduction areas are: innovation in design, innovation in materials and equipment, avoidance of supply shortages, sharing of risk through contractual practices, improvement of operational efficiency, and measurement of productivity. Related problems and causes have been discussed earlier.

However, recommendation of a highly detailed program is beyond the scope of this work. Though the preceding chapters include numerous conclusions, we have limited the actions we urge to the use of new incentives for progress in the industry. These recommendations reflect certain general concerns which appeared throughout the work. They are supported by reasonable amounts of data and offer examples of what can be achieved if tunneling is viewed as an industry and its people are accepted as rational decision makers. We offer the following recommendations to the U. S. Department of Transportation and the tunneling industry.

INNOVATION IN DESIGN. In U. S. transportation tunneling (including stations) a system has evolved which strongly discourages innovations or changes in practices or design. We believe that little improvement in productivity will occur until two major interrelated issues are addressed.

- Where combinations of organizations are directly involved in managerial decisions, such as establishing design criteria and practice, a system of accountability for decisions must be established.

- With accountability, a better risk sharing system is needed. This should encompass decisions made by the owner's staff, engineering consultants, and construction contractors.

These items are critical in achieving healthy levels of innovation and productivity in transportation tunneling. Other types of publicly-funded underground construction have experienced owner staffs who are able to make decisions involving design and practice with the help of a review process. Thus, risk is accepted by the owner through a process of accountability of decision resulting from effective reviews. This is totally missing in the U. S. transportation tunneling industry. In this industry, the owner generally relies on a consultant to make major decisions of criteria and practice. Current customs raise these questions:

- WHAT INCENTIVE DOES THE ENGINEERING CONSULTANT HAVE TO RECOMMEND COST EFFECTIVE CHANGES IF THE FIRM MUST ACCEPT TOTALLY THE RISK, HOWEVER SMALL, FOR THESE CHANGES?

  It appears that traditional design is the most prudent course. The consultant has nothing to gain from accepting the risk attached to any change.

- WHAT INCENTIVE DOES THE OWNER HAVE TO APPROVE COST EFFECTIVE CHANGES, IF THE RESPONSIBILITY ATTACHED TO THIS DECISION RESTS WITH ONE INDIVIDUAL OR ONE GROUP AND THERE IS NO PAYOFF FOR INNOVATION?

  Currently the owner must exercise judgment based on the potential gains or losses from a new design. If a risk decision is accepted and implemented successfully the particular manager is, by definition, exercising proper judgment. However, if the risk is accepted and the results are bad, then the manager has failed, even if the correct and prudent decision was made.

Without changing the current organization structure of the industry, the questions of accountability and risk can be dealt with by providing a "third party" review system. Critical requirements for such a review group would be:

1. Third party means specifically that members of such a review group may not have vested interests with the owners (be it the federal government or a local authority) or the contractor.

2. Reviews have to be conducted by people well versed in the technology and accepted as peers.

3. The review process entails no authority other than to ask for rational explanations to major criteria or practice decisions. Reviewers would then declare that these decisions are prudent and represent a proper exercise of judgment or publicly disagree with them.

If the industry cannot successfully implement this approach within owner organizations, then it is likely that federal officials will attempt to establish some group to monitor the cost-effectiveness of federally-funded underground transportation construction. We note that most bureaucratic interventions occur after a prolonged period when the industry involved is urged to solve its own problems. Industry members, who generally agree with our findings, can't expect the responsible federal money-allocators to put up with the present problems indefinitely.

INNOVATION IN MATERIALS AND EQUIPMENT. The tunneling industry has a relatively slow rate of technological innovation. Recently the Federal Government has funded a great deal of equipment, materials, research and development. Little of this research has led to results that are actually used in the industry.

One problem in guidance and evaluation of such Federal R & D is that no consensus exists as to the products which will be needed in future years. We recommend that the Federal government develop further knowledge of industry's future needs to identify areas of high potential payoff. Then R & D priorities could be established on a logical basis. Without such information, each Federal technical project must be evaluated individually and little cross-comparison can be made.

MINIMIZING SHORTAGES. The demand statistics show that development of BART and WMATA occurred at a time of strong demand for water and sewer tunnels and created severe demand peaks. These peaks triggered price escalation because of bidding practices, shortages of key personnel, and shortages in materials and equipment.

The peaks were aggravated by the way planning and scheduling is done at the federal level. The projects competed among themselves, since there was no mechanism for assessing overall demand or coordinating long-run plans. Also, some owners were encouraged to construct entire systems in a brief period of time. Both of these practices fostered excess demand and high prices. We recommend establishment in the federal government of periodic meetings of key agency people to coordinate but not control the federally-funded demand for tunneling.

SHARING OF CONSTRUCTION RISK THROUGH CONTRACTUAL PRACTICES. Risk affects pricing in this industry, as the report has shown. Even though individual firms are willing to accept the technical and legal risks associated with specific jobs, they charge the consumer (taxpayer) for this burden. While risk is unavoidable in this type of construction, it does not have to be apportioned as it is at present. Owners, who can spread the risk over a number of jobs can handle a larger share of it, in a more efficient manner, than the construction contractors, many of whom stake their survival on a small number of jobs.

We recommend such risk-sharing devices as subsurface contingency clauses, disclosure of fuller geological information, and owner-supplied key materials. We believe that the sharing of risk through such contractual devices will reduce the adversary climate and accompanying high costs of tunneling.

IMPROVEMENT OF OPERATIONAL EFFICIENCY. The role of the engineer in a construction contracting firm is becoming more difficult as jobs get larger, non-technical problems multiply, and management responsibilities become more formalized. We have shown how critical the skills of experienced engineer-executives are to the industry. They are the ones who must accomplish the jobs at a reasonable cost. They are the ones who must actually incorporate new technology in equipment, materials, and managerial techniques. They are the ones who must "sell" tunnel jobs to their firms in competition with other types of investment. It is imperative that the industry provide sufficient training for the future engineering executives. The overwhelming view, in our discussions with contractors, was that graduate programs, except for a handful, are of little value to the rising professional engineer in this industry as now constituted and used by engineers.

We recommend that the universities recognize the growing need for broadly-based engineering management training. Their programs should be closely tied to actual industry needs in technical management and financial management and be supplemented by specialized technical seminars. Construction firms should support these efforts by participating in classroom and seminar presentations. Some creative financial thinking should be applied to the problems of working engineers in their thirties who have to support families while undertaking graduate training.

MEASUREMENT OF PRODUCTIVITY. Programs aimed at increased productivity and innovation must include results that can be verified or measured. If this cannot be done then accountability is impossible in the program. At present, as we have shown, almost no aggregate data exists for the tunneling industry. At a detailed technical level, it is all but impossible to compare the results of most technical reports with preciseness, since the research is not grounded in a consistent theoretical production framework and common measures of outputs and inputs are not used.

The size of the public investment in tunneling and tunneling research calls for a clearer quantitative understanding of what the research is buying the public.

We recommend that the U. S. Department of Transportation initiate the development of a consistent methodology for the measurement of productivity in tunneling. This research should include both the theoretical framework and the empirical data requirements.

MANAGEMENT OF R & D EFFORTS. Research and development that is federally funded and directed should be carried out by industry and the universities as well as the government itself. It should also include incentives, operating experiments, and matching or participation arrangements of a multi-group nature. The management, commercial and institutional problems of the industry are larger than its technological problems. It is the former for which industry participants want and need help. Research which does not actively involve owners, engineers and contractors is much less likely to lead to realistic, cost-effective results.

APPENDICES

APPENDIX TITLE	APPENDIX IDENTIFICATION
Demand for Tunneling	A
Engineers in Tunneling Work	B
Construction Contracting Firms in Tunneling	C
Capacity of Construction Contracting Firms in Tunneling	D
Supplier Support for Bidding	E
Bonding Capacity Regulation	F
Schools Currently Providing Tunnel Engineers to the Industry	G
Industry Comments on Safety & Research	H
Acknowledgements	I
Report of No Patents	J
Bibliography	K
Index	L

APPENDIX A

DEMAND FOR TUNNELING

The pages that follow summarize the tunnel building demand in the continental United States (1955-85). Listed tunnels meet the criteria of tunnel definition outlined in Chapter 1. Generally, underpasses are excluded and the only cut-and-cover construction included is related to rapid transit.

Tunnel length and diameter are expressed in feet. End use abbreviations include RT - rapid transit, MV - motor vehicle, W - water, S - sewer. Tunnel status is indicated by showing the year in which it was completed, UC - under construction, or PS - planning stage. Where construction was done in sections, the number of contracts let or planned is shown where known.

Engineering firms and contractors, where known, are shown. Some agencies do their own engineering. In other cases more than one firm is involved. Where that information was available, all relevant firms and roles have been included.

Tunnels which are included in various plans, but which (in the opinion of the owners) are unlikely to be built or under construction by 1985, have been omitted. In most cases the source of the information is the authority which owns and operates the tunnel.

ABBREVIATIONS USED IN DEMAND WORKSHEETS

BART	Bay Area Rapid Transit, San Francisco
BuRec	Bureau of Reclamation, U. S. Dept. of Interior
BWS	Bureau of Water Supply, New York City
BWPC	Bureau of Water Pollution Control
COE	Corps of Engineers, U. S. Army, Washington
CTA	Chicago Transit Authority
GCMSD	Greater Chicago Metropolitan Sewer District
JV	Joint Venture
MARTA	Metropolitan Atlanta Rapid Transit Authority
MBTA	Mass. Bay Transit Authority, Boston
MWD	Metropolitan Water District, So. California, Los Angeles
NYCTA	New York City Transit Authority
NYMTA	Metropolitan Transit Authority for New York Area
PATH	Port Authority (NY-NJ) Trans Hudson, New York
SCRTD	So. California Rapid Transit District, Los Angeles
SEPTA	Southeastern Pennsylvania Transportation Authority (Philadelphia)
SFWD	San Francisco Water Dept.
WMATA	Washington Metropolitan Area Transit Authority

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
Mass Turnpike Authority	Wm. F. Callahan	5070	31'4"	MV	E-M Mole	1961		Singstad & Baillie	Perini
MBTA	South Cove			RT	Cut & Cover	1974		Parsons Brinker-hoff	Kiewit
MBTA	Haymarket North	2x235		RT	Sunken tube	1975		Bingham	Perini
Metro. District Commission	Wachusett-Marlborough	42250	14'	W	Drill & Blast	1964		In House	Perini-Walsh-Morrison-Knudsen
Metro. District Commission	Dorchester	33450	11'	W	Drill & Blast and Lawrence Mole	1974		C. T. Main	S. J. Groves
Conn. (State)	Bushnell Park (Hartford I-84)	2000	4 lns	MV		PS		Steinman, Boyn-ton, Gronquist & London	

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Contracts	Engineering Firm	Construction Company
PATH	E. 63rd Street	1510	38' x36'	RT	Sunken Tube	1973		Parson, Brinckerhoff, Quade, & Douglas; Sverdup, & Parcel Assoc.; Gibbs & Hill	Perini Corp.; Brown & Root; Gordon H. Ball
NYC/BWPC	Newton Creek	5000	8'6"	S	Drill & Blast	1959		In House	Andrew Catapano & Grow Constr.Co. Poirer-McLean
NYC/BWS	Richmond Tunnel	25000	12'	W	"	1966		" "	Perini Corp.
NYC/BWS	3-520	17611	26'10"	W	"	1969		" "	Walsh Const.
NYC/BWS	3-521	31370	26'10"	W	"	1969		" "	Walsh Const.
NYC/BWS	3-522	23151	22'10"	W	"	1969		" "	Walsh Const.
NYC/BWS	West Side Sewer	4212	21'	S	"	1968		" "	Poirer & McLean
NYMTA	63rd St. Subway	3140	box	RT	"	1969			Peter Kiewit Sons Co.
NYCTA	Route 101-13	3097	32x18	RT	"	1966			Cayoga, Johnson, Drake, & Piper
NYC/BWPC	Staten Island	17000	10'	S		UC		" "	Peter Kiewit & Richmond Const.[1]
NYC/BWS	Third Water Tunnel	72336	24'	W	Various	UC		" "	Water Tunnel Const.[2]

1 Richmond Constructors - a joint venture of Grow Tunneling, McLean-Grove, Morrison-Knudsen, Andrew Catapano, Grove Sheppard Wilson & Kruge

2 Water Tunnel Constructors - a joint venture of Walsh, Dravo, S. J. Groves, Arundel, L. E. Dixon, Ostrander

SUMMARY OF TUNNELS, PLANNED, UNDER CONSTRUCTION, AND IN USE

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company

Planned subway construction currently suspended due to budgetary constraints on the part of government agencies at all levels. City expects to finalize transportation policy during January 1976 and begin revised planning in the following months.

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
SEPTA	Broad St. Ext.	4000	48	RT	Cut & Cover	1974		Deleuw-Cather & A. J. Kuljian	Kiewit-Buckley
SEPTA	Center City Commuter Tunnel	5000	120 wide	RR	Cut & Cover	PS		Urban Engineers; Day & Zimmerman, Sanders & Thomas	
SEPTA	Frankford El	1300	40	RT	Cut & Cover	UC		Amman & Whitney	Slattery Assoc.
SEPTA	Airport Ext.	1000 est.*		RT	Cut & Cover	PS			

* To connect with existing station.

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Contracts	Engineering Firm	Construction Company
Maryland Mass	Bolton Hill	5000	Var.	RT		PS	50-100 est.	Bechtel (Design) DMJM (General eng. consult)	
	Baltimore Metro	24000	Var.	RT	Stations: Cut & cover tracks: shield				
Maryland Trans. Authority	Baltimore Harbor	7650	44	MV	Sunken Tube	1957	32	J. E. Greiner	Merritt-Chapman & Scott
	Fort McHenry	6900	8 lns	MV	Sunken Tube	PS		Per Hall, Pullerits, Zollman J.V. Rummel, Klepper and Kahl	
	Boulevard	580	6 lns	MV		PS			
	Fells Point	2100		MV	Double decked Slurry wall	PS			

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
WMATA	1A0011	2669		RT	Cut & Cover	1973		Sverdrup & Parcel	Peter Kiewit Sons'
	1A0021	2669		RT	Cut & Cover	1973		Tippetts, Abbett, McCarthy & Stratton	Morrison-Knudsen
	1A0031	1838		RT	Cut & Cover	UC		Rummel, Klepper & Kahl	Intercounty, Buckley & Conduit
	1A0044	1610		RT	Rock	UC		Kaiser	Granite Const.
	1A0043	4018		RT	Rock and Cut & Cover	1973		Kaiser	
	1A0061	10914		RT	Rock	UC		Harza Assoc.	Morrison-Knudsen
	1A0091	7677		RT	Rock	PS[1]		Ralph M. Parsons	
	1A0101	9056		RT	Rock	UC		Ralph M. Parsons	James McHugh
	1A011	12687		RT	Rock and Cut & Cover	PS		Matthews-Chatelain-Beall	
	1B0011	3492		RT	Cut & Cover	1974		Ammann & Whitney	Ball-Shea-Norair
	1B0021	2400		RT	Cut & Cover	1974		Greiner Eng.	Norair Eng.

[1] Bids 5 Feb. 1975 were rejected.

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Contracts	Engineering Firm	Construction Company
WMATA	1B0032	557		RT	Cut & Cover	1975		Greiner Eng.	P & Z - Mergentime
	1C0011	1299		RT	Cut & Cover	UC		MCA Eng.	Early-Massman
	1C0021	2714		RT	Cut & Cover	UC		Ralph M. Parsons	Morrison-Knudsen
	1C0031	2115		RT	Cut & Cover	UC		Hayes, Seay, Mattern & Mattern	Massman-Kiewit-Early
	1C0041	6247		RT	Rock & Earth	UC		Parsons, Brinckerhoff, Quade & Douglas	Shea-S & M-Ball
	1C0051	4217		RT	Rock	UC		Bechtel Corp.	Shea-Ball
	1C0061	4925		RT	Cut & Cover	UC		McGaughy, Marshall & McMillan	Morrison-Knudsen
	1C0062	1466		RT	Cut & Cover	UC		H. D. Nottingham	Norair
	1C0071	4441		RT	Earth and Cut & Cover	UC		Century Eng.	
	1C0081	3482		RT	Cut & Cover	UC		Hayes, Seay, Mattern & Mattern	Peter Kiewit Sons'
	1C0103	1500		RT	Cut & Cover	PS		Vosbeck, Vosbeck, Kendrick & Redinger	

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
WMATA	1D0011	2988		RT	Cut & Cover	UC		Daniel, Mann, Johnson & Mendenhall	P & Z - Shea
	1D0021	2030		RT	Cut & Cover	UC		David Volkert Assoc.	Swindell-Dressler
	1D0031	2672		RT	Cut & Cover	UC		Sverdrup & Parcel	Slattery-Grow
	1D0041	4372		RT	Earth	UC		Praeger-Kavanaugh-Waterbury	S & M-Traylor
	1D0042	1065		RT	Cut & Cover	UC		Praeger-Kavanaugh-Waterbury	Mergentime-Steers
	1D0043	698		RT	Cut & Cover	UC		Praeger-Kavanaugh-Waterbury	Healy-Kruse
	1D0061	5283		RT	Earth and Cut & Cover	UC		Edwards & Kelcey	Healy-Kruse
	1D0071	745		RT	Cut & Cover	UC		Wiley & Wilson	Norair
	1D0081	3963		RT	Earth and Cut & Cover	UC		Henningson, Durham & Richardson	Granite-Groves
	1D0091	2466		RT	Cut & Cover	UC		J. K. Knoerle	Fruin-Colnon
	1E0011	4328		RT	Earth and Cut & Cover	PS		Edwards & Kelcey	Fruin-Colnon

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con- tracts	Engineering Firm	Construction Company
WMATA	1E0012	2745		RT	Earth and Cut & Cover	PS		Edwards & Kelcey	
	1E0021	4730		RT	Earth and Cut & Cover	PS		C. E. Maguire Inc.	
	1F0012	3892	Var.	RT	Earth and Cut & Cover	UC		Corddry, Carpen- ter, Dietz & Zack	Dravo Corp.
	1F0021	4516		RT	Earth	UC		Parsons, Brinck- erhoff, Quade & Douglas	Traylor Bros.- S & M
	1F0022	738		RT	Cut & Cover	UC		Parsons, Brinck- erhoff, Quade & Douglas	Volpe-Head
	1F0031	7525		RT	Cut & Cover	PS		T.A.M.S.	
	1G0021	7790		RT	Earth and Cut & Cover	PS		Corddry, Carpen- ter, Dietz & Zack	
	1K0021	3001		RT	Cut & Cover	UC		Wiley & Wilson	Nello L. Teer
	1K0031	2074		RT	Cut & Cover	UC		Sanders & Thomas	Expressway Const.
	1K0042	2988		RT	Cut & Cover	UC		Century Eng.	Slattery Assoc.
	1K0041	1710		RT	Double Box Cut	UC		David Volkert	Morrison-Knudsen
	1L0011	3233		RT	Cut & Cover and Sunken Tube	PS		Praeger- Kavanaugh- Waterbury	

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
No. Charleston Service Comm.	Cooper R. Trunk	730	7'6"	S		1969			C.F.Smith & Son
NY Power Auth.	Blenheim-Gilboa	2838	Var.	W	Drill & Blast	1969		Sverdrup & Parcel	Perini Corp.
Chesapeake Bay Bridge & Tunnel	Baltimore Chan Thimble Shoals CH	5450 5738	37' 37'	MV MV	Sunken Tube Suken Tube	1965 1965		Sverdrup & Parcel Sverdrup & Parcel	Tidewater-Merritt Raymond Kiewit-Amer. Bridge
Pa. Turn. Auth.	Tuscarora	5326	38x33	MV	Bench & Header Drill & Blast	1968		Michael Baker,Jr. Inc.	Peter Kiewit Sons
Pa. Turn. Auth.	Kittatinny (	4727	38x33	MV	Drill & Blast	1967	)	Michael Baker,Jr. & Bellante & Clause	Langenfelder
Pa. Turn. Auth.	Blue Mt. (	4339	38x33	MV	Drill & Blast	1968	)		Langenfelder
Pa. Turn. Auth.	Allegheny Mt.	6070	38x33	MV	Drill & Blast Full Face	1963		Michael Baker,Jr. Inc.	Merritt Elkman & Scott
Norfolk & Western R R	Elkhorn	7110	32x31		Drill & Blast	1950			Haley-Chisom Morris
NJ Hiway Dept.	Rte. 280 Sewer	20380	10'	S	Drill & Blast	1965		Parsons-Brinker-hoff	McHugh
National Park Service	Mt. Pisgah Hiway	1000	30x18	MV	Drill & Blast	1963			Blythe Bros.
B&O Railroad	B&O Tunnel WVa	1900	19x27	RR	Drill & Blast	1964			Langenfelder
WVa Hiway Dept.	Wheeling Hiway	2851	24x31	MV	Drill & Blast	1964			Langenfelder
NC Hiway Dept.	I-40 Interstate	1200	31x24	MV	Drill & Blast	1964			Cowan
Niag-Mohawk Power Co.	Ninemile Nuclear NY	1780	12'	W	Drill & Blast	1966			Wilkstrom

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
Hartford Metro District	Talcott Mtn.	5380	6x7	W	Drill & Blast	1963		Frank Fahlquist	Square & Marra
Rochester, N.Y.	Norton St.	300	10'6"	S	Drill & Blast	1965		In House	McHugh
"	Keeler St.	2650	7'7"	S	Drill & Blast	1965		" "	"
"	Central Ave.		8'6"	S		1960		" "	"
"	Main & Front		8'6"	S		1960		" "	"
"	Clarissa St.		8'6"	S		1960		" "	"
"	Upper Falls	300	10'	S		1970		" "	"
"	Upper Falls/Bausch	600	10'	S		1974		" "	"
Monroe County Pure Waters Agency	Genesee-S/W	8000	16'	S	Mole	UC		Erdman Anthony	
	Genesee-S/E	15850	12'	S	Mole	PS		Charles Sells	
	Culver-Goodman	26400	16'	S	Mole	PS		Lozier Engineers	
	Deep Tunnels	27000	16'-20'	S	Various	PS			
Rochester-Genesee Rapid Transit Auth.	Metro	1000		RT	Cut and cover	PS			
Niagara Frontier Transit Authority	Buffalo-Amherst	27456[1]		RT	Cut and cover and moles	PS			

1 alignment to be finalized during 1976

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
COE	North Fork, Pound Virginia	641	8"	W	Drill & Blast	1964		In House	
"	Fishtrap Kentucky	720	16'	W	"	1964		" "	Cowan Const.
"	Gathright Virginia	1181	18'	W	"	1972		" "	
"	Jadwin Dam Pennsylvania	554	9'	W	"	1958		" "	
"	J. W. Flannagan Virginia	780	17'	W	"	1961		" "	
"	Sutton Lake West Virginia	555	22'	RR	"	1958		" "	
"	Summersville West Virginia	1863	30'	W	"	1962		" "	Mntn. States Construction
"	A. R. Bush Pennsylvania	768	14'	W	"	1962			
"	Grayson Kentucky	390	15'	W	"	1965		" "	
"	Buford (four tunnels) Georgia	848	Var.	W	"	1958		" "	
"	Carter's Dam Georgia	2405	24'	W	"	UC		" "	
"	Colebrook River Connecticut	683	12'	W	"	UC		" "	

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Contracts	Engineering Firm	Construction Company
COE	Littleville Massachusetts	285	9'	W	Drill & Blast	1965		In House	
"	No. Springfield Vermont	600	13'	W	"	1960		" "	
"	Union Village Vermont	1178	14'	W	"	1950		" "	
"	Ball Mountain Vermont	865	14'	W	"	1961		" "	
"	Worcester Diver.	4300	20'	W	Various	1960		" "	
	Hampton Roads I	7500	2 lns	MV	Sunken Tube	1957			Tidewater & Merritt-Chapman
	Hampton Roads II (I-64)	7500	2 lns	MV	Sunken Tube	UC		Parsons, Brinckerhoff, Quade, Douglas	Tidewater - Raymond J.V.
	Admiral Taussig Blvd. (I-564) Norfolk	665	4 lns	MV	Cut and cover	UC		Whitman, Requardt & Associates	
	Craney Island (I-664)	4250	4 lns	MV	Sunken Tube	PS		McGaughy, Marshall & McMillen	
	Elizabeth River I Portsmouth (I-264)	3500	2 lns	MV	Sunken Tube	1953			
	Elizabeth River II	3500	2 lns	MV	Sunken Tube plus Cut and cover	PS			
State of West Virginia	East River Mt.	5700	4 lns	MV	Drill & Blast	1974		M. Baker, Jr.	

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Contracts	Engineering Firm	Construction Company
MARTA	Atlanta Metro	53328		RT	Mainly Cut & Cover	UC	40		
City of Atlanta	Airport Tunnel	800	22'6"	A	Shield				Grow Tunneling

[1] Report on alternative alignments and modes due January 1976. Final plans contingent upon that report.

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
Port Authority Transit[1]		3696		RT		PS			
City of Pittsburgh[2]	Squirrel Hill 3 (I-76)	4200	3 lns	MV		PS		M. Baker, Jr.	

[1] In addition to contemplated construction, P.A.T. completed $4.7 million renovation of abandoned Wabash R.R. Tunnel for use of "skybus" route. Also renovated Mt. Washington Trolley Tunnel. Final plans contingent upon consultants report due February 1976.

[2] PennDot official says City opposes this. No funds included in the six year program.

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company

No RT subway construction in place or planned. On 7/22/75 tax proposal went into effect allowing 1% piggyback sales tax in Cuyahoga County. The Cleveland Transit System has become the Greater Cleveland Transit Authority. Also as part of tax plan, there will be a statutory 5 year building moratorium to help keep fares down.

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Contracts	Engineering Firm	Construction Company
City of Detroit	1st-Hamilton Sec IV	22000	20	S	Mole	1966			DiMambro
	Schoolcroft Relief	16000	17	S	Mole	1964			Healy-Gagaro
	Bedford-Cadieux	10791	14'4"	S	Mole	1969			Greenfield-Mancini
	Wyoming Relief	10494	14'8"	S	Mich. Sewer Mole	1969			Michigan Sewer-Jay Dee Const.
	PC1-5 Intercept.	14630	16'9"	S	Calweld Mole	1970			Corridor Const.
	PC1-6 Intercept.	13033	16'9"	S	Calweld Mole	1970			Corridor Const.
	PC1-7 Intercept.	13633	16'9"	S	Memco Mole	1970			Michigan Sewer
	North Intercept.	5713	22	S	Decker Mole	1970			Corridor Const.
	PC1-18 Intercept.	15671	15'6"	S	Scott Mole	UC			Michigan Sewer
	PC1-19 Intercept.	12531	17'6" & 15'6"	S	Calweld Mole	UC			Gagaro Const.
	PC1-20 Intercept.	12441	17'6"	S	Memco Mole	UC			C. J. Rodgers
	PC1-21 Intercept.	16925	17'6"	S	Mole	PS			
	PC1-22 Intercept.	16053	17'6"	S	Mole	PS			
	PC1-29 Intercept.	12370	11'4"	S	Mole	PS			
	PC1-30 Intercept.	12753	11'4"	S	Mole	PS			
Southeastern Michigan Transp. Authority	Detroit Subway	9.2m.		RT		PS			

SUMMARY OF TUNNELS, PLANNED, UNDER CONSTRUCTION, AND IN USE

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
City of Chicago	NW Inceptor S	5300	26'	S		1965		In House	S. A. Healy Co.
" " "	Lombard St. S	5300	25'10"	S		1959		" "	John Doherty
" " "	Main Drain S. Rte Express.	9000	11'	S		1959		" "	John Doherty
" " "	Sewer	18000	9'	S				" "	S. A. Healy
" " "	Lawrence Avenue	25764	13'18"	S	Lawrence mole	1967		" "	McHugh, Healy, & Kenny
" " "	Lawndale Avenue	17634	13'10"	S	Robbins mole	1968		" "	Healy & Kenny
" " "	Crawford Avenue	18320	16'10"	S	Jarva mole	1968		" "	S&M Constructors
" " "	NW Inceptor	5580	14'4"	S		1965		" "	Kenny Construct.
" " "	Leamington Avenue	4695	14'4"	S		1968		" "	Potarelli & O'Brien
" " "	Normal Avenue	12125	15'6"	S		1968		" "	Healy & Kenny
CTA	Eisenhower Ext.	2896	49'	RT	Various			" "	Healy-McQueen-Boyle
CTA	Kennedy Ext.	6260	29'	RT	Cut and cover	1970		DeLeuw Cather	Kenny- Consoli-dated-Arcole
Chicago Urban	CATP Development	12 m.		RT	Cut and cover	PS			Midwest
GCMSD	Inceptor Sewer	7800	19'	S		1965		In House	S. A. Healy
GCMSD	Sewer	5875	11'4"	S		1965		" "	Geo. Hardin Con.
GCMSD	Sewer	12000	9'	S				" "	Kenny Construct.
GCMSD	Sewer	5500	7'6"	S		1963		" "	Kenny Construct.
GCMSD	Expressway Sewer	5995	66"	S	Open cut	UC		" "	Kenny Construct.
GCMSD	Cook Co. Sewer	6450	8'	S		1968		" "	Porter Construct. & F.D. May Co.

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
GCMSD	O'Hare Plant	750	8'	S		PS			
GCMSD	73-317-2S	22102	22'	S		PS			
GCMSD	73-320-2S (	10870	18'	S	Mole	PS			
	(	2065	10'	S	Mole	PS			
GCMSD	72-049-2H	27750	22'	S		UC			Kenny-Paschen
		24020	24'	S		UC			
GCMSD	Deep Tunnels	40000	Var.	S	Various	1974			Healy-McHugh
GCMSD	Deep Tunnels	97 m.	Var.	S	Various	PS			

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
Milwaukee Sewer Comm.	Sewer	8330	8	S		1972		Alvord, Burdick & Howson	R.W. Const. Inc. & W. J. Lazynski
Milwaukee Sewer Comm.	233	7138	8	S		1973		Alvord, Burdick & Howson	W. J. Lazynski
Milwaukee Sewer Comm.	239	9200	8	S		1973		Alvord, Burdick & Howson	Tomaro Const.
Milwaukee Sewer Comm.	865	6845	8	S		UC		Alvord, Burdick & Howson	Tomaro Const.
Milwaukee Sewer Comm.	866	5920	8	S		PS		Alvord, Burdick & Howson	

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
City of Minn.	2781-26	8824	Var.	W					Al Johnson Co.
City of Minn.	2782-50	4346	14	W					Al Johnson Co.
City of Minn.	2783-06	3465	16	W					Al Johnson Co.
City of Minn.	2782-17	6509	14	W					Foley Bros. Hurley, Winston
City of Minn.	2782-71	1593	14	W					Foley Bros. Hurley, Winston
City of Minn.	2783-19	6587	15	W	Delaware VM Mole				Delaware Corp. & Amer. Struct.
City of Minn.	6282-23	4400	14	W					Foley Bros. Hurley, Winston
City of Minn.	6282-41	2303	14	W					Foley Bros. Hurley, Winston
Metro Transit Commission[1]		190080		RT		PS			
City of Minnesota[2]	Minnehaha Park	965	6 lns	MV	Cut and cover	PS		Van Doren, Hazard, Stallings, Schnacke	

[1] Plans contingent upon State legislature's action.

[2] City council studying a bridge-boulevard alternative.

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
Metro Sewer District St. Louis	City Sewer	21000	9'	S	Drill & Blast				Traylor Bros.
City of Omaha	Minne Lusa	7500	12'	S		1962			Rocco Ferrea Co.
COE	Oake (6 tunnels) S. Dakota	72335	Var.	W	Moles	1958		In House	
COE	Wilson Kansas	998	14'	W		1963		"	
COE	De Gray Arkansas	1667	30'	W	Drill & Blast	1964		"	
COE	Gilham Arkansas	627	12'	W		UC		"	
COE	Broken Bow (2) Oklahoma	2990	Var.	W		1964		"	
COE	Ft. Randall (4) S. Dakota	10026	24'-30'	W	Drill & Blast	1956		"	
COE	Pomme de Terre Missouri	514	13'	W	Drill & Blast	1959		"	
Prairie Farm Rehab. Agency	Gardiner	20000	22'	W	M-K Mole	1969		COE	Morrison-Knudsen

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
City of Houston	Storm Sewer	2840	11'8	S		1959		In House	Elmer Gardner
		3821	10	S		1966		" "	Boring & Tunneling Co. of America
		730	12	S		1973		" "	John G. Holland
City of Austin	Crosstown Intercept.	57836	8	S	Moles	UC		A. A. Mathews-CRS Design-Lees, Hill, Jewett, Bryant & Curington	Kiewit-Granite
City of Ft. Hood		330	6	W	Drill & Blast	1969		COE	
International Boundary & Water Commission	Amisted Dam	1620	15	W	Drill & Blast	1970		COE	

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
City of Denver	H. D. Roberts	123024	13'3	W	Drill & Blast	1962			Blue River Const.[1]
City of Denver	Williams Fork	3700	10	W	Drill & Blast	PS			
Colo. Hiway Dept.	Eisenhower #1 (West)	8941	48	MV	Drill & Blast	1973		Tippetts-Abbett-McCarthy-Stratton	Straight Creek Constructors[2]
Colo. Hiway Dept.	Eisenhow (East)	8940	48	MV	Drill & Blast	UC		T.A.M.S.	Brown & Root-Kiewit
Colo. Hiway Dept.	Glenwood Springs	2000	34x 26	MV	Drill & Blast				Colorado Const.
Colo. Hiway Dept.	Loveland Pass	8282	11'11	MV	Drill & Blast	1964			Mid-Valley Const.
BuRec	Carter Lake	5792	8	W		1952			
BuRec	Rattlesnake	8757	9'9	W		1952			
BuRec	St. Vrain	1200	8'6	W		1953			
BuRec	Rabbitt Mt.	3145	8'6	W		1953			
BuRec	Chapman	14600	7'0	W		1971			
BuRec	Boustead	28500	10'6	W		1971			
BuRec	Hunter	29049	8'6	W		1973			
BuRec	Hunter #2	15850	8'6	W		UC			Perini
BuRec	Nast	15840	7'8	W	Wirth Mole	1974			Kiewit
BuRec	South Fork	16250	8'0	W		1971			

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
BuRec	Azotea	67892	10'11	W	Robbins Mole	1970			Gibbons & Reed-Boyle Bros.
BuRec	Blanco	45636	8'7	W	Robbins Mole	1969			Colorado Const.-A. S. Horner
BuRec	Oso	26660	8'7	W	Robbins Mole	1970			Boyle Bros.
Denver Rapid Transit Dist.	Denver Subway	6350		RT	Cut & Cover	PS[3]			
Southgate Sanitation Dist.	Orchard	7600		S		PS			

[1] A joint venture of Mid-Valley Utility Constructors, S. A. Healy, C. H. Tompkins, J. A. Jones, A. S. Horner, and Colorado Constructors.

[2] A joint venture of Al Johnson, Gibbons & Reed, Kemper, and Western Paving.

[3] Plan subject to approval at public hearings. Final decision due late March 1976.

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Contracts	Engineering Firm	Construction Company
MWD/So. Cal.	Balboa Inlet	5000	18'4	W	Kemper Shield	1967		In House	Dixon-Arundel McDonald-Kruse Kiewit
MWD/So. Cal.	Glendora	34103	18'6	W	Drill & Blast	1965		" "	J. F. Shea Co.
MWD/So. Cal.	Newhall	18290	25'7	W	Calweld Mole	1966		" "	Dixon-Arundel et al.
MWD/So. Cal.	Castaic	25085	25	W	Memco Mole	1966		" "	Delaware-V-M.
MWD/So. Cal.	Sepulveda	7000	11	W	Calweld Mole and Drill & Blast	1970		" "	Drummond & Brannock
MWD/So. Cal.	Bernasconi #2	5000	13	W	Drill & Blast	1971		" "	J. F. Shea Co.
MWD/So. Cal.	Tonner 1 & 2	22900	11	W	Calweld Mole	UC		" "	J. F. Shea Co.
MWD/So. Cal.	Diemer tunnel shaft	1400 250	11 11	W	Drill & Blast	UC		" "	J. F. Shea Co.
MWD/So. Cal.	San Fernando	29000	22	W	Robbins Mole	1975		" "	Lockheed Ship-building & Const.
So. Cal. RTD	L.A. Subway[1]	13500		RT		PS			

[1] Alignment to be determined in 1976.

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
California Dept. Water Resources	Carley Porter	25080	24	W		1965		In House	Dravo-Atkinson Groves
" " "	Angeles	37774	35	W		1966		" "	Shea-Kaiser-Lockheed-Healy
" " "	Tehachapi	16052	29	W	Drill & Blast	1966		" "	Granite-Bell-Gatest Fox
" " "	San Bernadino	20123	16	W		1967		" "	J. F. Shea Co.
" " "	Del Valle	1800	34	W	Drill & Blast	1967		" "	Green-Winston
" " "	Castaic Dam Diversion	3600	33	W		1967		" "	Peter Kiewit

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
Dept. of Army		790	7x9	W	Drill & Blast	1970			
BART	Berkeley Hills Subway	16200	20	RT	Drill & Blast	1967		Parsons, Brinck-erhoff-Tudor-Bechtel	J. F. Shea Co. & Macco, Kaiser
BART	Berkeley Station	2900	18'8	RT		1968		" " "	J. F. Shea Co. & Macco
BART	Subway Contract S0021	17580	18'6	RT	Memco Mole	1967		" " "	Delaware V.M.
BART	Subway Contract S0011	6280	18'6	RT	Jarva Mole	1967		" " "	Shea, Ball, Granite, Olson
BART	Subway Contract B0031	2800	18'6	RT		1967		" " "	Perini-Brown & Root
BART	Subway Contract M0031	9100	18'8	RT		1968		" " "	Perini-Brown & Root
BART	Subway Contract M0011	6940	18'8	RT	Calweld Mole	1968		" " "	Kiewit-Traylor
BART	Subway Contract K0016	3260	18'8	RT		1968		" " "	Oakland Wye Constructors
BART	Subway Contract K0014	4170	18'8	RT		1968		" " "	Oakland Wye Constructors
BART	Subway Contract S0022	10200	17'6	RT		1967		" " "	Morrison-Knudsen, Perini, Brown & Root
BART	Subway Contract K0061	4874	18'8	RT		1968		" " "	

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
BART	Subway Contract M0042	3560	18'8	RT	Calweld Mole	1968		Parsons, Brinck-erhoff-Tudor-Bechtel	
BART	Subway Contract C0041	32400	20'8	RT		1968		" " "	Shea, Kaiser, Macco
BART	S.F. Yerba Project	2500	12	S				" " "	Pamco
Oakland Co. Drain Comm.	Eight Mi. Drain	13000	15	W		1963			Healy & Gargaro
Stanford Univ.	Special Purpose	600	15			1968			Kemper Const.
Eastbay Munic. Util. Dist.	LaFayette Util. Tunnel	4269	13	W		1968			J. A. Artukovich Sons
S.F. WD	Crystal Spgs.	17144	12'6	W		1969			Gates & Fox
Metro Util. Dist.	LaFayette Tunn.	16716	8	W	Drill & Blast	1961			Stolte-Early

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
City of Seattle	Sewer	10000	12'	S		1967			Pacific Mechanical Contractors & Traylor Bros.
City of Seattle	Lake City	17000	8'	S		1967			"
COE	Howard A. Hanson Dam	880	19'9"	W		1962		In House	
State of Washington	Baker Ridge (I-90)	2100	6 lns	MV		PS		Howard, Needles, Tammen & Borg.	
State of Washington	Mercer Island (I-90)	3000	10 lns	MV		PS		Tudor Eng.	

SUMMARY OF TUNNELS, PLANNED, UNDER CONSTRUCTION, AND IN USE

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
Nevada Highway Dept.	Carlin (2)	1426	33x24	MV		1975			Lockheed Ship. and Const.
Sacramento Metr. Utility Dist.	Loon Lake	21152	18'	W		1966			Walsh
	White Rock	25800	24'	W		1964			Walsh
Yuba City Water Agency	Lowman Ridge	19410	14'	W		1966			Perini
	Camptonville	6107	16'	W		1966			Perini
	Colgate	23624	24'	W		1966			Perini-Yuba
Idaho Power Co.	Hells Canyon	1694	43'	W	Drill & Blast	1966			Peter Kiewit
Pacific Gas & Electric Co.	Pitt-McCloud			W		1965			Peter Kiewit
	Belden			W		1968			Lockheed Ship. and Const.
California Dept. of Water Resources	Saugus-Castaic-	26400	26'	W		1968		In House	Delaware-V-M
California Dept. of Water Resources	Feather River (2)	8830 4410	21' x30'	RR RR	Drill & Blast	1963		"	Peter Kiewit

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
COE	Ft. Peck Montana	3756	24'	W	Top Heading & Bench	1960		In House	
COE	New Melones California	3790	24'	W	Drill & Blast	1973		"	
COE	Flathead Montana	35300	25' x18'	RR	Drill & Blast	1969		"	
COE	Shettisham (3) Alaska	10432	Var.	W	Drill & Blast	1972		"	
COE	Abiquiu Dam New Mexico	2078	14'	W	Drill & Blast	1956		"	
COE	Hills Creek (3) Oregon	2362	14'- 24'	W	Drill & Blast	1962		"	
COE	Green Peter (2) Oregon	1050	30'	W	Drill & Blast	1972		"	
COE	Alamo Dam California	962	13'	@	Drill & Blast	UC		"	
COE	Dwoshak Dam Washington	1721	42'	W	Full Face Excavation	UC		"	

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
COE	Terminus Dam California	1060	13'	W	Full Face Excavation	1962		In House	
COE	Cougar (3) Oregon	1979	Var.	W.	Drill & Blast	1964		"	
COE	Foster Oregon	565	32'	W	Drill & Blast	UC		"	
COE	Black Butte Dam California	545	23'	W	Various	1963		"	
COE	Lucky Peak Idaho	1120	23'	W	Drill & Blast	1956		"	
COE	Blue River Oregon	1797	25'	W	Drill & Blast	UC		"	
COE	Big Cliff Oregon	534	25'	W	Drill & Blast	UC		"	
COE	Painted Rock Arizona	925	25'	W	Drill & Blast			"	
COE	Isabella Dam California	758	16'	W	Drill & Blast	1953		"	

SUMMARY OF TUNNELS, PLANNED, UNDER CONSTRUCTION, AND IN USE

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
Bu Rec	Currant Utah	8976	12'	W	Robbins Mole	1975			S. A. Healy Co.
Bu Rec	Layout Utah	16896	12'	W	Robbins Mole	1975			S. A. Healy Co.
Bu Rec	Starvation Utah	5345	8'	W	Robbins Mole	1968			W. W. Clyde
Bu Rec	Water Hollow Utah	21571	12'	W	Robbins Mole	1971			Boyle Bros.
Bu Rec	Camino	2289	8'	W		1955			
Bu Rec	Camp Creek	2845	8'	W		1953			
Bu Rec	Clear Creek	56668	18'	W		1962			
Bu Rec	Carr Powerplant	270	8'	W		1970			
Bu Rec	Pacheco	9540	14'	W		1968			
Bu Rec	Tailrace	567	21'	W		1962			
Bu Rec	Spring Creek #1	8257	20'	W		1963			
Bu Rec	Spring Creek #2	4450	20'	W		1963			

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
Bu Rec	Colbran/South	2388	8'	W		1960			
Bu Rec	Frenchmen Hills	9280	15'	W		1953			
Bu Rec	Navajo #1	10079	20'	W	Williams Mole	1967			Fenix & Scisson
Bu Rec	Navajo #2	25720	20'	W		1968			
Bu Rec	Navajo #3	15438	19'	W	Dresser Mole	1974			Fluor
Bu Rec	Navajo #3A	3312	20'	W		1974			
Bu Rec	Navajo #4	4999	20'	W		1974			
Bu Rec	Navajo #4A	564	20'	W		1975			
Bu Rec	Helena Valley	13985	8'	W		1958			
Bu Rec	Sherman	2053	14'	W		1962			
Bu Rec	Glendo Powerplant	2099	22'	W		1956			
Bu Rec	Fremont 1 & 2	15741	20'	W		1960			
Bu Rec	River Mountains Nevada	19970	12'	W	Jarva Mole	1971			Utah Mining & Construction

OTHER WESTERN

SUMMARY OF TUNNELS, PLANNED, UNDER CONSTRUCTION, AND IN USE

Owner	Tunnel Name	Lgth.	O.D.	Use	Construction Method	Status	No. of Con-tracts	Engineering Firm	Construction Company
Bu Rec	Intake/Plant #1 Nevada	1600	13'	W		1970			
Bu Rec	Buckskin Mtn. Arizona	36432	23'	W		UC			
Bu Rec	Frying Pan Arkansas	15100	9'	W		UC			

APPENDIX B

ENGINEERS IN TUNNELING WORK

On the next nine pages is the comparative information about the forty-one firms. They, and the seven firms omitted for the reasons shown on Page 9-3, are all of the firms listed as engineers on tunnel contracts in recent years or claiming expertise on Standard Form 251 (U. S. Government Architect-Engineer Questionnaire).

Quantitative and qualitative questions were developed and asked.

- Number of years in business
- Number of years in tunneling work
- Percentage of firm revenues from tunnel work
- Number of permanent tunnel staff employed
- Number of experienced tunnel people now employed
- Number of tunnel projects during given years
- Types of tunnel construction experience
- End use of tunnels involved
- Role of the firm in its projects

Attempts to compare tunnel engineers quantitatively are not fully successful because of grey areas:

a. Overlaps in project roles

b. Number and size of tunneling projects

c. Size and experience of tunnel staff

d. Impact of WMATA organization approach

e. Duration of tunnel capability

These are discussed in Chapter 9 of this report.

CATEGORY I Name of Firm	Jacobs Assoc.	Jenny Engineering	A. A. Mathews	Transit & Tunnel Consultants	Woodward Clyde Consult.
Years in Business	21	10	22	3	26
Years in Tunneling	21	10	22	3	26
% of Business in Tunneling	25-50%	90%	>50%	<50%	<10%
Size of Permanent Tunnel Staff	3-4	10	30-40	30****	6
No. of Experienced Tunneling People	18	10	50-75	30****	80
Number of Projects 1960-65	50	0	50	0	NA
1965-70	70	(40+)***	75	0	35
1970-75	80		125	3	40
Type of Project Cut & Cover	Yes	Yes	Yes	Yes	Yes
Earth	Yes	Yes	Yes	Yes	Yes
Rock	Yes	Yes	Yes	Yes	Yes
End Use - Rapid Transit	Yes	Yes	Yes	Yes	Yes
Vehicle	Yes	Yes	Yes	Yes	Yes
Water	Yes	Yes	Yes	No	Yes
Sewer	Yes	Yes	Yes	No	Yes
Other	No	Utility & Railroad	No	No	No
Role - Design	No	Yes	Yes	Yes	No
Inspect	No	Yes	Yes	Yes	Yes
Spec. Check	No	Yes	No	No	No
Consultant	Yes	Yes	Yes	Yes	Yes

***Spread over 10 years.

****New American venture of British-Canadian Firms; believe staff reflects parent firms.

CATEGORY II Name of Firm	Bechtel Corp.	Daniels, Mann Johnson & Mendenhall	DeLeuw Cather	Edwards & Kelcey
Years in Business	78	29	56	29
Years in Tunneling	45+	25	20	24
% of Business in Tunneling	<10%	10-25%	10-25%	10-25%
Size of Permanent Tunnel Staff	~150	10	15-20	3
No. of Experienced Tunneling People	150+	25-30	60	8
Number of Projects 1960-65	10	3-5	5	5
1965-70	31	3-5	12	5-10
1970-75	24	3-5	25	10+
Type of Project Cut & Cover	Yes	Yes	Yes	Yes
Earth	Yes	Yes	Yes	Yes
Rock	Yes	Yes	Yes	Yes
End Use - Rapid Transit	Yes	Yes	Yes	Yes
Vehicle	Some	Prelim.Eng.Work	No	Yes
Water	Yes	Yes	Yes	Yes
Sewer	Recently	Yes	No	Yes
Other	No	No	No	No
Role - Design	Yes	Yes	Yes	Yes
Inspect	Yes	Yes	Yes	Yes
Spec. Check	No	No	No	No
Consultant	Yes	No	No	No

CATEGORY II Name of Firm	Harza Engineering	Keifer & Associates	Parsons- Brinkerhoff Quade & Douglas	Sverdrup & Parcel
Years in Business	55	2	90	47
Years in Tunneling	40-50	28 (C. Keifer)	70	25
% of Business in Tunneling	10-25%	50-75%	25%	10%
Size of Permanent Tunnel Staff	5	10	15-20	50
No. of Experienced Tunneling People	150	10	40	50+
Number of Projects 1960-65	5		3+	5
Number of Projects 1965-70	6		4+	5
Number of Projects 1970-75	8	3(?)	6+	5
Type of Project – Cut & Cover	Yes	Yes	Yes	Yes
Type of Project – Earth	Yes	Yes	Yes	Yes
Type of Project – Rock	Yes	Yes	Yes	Yes
End Use – Rapid Transit	Yes	No	Yes	Yes
End Use – Vehicle	No	No	Yes	Yes
End Use – Water	Yes	Yes	No	Yes
End Use – Sewer	Yes	Yes	No	Yes
End Use – Other	No	No	Railroad	Railroad
Role – Design	Yes	Yes	Yes	Yes
Role – Inspect	Yes	Yes	Yes	Yes
Role – Spec. Check	No	No	No	No
Role – Consultant	No	Yes	No	No

Category III Name of Firm	Ammann & Whitney	Century Engineering	Gannet, Fleming Corddry & Carpenter	Gibbs & Hill	Greiner Engineering
Years In Business	30*	2*	60	52	67
Years In Tunneling	36	15-20	25	5	25-30
% Of Business In Tunneling	<10%	<10%	<10%	<10%	<10%
Size Of Permanent Tunnel Staff	0	30**	0	0	0
No. Of Experienced Tunneling People	5+	30	10-15	15	15
No. Of Projects 1960-65 1965-70 1970-75	0 3 4	2 2 4	1 1 3	0 1 3	2-3 2-3 2-3
Project Type - Cut & Cover Earth Rock	Yes Yes Not recently	Yes Yes No	Yes Yes Minimal	Yes No Yes	Yes Yes Yes
End Use - Rapid Transit Vehicle Water Sewer Other	Yes Yes Overseas Yes No	Yes No Yes Yes No	Yes Minimal Yes Yes No	Yes No Yes No No	Yes Yes No No No
Role - Design Inspect Spec. Check Consultant	Yes Yes No No	Yes Some No No	Yes Yes No No	Yes Yes No No	Yes Yes No No

* Existing firm result of merger of older firms.
** Reflects firms 5 year involvement in WMATA.

Category III Name of Firm	Hayes-Seay-Mattern & Mattern	Hazelet & Erdal	Henningson Durham & Richardson	Howard-Needles Tammen & Bergendoff	International Engineering
Years In Business	29	78	58	61	30
Years In Tunneling	15+	30-35	10	15	30
% Of Business In Tunneling	<10%	<10%	<10%	<10%	10%
Size Of Permanent Tunnel Staff	0	0	0	1	3
No. Of Experienced Tunneling People	50	10	4-5	10-15	12
No. Of Projects 1960-65	5	1	0	5	8
1965-70	5	1	2-3	5	8
1970-75	6	3	5-6	5	8
Project Type - Cut & Cover	Yes	Yes	Yes	Yes	Yes
Earth	Prelim.Eng.Work	No	Yes	Yes	Yes
Rock	Prelim.Eng.Work	Some	No	Yes	Yes
End Use - Rapid Transit	Yes	Yes	Yes	No	Some
Vehicle	Yes	No	Yes	Yes	Yes
Water	Yes	Yes	Yes	Minimal	Yes
Sewer	Yes	No	Yes	No	No
Other	-	No	No	No	No
Role - Design	Yes	Yes	Yes	Yes	Yes
Inspect	Util.Tunnels	Yes	Some	No	Yes
Spec. Check	No	No	No	No	Yes
Consultant	No	No	No	No	No

Category III Name of Firm	Kaiser Engineers	Knorle, Bender Stone	MCA Engineering	McGaughy, Marshall & McMillan	C. E. Maguire
Years In Business	34	24	20	28	37
Years In Tunneling	30	19	13	12	19
% Of Business In Tunneling	10-25%	<10%	<10%	<10%	<10%
Size Of Permanent Tunnel Staff	0	8	0	0	0
No. Of Experienced Tunneling People	6-8+	15	6	6-10	25
No. Of Projects 1960-65 1965-70 1970-75	4 4 4	0 1 3	? 6 9	2 3 3- 4	6-8 1-2 5+
Project Type - Cut & Cover Earth Rock	Yes Yes Most	Yes Yes Yes	Yes Yes No	Yes Yes Minimal	Yes Yes Yes
End Use - Rapid Transit Vehicle Water Sewer Other	Yes Yes Yes No No	Yes Yes No Yes Yes	Yes No Yes Yes No	Yes Yes Minimal Minimal No	Yes Yes Yes Yes No
Role - Design Inspect Spec. Check Consultant	Yes Yes No No	Yes Minimal No No	Yes Yes No No	Yes Some No No	Yes Small No Yes

Category III Name of Firm		Charles T. Main	Ralph M. Parsons	Rummel Klepper & Kahl	Sanders & Thomas	Tippetts Abbett McCarthy & Stratton
Years In Business		75+	31	56	31	35
Years In Tunneling		40+	10-13	15	5	20-25
% Of Business In Tunneling		<10%	<10%	<10%	10-25%	10-25%
Size Of Permanent Tunnel Staff		0	3- 4	0	0	0
No. Of Experienced Tunneling People		30	10-15	15	60	15-20
No. Of Projects	1960-65 1965-70 1970-75	5 5 5	0 2+ 3+	2 4 5	0 0 4	3 4 5
Project Type -	Cut & Cover Earth Rock	Yes Yes Yes	Yes Yes Yes	Yes No No	Yes Yes Yes	Yes Yes Yes
End Use -	Rapid Transit Vehicle Water Sewer Other	Yes Yes Yes Yes No	Yes Foreign Foreign Foreign Yes	Yes Yes No Yes No	Yes Yes No Yes No	Yes Yes Yes No No
Role -	Design Inspect Spec. Check Consultant	Yes Yes No No	Yes Yes No No	Yes Yes No No	Yes No No No	Yes Yes No No

Category III Name of Firm		Tudor Engineering	URS/ Madigan Praeger	David Volkert & Assoc.	Westenhoff & Novick	Wiley & Wilson
Years In Business		25	47	50	15	52
Years In Tunneling		15	20+	20	2	15+
% Of Business In Tunneling		<10%	<10%	<10%	<10%	10%
Size Of Permanent Tunnel Staff		0	0	0	0	0
No. Of Experienced Tunneling People		6	6	25	4	3-5
No. Of Projects	1960-65 1965-70 1970-75	1 3 5	2-3 2-3 3-4	3 1 5	0 0 2	5 5 6-7
Project Type -	Cut & Cover Earth Rock	Yes Yes Yes	Yes Yes Yes	Yes Yes No	Prelim.Design Yes No	Yes Some Some
End Use -	Rapid Transit Vehicle Water Sewer Other	Yes No Yes No No	Yes Yes Yes Yes No	Yes Yes Yes No No	Yes No No No Utility	Yes No Yes Yes No
Role -	Design Inspect Spec. Check Consultant	Yes Yes No No	Yes Some No No	Yes Yes No No	Yes Yes No No	Yes Yes No No

Category IV Name of Firm	Lockwood-Kessler & Bartlett	Murphy Engineering	H. D. Nottingham & Assoc.	Vosbeck Vosbeck Kendrick & Redinger
Years In Business	41	9	20	8+
Years In Tunneling	23	3	3	2
% Of Business In Tunneling	<10%	<10%	<10%	<10%
Size Of Permanent Tunnel Staff	1	0	0	0
No. Of Experienced Tunneling People	1	5	10	1
No. Of Projects 1960-65 1965-70 1970-75	0 0 1	0 1 2	0 0 1	0 0 1
Project Type - Cut & Cover Earth Rock	No No Yes	Yes No No	Yes No No	No Yes No
End Use - Rapid Transit Vehicle Water Sewer Other	No No Yes No No	No No No No Pedestrian	Yes No No No No	Yes No No No No
Role - Design Inspect Spec. Check Consultant	Yes No No No	Yes Some No No	Yes No No No	Yes No No No

APPENDIX C

CONSTRUCTION CONTRACTING FIRMS IN TUNNELING

The firms listed in Chapter 10 as Tunnel Contractors are described in this appendix in more detail. Included here:

- Name of Company
- Headquarters Location
- Telephone Number
- Type of Ownership
- Corporate Affiliations
- Its Position on the 1975 ENR "400" List published by Engineering-News Record
- Number of Years in Business
- Number of Years in Tunnel Work
- Miles of Tunnels Driven
- Percentage of total business in tunnels
- Estimated tunnel-building revenue

The firms are arranged in alphabetical order and it is believed to be a complete list. All information was furnished by one or more people in each firm. Only contracting individual firms are included. Some contracts are awarded to a named joint venture entity but we have included such activity with the joint venture participant firms.

TUNNEL CONTRACTING FIRMS

Name of Company	Headquarters Location And Telephone	Company Owner-ship	Place On ENR 400	No. Years In Business Total	No. Years In Business Tunnels	Miles Of Tunnels Driven	% Total Bus. In Tunnels	Estimated $ Tunneling Yr.	Estimated $ Tunneling Amt.
American Structures, Inc.	Annapolis (301) 263-8881	Private		11	11	24	100%	1975 1974 1973	$ 15MM 11 10
Armco Steel Corp. Construction Div.	Middletown, Ohio (614) 451-4470	Parent is ARMCO Steel Corp. Public		40	40	150(?)	100% (Const. Div.)	1974 1973 1972	$ 35MM 30 25
John Artukovich & Sons	Paramount, Ca. (213) 636-3247	Private		57		-	10%	1975	$ 10MM
Arundel Corp.	Baltimore (301) 296-6400	Private		56	56	27	15%	1975	$ 1MM
Guy F. Atkinson Co.	S. San Francisco (415) 761-0600	Owns Walsh Const. Private	15	145	74	75-100	10%	1975 1974 1973	$ 80MM 20Est. 20Est.
Roger Au & Sons	Box 864, Mansfield, Ohio (419) 529-3213	Private		40	5	5		1974 1973	$ 2MM 2MM
Gordon Ball Inc.	Danville, Ca. (415) 935-2550	Subsidiary of Dillingham Corp.		23	7	15	33%	1975	$ 10MM
Balport Construction Co.	Elmsford, N.Y. (914) 592-9231	Private		22	4	1	6-8%	3yrs.	$200M/yr.
Bechtel, Inc.	Oakland, Ca. (415) 764-6504	Private	4	64	64	100	10%	1975 5yr. avg.	$100MM 50MM
Brown & Root, Inc.	Houston (713) 616-4481	Subsidiary of Halliburton Corp.	2	55	20	50	10%	1975 5yr. avg.	$113MM 20MM

TUNNEL CONTRACTING FIRMS

Name of Company	Headquarters Location And Telephone	Company Owner-ship	Place On ENR 400	No.Years In Business Total	No.Years In Business Tunnels	Miles Of Tunnels Driven	% Total Bus. In Tunnels	Estimated $ Tunneling Yr.	Estimated $ Tunneling Amt.
C.C. & T. Construction Co. (Subcontracting Only)	Luthersville, Md. (301) 252-2531	Private		17	17	18 (small)	100%	1974 1973 1972	$2.5MM 2.2 2.0
Capitol Tunneling Corp. (Formerly Hanson)	Columbus, Oh. (614) 294-5668			15	15	18	100%	1975 10 yr. average	$2MM 2MM
Andrew Catapano Co.	Glendale, N.Y. (212) 275-1100	Private		50	19	25	45%	1975 1974	$ 30MM 34
Cayuga Construction Co.	New York (212) 349-0560	Private		39	39	5	35%	1975	$ 20MM
Cementation Co. of America (Mine Shafts, Development & Grouting)	Brampton, Ont. (416) 451-1033	Subsidiary of Trafalgar Investments, London, England		15	-	75 shafts	-	5yr. avg.	$ 50MM/ yr.
Cooper Construction Co.	Mt. Clemmons, Mich. (313) 949-3444	Private		6	5	7	90%	1975 1974 1973 1972/1971/1970- $1MM Per Yr.	$ 7MM 4MM 3MM
Carl Decker Inc. (Also Builds Moles & Other Equipment)	Detroit (313) 892-2336	Private		26	10	20	-		-
DiMambro Contractors, Inc.	Oak Park, Mich. (313) 399-1600	Private		25	25	35	99% mostly sewers	1974	$ 4MM
Dravo Corp.	Neville Island, Pittsburgh	Public	32						

TUNNEL CONTRACTING FIRMS

Name of Company	Headquarters Location And Telephone	Company Ownership	Place On ENR 400	No. Years In Business Total	No. Years In Business Tunnels	Miles Of Tunnels Driven	% Total Bus. In Tunnels	Estimated $ Tunneling Yr.	Estimated $ Tunneling Amt.
Fred Early Co.	San Francisco, Ca. (414) 982-5262	Private		37	10		Less than 5%		
Eastern Tunneling Corp.	Columbia, Md. (301) 730-2440	Private		13	13	13 (small)	100%	3yr. avg.	$ 3MM/ yr.
Fattore Construction Co.	Warren, Mich. (313) 939-9400	Private		54	40	80	70%	1975 1974 1973	$1.1MM 1.1 0.2
Fenix & Scisson Inc. (Mostly Mine Shafts)	Tulsa, Okla. (918) 835-9471	Private		25	25	2-3 shafts per yr.	40%	1975	$ 6MM
Fluor-Utah Corp. (All Mine Development Now)	San Mateo, Ca. (415) 574-1111	Private	3	50	50	20 mi. in Peru	-	1975	$1.5 billion
Foley Bros. Inc.	St. Paul, Minn. (612) 224-4933	Private		105	-	20 mi. in recent yrs.	-		-
J. M. Foster Co.	Gary, Ind. (219) 949-4020			28	?	15	5%	Av.	$3MM
Frontier Constructors Inc.	Arvada, Nev. (812) 426-2741			10	8	5	100% (incl. shafts & mine devel.)	1975 1974 1973	$7-8MM 3 1.5
Fruin-Colnon Corp.	St. Louis, Mo. (314) 997-7750	Private		103	12	1(?)	5%		-
Don Gargaro Co.	Detroit (313) 544-2512	Private		40	30	12	90%	1975 1974 1973	$ 6MM 3MM -0-
Gates & Fox Co., Inc.	Loomis, Cal. (916) 652-7292	Private		27	27	54	100% incl. shafts & underground powerhouses	1975 1974	$ -0- 8MM

TUNNEL CONTRACTING FIRMS

Name of Company	Headquarters Location And Telephone	Company Owner-ship	Place On ENR 400	No. Years In Business Total	Tunnels	Miles Of Tunnels Driven	% Total Bus. In Tunnels	Estimated $ Tunneling Yr.	Amt.
Granite Con- struction Co.	Watsonville,Ga. (408) 722-2716	Private		52	15	15	25%	3yr. total	 $ 46MM
Green Con- struction Co.	Des Moines (515) 244-7251	Private		43	25	6	10%	1975 1974 1973	$ -0- -0- 3MM
Greenfield Con- struction Co.	Livonia, Mich. (313) 425-3900	Private		33	33	64	60%	1975 1974	$ 16MM 21MM
S.J. Groves & Sons Co.	Minneapolis (612) 338-6943	Private	53	70	10	24	10%	5yr. avg.	$ 10MM/ yr.
Grow Tunneling Corp.	New York (212) 586-1760	Subsidiary of Alpha Portland, Inc.		30	30	8-1/2	100%	1975 1974 1973	$ 25MM 20MM 15MM
Gunther-Nash Mining & Con- struction Co.	St. Louis (314) 261-2611	Subsidiary of J.S. Alberici		8	8	30 shafts, 12 slopes	90% shafts & slopes	1975 1974	$ 12MM 8MM
S. A. Healy Co.	McCook, Ill. (312) 242-2844	Private	320	53	53	300	90%	6yr. avg.	$ 30MM/ yr.
Intercounty Construction Corp.	Hyattsville,Md. (301) 779-9100	Private	134	43	35	4-5 recently	5%	1975 1974	$200M 20MM
Jay Dee Con- tractors	Livonia, Mich. (313) 427-4100			10	10	45	100%	1975 7 yr. Average	$10MM 10MM
Al Johnson Con- struction Co.	Minneapolis (408) 462-0600	Private	128	75	25	25	20%	1975 5yrs.	$ 9MM 10-15MM/ yr.
J. A. Jones Con- struction Co.	Charlotte (704) 364-6280	Private	18	85	25	40	zero now but would	1975	$ -0-

TUNNEL CONTRACTING FIRMS

Name of Company	Headquarters Location And Telephone	Company Ownership	Place On ENR 400	No. Years In Business: Total	No. Years In Business: Tunnels	Miles of Tunnels Driven	% Total Bus. In Tunnels	Estimated $ Tunneling: Yr. Amt.
Kassouf Construction Co.	Cleveland (216) 651-3333	Private		52	25	15	75%	1975 $ 4MM 1974 4MM $2MM/yr. prior 3 -4 yrs.
Kemper Construction Co.	Los Angeles (213) 870-4838	Private		53	53	150	95%	Est. $5-10MM
Kenny Construction Co.	Wheeling, Ill. (312) 775-0440	Private		46	40	35	35%	1975 $ 5MM 1974 6 1973 10
Peter Kiewit Sons Co.	Omaha (402) 342-2052	Private	25	91	22	38	20%	1975 $100MM 1974 30 5yr. avg.$20MM/yr.
LaFera Contracting Co.	Newark, N. J. (703) 979-1510	Private		42	30	12	10%	1974 $ 2MM 1973 23
C.J. Langenfelder & Sons	Baltimore, Md. (301) 682-2000	Private	270	53	15	28 highway tunnels	15%	1973 $ 28MM 1971 26
Lockheed Ship Building & Construction Co.	Seattle, Wash. (206) 932-1692	Subsidiary of Lockheed Corp.		12	10	10	50%	5yr. avg.$10MM/yr.
W. J. Lazinski Co.	Milwaukee (414) 781-8700	Private		61	51	100	95%	5yr. avg.$10MM/yr.
MacLean-Grove Co.	New York (212) 687-8996	Private		23	23	25	95%	1975 two new jobs 1974 $ 25MM 1973 10MM
McHugh Construction Co.	Chicago (312) 463-5790	Private		75	20	35	33%	5yr. avg.$10MM/yr.
Mancini Construction Co.	Warren, Mich. (313) 776-7300	Private		63	-	55	95%	1975 $1.5MM 1974 0.5MM 1973 0.5MM

TUNNEL CONTRACTING FIRMS

Name of Company	Headquarters Location And Telephone	Company Ownership	Place On ENR 400	No. Years In Business Total	No. Years In Business Tunnels	Miles of Tunnels Driven	% Total Bus. In Tunnels	Estimated $ Tunneling Yr.	Estimated $ Tunneling Amt.
Mergentime Corp. (The)	Flemington, N.J. (201) 782-0500	Private		7	7	2	65% mostly open-cut or cut & cover	1975 1974 1973	$ 2MM 4 5
Michigan Sewer Construction Co.	Detroit (313) 775-2490	Private		29	29	40	90%	1975 1974 1973	$ 10MM 4 4
Mole Construction Co.	Romulus, Mich. (315) 941-5300	Private		25	25	7-8	50%	1975 1974 1973	$ 3MM 3MM 2-3MM
Morrison-Knudsen Co., Inc.	Boise, Idaho & Darien, Conn. (208) 345-5000	Public	13	63	48	300	6%	1975 1974 10yr.	$ 40MM 30 avg.$15MM/yr.
Paschen Contractors	Chicago, Ill. (312) BR 8-4700			70	55	125	50%	1975 5 yr. Average	$ 40MM 10-12MM
Perini Corp.	Framingham, Mass. (617) 567-1834	Public	40	75	30	60	10%	1975 1974	$ 14MM 5MM
Pioneer Co. (Formerly Mountain States Construction Co.)	Charleston, W. Va. (304) 345-1910	Private		20	20	25	50%	1975 1974 1973	$ -0- -0- 2MM
Raymond International Inc. (Primarily Sunken Tubes)	Houston (713) 623-1107	Public	41	80	30	15	15-20%	15yr.	avg.$20/MM
Reliance Underground Construction Co.	Elk Grove Village, Ill. (312) 437-6300	Private		25	25	50	50%	1975 5 yr. avg.	$ 2.5MM 1.5MM

TUNNEL CONTRACTING FIRMS

Name of Company	Headquarters Location And Telephone	Company Ownership	Place On ENR 400	No. Years In Business Total	No. Years In Business Tunnels	Miles of Tunnels Driven	% Total Bus. In Tunnels	Estimated $ Tunneling Yr.	Estimated $ Tunneling Amt.
S & M Constructors	Solon, Ohio (216) 248-0376	Private		11	11	32.5	95%	1975 1974 1973	$ 15MM 21MM 10MM
J. E. Seiben Inc.	Leawood, Kan. (816) 795-8130	Private		11	6	4	35%	1975 1974 1973	$ 16MM 6MM 2MM
J. F. Shea Co.	Walnut, Cal. Wash., D. C. (714) 595-7432	Private		75	50	-	33%	1975 5yr.	$137MM avg.$20MM/yr.
Slattery Associates (Highways, Bridges, Foundations)	Maspeth, N. Y. (212) 392-2400	Subsidiary of Alpha-Portland Inc.	47	48	-	-	very little		-
Square Construction Co.	Baltimore (301) 732-3456	Private		43	43	70	75%	1974 1973	$ 2MM 23MM
J. Rich Steers, Inc.	New York (212) 943-3500	Private	188	62	8	15	30%	1975	$ 14MM
Nello L. Teer Co. (Highway, Little Tunnel Work)	Durham, N.C. (919) 682-6191	Private	78	66	1935 to 1945	1	Building $30MM WMATA Section		$ -0-
Thalle Construction Co.	Briar Cliff Manor, N. Y. (914) 762-3415	Private		30	6	2	15%	1975 3yr.	$ 2MM avg.$1MM/yr.
Tidewater Construction Co.	Norfolk, Va. (804) 420-4140	Private		40	40	10-12 Sunken Tube & Open Trench	5-50%	1975 1974	$ 20MM 40MM
Tomaro Contractors, Inc.	Cudahy, Wisc. (414) 481-4000	Private		50	25	20	-	1975 5yr.	$11.5MM avg.$5MM/yr.
Traylor Bros. Inc.	Evansville, Ind. (812) 477-1542	Private	277	29	24	40	50%	1975 1974 1973	$ 27MM 28MM 12MM
Walsh Construction Co.	Darien, Conn. (203) 655-7711	Subsidiary of G.F. Atkinson		76	50	60.75	20%		-

APPENDIX D

CAPACITY OF CONSTRUCTION CONTRACTING FIRMS IN TUNNELING

Contractor capacity has several boundaries. As reported in the study, a crucial one is having the needed key people available in the right numbers. Contractor experience in prior jobs plus its financial resources has a great deal to do with its bonding support and its job size capacity. One way to increase capacity is via joint ventures with other contractors.

Some contractors have the desire, resources and know-how to operate over a broad geographical area while others prefer to restrict themselves to specific regions. These preferences affect the supply of contractors. So, too, do the prevailing labor practices and customs. Comparative information about these capacity matters is presented in this appendix for all Tunnel Contractors listed in Chapter 10.

The source of the information is contractor employees.

TUNNEL CONTRACTOR CAPACITY

Name of Company	Tunnel Staff 1965	Tunnel Staff 1975	Largest Job On Own	Smallest Job Acceptable	History of Joint Ventures	Union or Open Shop	Geographic Operating Areas
American Structures, Inc.	1	26	$ 18MM	$ 1.5MM	Twice with M-K	-	Eastern
Armco Steel Corp. Construction Div.	50	150	No Limit	?	None	Mostly Union	National
John Artukovich & Sons	3	3	$ 35MM	$250MM	On Large Jobs, yes, but not recently	Union	West Coast
The Arundel Corporation	10	10	$ 20MM	$100M	Approx. 20 in recent years, mostly L. E. Dixon	Union	Mid-Atlantic
Guy F. Atkinson Co.	3 or 4	7	$ 50MM	$ 1MM	Yes, two recently	Union	International
Roger Au & Sons	-0-	5	$ 75MM	$ 1MM	None	Open	Great Lakes
Gordon Ball, Inc.	-0-	20	$ 25MM	$ 1MM	Ten recently	Union	National
Balport Construction Co.	6	6	$ 12MM	$ 25MM	None	Union	Eastern
Bechtel, Inc.	50	100	No Limit	$ 10MM	Seldom	Union	National
Brown & Root, Inc.	12	6	$ 20MM	$ 4MM	Ten recently	Open	National
C. C. & T. Construction Co.	10	10	$ 1MM	$ 10MM	Solely sub-contractor	Both	Eastern
Capitol Tunneling Corp.	4	5	$500M	$ 1M	None	Union	
Andrew Catapano Co.	-	-	$200MM	$250MM	Nearly always	Union	Eastern

Name of Company	Tunnel 1965	Staff 1975	Largest Job On Own	Smallest Job Acceptable	History of Joint Ventures	Union or Open Shop	Geographic Operating Areas
Cayuga Construction Co.	10	25	$ 10MM	$500MM	3 in recent years	Union	Eastern
Cementation Co. of America	35	75	No Limit	$ 10M	None	70% Union 30% Open	International
Cooper Construction Company	0	5	all jobs joint ventures with C. J. Rogers of Flint, Michigan	$1/2M	ALL	Union	Great Lakes
Carl Decker Inc.	8-9	6	Now mostly making equipment		A few	Open	-
Di Mambro Contractors, Inc.	2	12	$ 12MM	$300MM	8 in recent years	Union	Michigan & W. New York
Dravo							
Driscoll Construction Co.	7	7	$ 25MM	$ 1M	None but would	Union	Mid-Atlantic
Fred Early Co.	10 subway stations & some sewer work	0	N/A	N/A	No Tunnel Work with-out joint venture	Union	National
Eastern Tunneling Corp.	3	8	$ 6MM	$ 50M	None but would	Open	Eastern
Fattore Construction Co.	8	5	-	-	Occasionally	-	Great Lakes
Fenix & Scisson, Inc.	30	200	$ 10MM	$700M	2 in recent years	Both	National
Fluor-Utah Corp.	-0-	40	No Limit	$ 5M	3 recently	Union	Western
Foley Bros., Inc.	6	6	-	-	6 recently	Union	N.W. & Canada

Name of Company	Tunnel Staff 1965	Tunnel Staff 1975	Largest Job On Own	Smallest Job Acceptable	History of Joint Ventures	Union or Open Shop	Geographic Operating Areas
J. M. Foster Co.	5	5	No limit	$250M	3 recently	Union	
Frontier Constructors, Inc.	-0-	10	$ 2MM	$300M	Only with Kemper	Both	Western
Fruin-Colnon Corp.	4	-0-	$ 20MM	$ 2MM	10 recently	Union	National
Don Gargaro Co.	4	7	$ 4MM	$400M	2 recently	Union	Great Lakes
Gates & Fox Co., Inc.	5	15	$ 30MM	$500M	As sponsor	Union	National
Granite Construction Co.	5	25	$ 35MM	$ 3MM	12 recently	Union	National
Green Construction Co. (Specializes in earth moving)	3	3	$ 25MM	$ 3MM	Always, on large tunnel projects	Union	National
Greenfield Construction Co.	2	5	$ 20MM	$ 3MM	3 (Healy, Corridor & Ball)		Great Lakes
S. J. Groves & Sons, Inc.	-0-	5	$ 25MM	$ 1MM	5 recently	Union	National
Grow Tunneling Corp.	10	20	$ 20MM	$100MM	Nearly all	-	New York
Gunthur-Nash Mining & Construction Co.	-0-	35	$ 20MM	$500MM	No but would	Both	Midwest
S. A. Healy Co.	20	40	$ 60MM	$ 5MM	Almost always	Union	National
Intercounty Construction Corp.	10	10	$ 50MM	$200MM	10 in recent years	Union	Mid-Atlantic
Jay Dee Contractors	0	8-10	$ 5MM	$500M	3 recently	Union	Chicago Area
Al Johnson Construction Co.	10	25	$ 60MM	$ 1.5MM	10 in recent years	Union	National
J. A. Jones Construction Co.	?	A few	No Limit	$ 20MM	5 recently	Union	International

Name of Company	Tunnel Staff 1965	1975	Largest Job On Own	Smallest Job Acceptable	History of Joint Ventures	Union or Open Shop	Geographic Operating Areas
Kassouf Construction Co.	-0-	3	$ 20MM	$ 50MM	3 recently	Union	Great Lakes
Kemper Construction Co.	10	10	$ 50MM	$ 1MM	12 recently	Both	Western
Kenny Construction Co.	25	40	$ 30MM	$500M	Often	Union	Midwest
Peter Kiewit Sons Co.	18	35	$ 50MM	$ 1MM	10 in recent years	Union	National
La Fera Contracting Co.	2	6	$ 10MM	-	Always	Open	Eastern
C. J. Langenfelder & Sons	30	7-15	$ 50MM	$ 1MM	Seldom	-	Mid-Atlantic
Lockheed Shipbuilding & Construction Co.	-0-	10	No Limit	$ 1.5MM	2 recently	Union	Western
W. J. Lazinski, Inc.	45	45	$ 30MM	$500M	Never, so far	Union	Wisconsin
McHugh Construction Co.	10	10	$ 40MM	$300M	Seldom	Both	National
MacLean-Grove Co.	6	8	$ 25MM	$ 5MM	Almost all	Union	Mostly New York
Mancini Construction Co.	5	6	$ 20MM	$100M	7 in recent years	Union	Great Lakes
The Mergentime Corp.	-0-	3	$ 12MM	$ 50M	4 in recent years	Union	Mid-Atlantic
Michigan Sewer Construction Co.	5	20	$ 30MM	$ 1M	Seldom	Union	Great Lakes
Mole Construction Co.	5	10	$ 15MM	$500M	Seldom	Both	Great Lakes
Morrison-Knudsen Co., Inc.	45	70	$ 50MM	$ 5MM	Frequent; 65% recently	Union	International
Paschen Contractors	0	28	$ 40MM	$500M	1 recently	Union	Chicago
Perini Corp.	15	5	No Limit	$ 50M	12 recently	Union	International

Name of Company	Tunnel Staff 1965	Tunnel Staff 1975	Largest Job On Own	Smallest Job Acceptable	History of Joint Ventures	Union or Open Shop	Geographic Operating Areas
Pioneer Co.	-	20(?)	$ 15MM	$ 1MM	4 recently	Union	Eastern
Raymond International, Inc.	5	5	No Limit	$500M	10 recently	Union	International
Reliance Underground Construction Co.	10	30	$ 3MM	$500M	Seldom	Union	Chicago
S & M Contractors	2	18	$ 30MM	$ 2MM	3 recently	Union	Eastern
J. E. Seiben, Inc.	3	12	$ 5MM	$100M	None but would	Union	Midwest
J. F. Shea Co.	3	20	$100MM	$ 2MM	None at present but 8 in recent years	Union	National
Slattery Associates	-0-	-0-	$ 70MM	$500M	6 recent yrs.	Union	Eastern
Square Construction Co.	6	10	$ 15MM	$250M	8 recently	-	Mid-Atlantic
J. Rich Steers, Inc.	-0-	18	$ 60MM	$ 5MM	8 recently	Union	Mid-Atlantic
Nello L. Teer Co.	-0-	-0-	No Limit	-	M-K in San Salvador	Open	International
Thalle Construction Co.	-0-	10	$ 5MM	$250M	1 recently	Union	Northeast
Tidewater Construction Co.	10	12	$ 20MM	$ 20M	7 in recent years	Union	National
Tomaro Contractors, Inc.	2	4	$ 15MM	$200M	Seldom	Union	Milwaukee
Traylor Bros., Inc.	15	20	$ 25MM	$500MM	4 recently	Union	Midwest & West
Walsh Construction Co.	25	25	$ 50MM	$ 50M	6 recently	Union	National

APPENDIX E

SUPPLIER SUPPORT FOR BIDDING

Specialized equipment suppliers in the mine and tunnel industries frequently provide considerable assistance to contractors in the preparation of bids. Larger suppliers, or those with narrow product lines, usually confine their help to providing a quotation of price and terms and sharing information in phone conversations.

Smaller equipment and service suppliers, especially those involved in fabricating custom equipment, often journey to job sites, study bid specifications, and offer suggestions to contractors on alternate ways to accomplish various objectives. One supplier furnished copies of material he sends to all firms on a proposed job who are prospective bidders (have made a bid deposit or specifically requested quotes for equipment).

In most cases the contractor who wins the award will split his business among several suppliers, even though one might be able to furnish all of the equipment. It appears that the customary long-term considerations of maintaining competitive sources and supplier goodwill are not dominant reasons for this practice. Rather, the supplier representatives, are regarded as sources of free technical advice and trade intelligence. Splitting the order provides a contractor with access to several such people rather than just one.

On the pages that follow are the details of equipment quotes furnished to bidders.

SUBJECT: Irondequoit Bay, Monroe County, N. Y.

Gentlemen:

Bids are to be taken April 20, on about 30,800 lineal feet of tunnel, 12' ID to bore 13'8", which includes 4" for misalignment. I believe you will require two Moles, one working south from the Pumping Station (16,500') and one working south from Shaft #3, (14,300'), both working "up hill", although this tunnel is nearly flat.

Assuming maximum progress of 12' per hour (happy day!) you will product 96-cyd of loose muck per hour. We propose a 6-cyd Car which means you will fill an eight-car train every 30 minutes. We must be able to hoist a 6-cyd Skip in less than 3-3/4 minutes.

HAULAGE. Based on three 8-car trains, you will need 24 Cars per heading. The Cars and Car Dumper are shown on Drawing B-1272A.

24 -	Side Dump Cars, 6-cyd capacity x 30" gauge as shown on Drawing B-1272A. With 14" wheels, Timken bearings and Mayo Rotary Couplers @ $2,320 ea. ..... (Weight on one about 3 tons)	$55,680.00
4 -	Flat Cars, same as Muck Cars except with wood deck, 4'6" x 10' @ $1,205 ea. ... (Weight on one 2200#)	4,820.00
2 -	Brookville Diesel Locomotives, 8-ton x 30" gauge with Cat D330C Engine, Twin Disc 1300 Torque Converter, Electric lights and starter. May Rotary Couplers and Exhaust Scrubber @ $17,500 ea.	35,000.00
2 -	Tool Trays and Reflectors for Locomotive @ $350 ea.	700.00
	TOTAL, F.O.B. OUR SHOP OR BROOKVILLE	$96,200.00

ROTARY CAR DUMPER. (Brand) Rotary Car Dumper, a very compact unit, is shown on B-1272A and you will note that you can dump an entire train, one at a time, without uncoupling. You will need one at each working shaft.

1 -	Rotary Car Dumper, complete as shown on Drawing B-1272A, including electric pump .... (Weight about 6 tons)	$ 8,300.00

CALIFORNIA SWITCH. We propose to supply two California Switches, wheel-mounted as shown on A-517N. These will be of 40# rail, 30" gauge with a 5'0" track center. There will be a diamond turnout on one end only and incline to the main line track. There will be 120 feet of double track, enough to load an entire eight-car train. If you use a "tripper" on the belt you can eliminate a locomotive standing by to switch cars.

1 - California Switch, mounted on 10" wheels, of 40# rail for 30" gauge track including one turnout, spring throw, incline points and 120 feet of double track............................$10,600.00
(F.O.B. Pomeroy, Ohio: Wt. about 11 tons)

KOEPE HOIST. We propose to furnish a Koepe Hoist as shown on D-1436A which has a 6-cyd Skip and a Cage 5'0" X 11'0". This will be almost identical to the one we supplied to Perini at Roxbury EXCEPT THAT WE INCLUDE A 6-CYD MEASURING POCKET AT FOOT OF SHAFT.

1 - Headframe, as shown on Dwg. D-1436A, 7'6" X 17' X 66' high, including ladders and wind-leg...................................$12,600.00
(Wt. about 16 tons)
1 - Hoist House and Operator's Booth..........$ 2,650.00
(Wt. about 2 tons)
1 - Muck Skip, Kimberly Type, 6-cyd capacity..$ 4,000.00
(Wt. about 7000#)
1 - Cage, 5'0" X 11'0" with Safety Dogs for four wood guides..........................$ 4,850.00
(Wt. about 5200#)
1 - Counterweight, consisting of cast iron slabs in a steel frame....................$ 3,700.00
(Wt. about 21,000#)
1 - Set of six Hoisting Cables including clips and thimbles........................$ 1,600.00
(Wt. about 1 ton)
1 - Measuring Pocket, 6-cyds, with air-operated gate.............................$ 6,650.00
(Wt. about 6 tons)
1 - Muck Bin, 33-cyd capacity, including air-operated undercut gate................$ 9,500.00
(Wt. about 10 tons)

TOTAL, F.O.B. OUR SHOP, ONE SHAFT.......$45,550.00

The above price does not include the hoist itself. We propose to furnish a 60 HP DC motor with variable speeds from 60 fpm to 125 fpm. Included is a M-G set or rectifiers to generate the DC current. Also included are the push buttons, limit switches and other necessary items. The price is $37,500 F.O.B. Baltimore and the weight is about 6 tons.

STEEL GUIDE FRAME. Attached Sketch A-519A shows a Steel Guide Frame for a 15' dia. Shaft. At Roxbury the contractor installed the Buntons himself. I belive it would be better and cheaper to build this all steel Guide Frame which could be assembled on the surface in 28' lengths and lowered into the hole. This runs from the Collar to the bottom of the Sump. We include the caged ladder but not the wood guides.

1 - Guide Frame and Ladders for Shaft #3,
about 115 OAL................................$12,550.00
(Wt. about 17 tons)
1 - Guide Frame and Ladders for Pumping
Station Shaft, about 80' OAL.................$ 9,025.00
(Wt. about 12 tons)

STEEL FORMS. Proposed Full-Round Telescopic Steel Forms are shown on Drawing B-1275A. We propose to furnish 160 lineal feet and one Traveler. These Forms will be built in 20' units and the traveler will be fully hydraulic, including hydraulic drive on one pair of wheels.

160 Lineal Feet (8 - 20' units) of Full-Round
Telescopic Steel Form, 12' diameter as
shown on B-1275A, with Leg Bolts............$72,560.00
(Wt. about 76 tons)
1 Extra 20' unit of Invert Form...............$ 1,875.00
(Wt. about 2 tons)
1 Traveler, to telescope a 20' section,
Arch and Invert, of above Forms. Completely
hydraulically operated including electri-
cally driven pump...........................$ 8,530.00
(Wt. about 4-1/2 tons)

TOTAL, F.O.B. OUR SHOP....................$82,965.00

OTHER SIZES. The contractor is offered the option of driving a tunnel 12' ID, 14' ID or 16' ID. Even with the larger tunnel I doubt if you can exceed 96 cyd/hr of loose muck. For the present you can proportion the cost of the Forms if you elect to bid a larger diameter.

Hoping that this will aid you to the successful bid, I remain

Yours very truly,

Encls: Engineering Drawings
B-1272A - B-1275A
D-1436A
A-517N - A-519A

Example No. 2 SUBJECT: Drill Jumbo East River Mountain Tunnel Virginia-West Virginia

This job will be bid on June 10. Two highway tunnels, each 5,400 feet in length, will be driven from the Virginia end.

RAIL MOUNTED JUMBO. You have all seen (I hope) our Drill Jumbos working at Big Walker. These are well described in Contractors and Engineers Magazine, January, 1969.

2 - Rail mounted Drill Jumbos, very similar to those on Big Walker with provisions for 9 boom-mounted drills @ $22,500 each. $45,000.00
(Weight on one Jumbo about 40 tons)

We do not include the wood decks nor the rails. We do include the hydraulic rams for raising the "wings" but not the hydraulic pump nor hoses.

RIB SETTER. This job will have 10"-33# steel ribs which are big and heavy. We would like to supply a rib-setting device for handling and setting the steel. There will be two I-Beams running the full length of the Jumbo with three trolleys and 1-ton chain hoists on each side to move and set the legs. On the top deck, at the rear end, will be a storage rack for holding the roof beams. There will be a small traveling car to carry a pair of ribs from the storage rack to the front end. In this carriage is mounted two air rams for raising the half-ribs until they can be bolted. No air hoses.

2 - Steel Setting Devices consisting of two I-Beams, six trolleys, storage rack and arch setting carriage @ $4,500 each. .... $ 9,000.00
(Weight on one complete unit 3 tons)

TRUCK-MOUNTED JUMBO. As an alternate we can offer a Truck-Mounted Jumbo as shown on our Drawing C-1492. There will be two of these units, working side by side, each carrying five booms. On completion of the drilling cycle, these rigs are backed out of the tunnel and into the other heading. These are shown on "Euke" trucks which we do not furnish.

2 - Truck-Mounted Drill Jumbos as shown on Drawing C-1492 enclosed, each to carry five boom-mounted drills. Including hydraulic rams for wings but no hydraulic pump, hoses nor wood @ $19,745 each. $39,490.00
(Weight on one unit about 28 tons)

All prices quoted are F.O.B. our shop. We do not include the booms, drills, hoses nor hydraulic pumps or manifolds. We do include air and water manifolds for both Jumbos.

RIB SETTER. If you use Eukes, I would suggest you set the steel with a "cherry picker" but you should have a truck with a platform so that the miners can reach the crown of the tunnel to set lagging and collar braces.

Very truly yours,

Example No. 3. Subject: SINKING FRAME - OZARK LEAD COMPANY

Gentlemen:

The Ozark Lead Company will take bids January 25 on one shaft at Ellington, Missouri. This shaft is 20' ID, 23' OD and 1420' deep.

The permanent Head Frame is supposed to be used for sinking but there is a possibility that it will not be ready in time, therefore I am quoting on a Sinking Frame and all the other equipment required. I am breaking down this quotation so that, if you do have the permanent Head Frame, you can pick out the items you will require.

1 - Sinking Frame, 10' x 22' x 65' high, as shown on D-1503 including cages, ladder and three 24" sheaves at the top for handling the stage ropes.....$ 8,500.
(Wt. about 17 tons)

1 - 60" dia. Sheave roller bearing, pedestal mounted....$ 1,250.
(Wt. about 1300 lbs.)

1 - Kibble Dumper including chute and bent. With two 8" rams and one Solenoid Valve. No hose............$ 5,750.
(Wt. about 5-1/2 tons)

1 - Pair of Shaft Doors, to give clear opening 7'6" x 8'8", including two 6" rams and two Solenoid valves, no hose....................................$ 2,750.
(Wt. about 4,500 lbs.)

2 - 3 cyd Kibbles, 5' dia. x 4'4" deep with chain bail and dingle ball @$1,325 each........................$ 2,650.
(Wt. on one about 2800 lbs.)

1 - Detaching Gilley for rope guides including "torpedo" for 1-1/8" hoist rope....................$ 650.
(Wt. on one about 800 lbs.)

1 - Galloway Stage, with two decks, 10' cc, to pass Forms of a 20' ID shaft. Including four 24" sheaves for stage ropes. No decking...............$ 3,300.
(Wt. about 10,000 lbs.)

TOTAL, F.O.B. OUR WORKS EASTERN PENNSYLVANIA...........$24,850.

We have recently shipped several Sinking Frames into Missouri and from our experience we believe that the trucking bill will amount to about $1500.

SHAFT JUMBO: Attached photograph shows a Drill Jumbo which we recently built for Muddy Run. We are quoting you on a folding jumbo as shown on C-1398, using the same equipment which was furnished on Arundel's job.

1 - Shaft Jumbo, as shown on C-1398, including four Gardner-Denver drifters DH99, four jibs, etc., with two hydraulic pumps, mounted on a 12" pipe supported on four folding legs.
Including hoses and oilers.................. $55,000.00

This price is F.O.B. our shop, trucking to job will be about $450.

This does not include the assembly of the jibs, drills and hoses which will have to be done on the site.

Very truly yours,

BOND CAPACITY REGULATION

The limit on size of a single performance or payment bond which any insurer (surety company) can issue is ten percent of its combined equity and reserves. For the convenience of owners, and as a control for federal commitments, the U. S. Treasury publishes annually a list of companies and their bonding limits.

Titled Surety Companies Acceptable on Federal Bonds, the circular is issued in July as part of the Federal Register. It is compiled by the Bureau of Government Financial Operations, Fiscal Service, U. S. Treasury. The 1975 issue, which is illustrated in sample on the next two pages, listed firms and their underwriting limits, states in which licensed, and states in which they're incorporated or have process agents.

The full discussion of bonding practices is included in Chapter 11 and bonding problems are discussed in Chapter 12. Exhibit F-A below compares the 1975 versus 1974 underwriting limitations on twelve companies selected at random.

EXHIBIT F-A

CHANGES IN UNDERWRITING LIMITATIONS

	COMPANY & PRINCIPAL OFFICE	1975 limit ($000)	1974 limit ($000)
1.	American Bonding Company Los Angeles, Calif.	79	83
2.	American Casualty Company of Reading Reading, Pa.; Chicago, Ill.	3,159	5,084
3.	American Credit Indemnity Co. of N. Y. Baltimore, Md.	1,712	2,427
4.	The American Druggists' Insurance Co. Cincinnati, Ohio	173	340
5.	American Economy Insurance Company Indianapolis, Indiana	3,470	2,396
6.	American Empire Insurance Company Watertown, N. Y.	1,289	2,118
7.	American Employers' Insurance Company Boston, Mass.	3,665	6,290
8.	American Fidelity Company Manchester, N. H.	418	447
9.	American Fidelity Fire Insurance Company Woodbury, N. Y.	524	687
10.	American Fire and Casualty Company Hamilton, Ohio	739	782
11.	American and Foreign Insurance Company New York, N. Y.	793	1,734
12.	American General Insurance Company Houston, Texas	16,880	35,552

federal register

THURSDAY, JULY 10, 1975

WASHINGTON, D.C.

Volume 40 ■ Number 133

PART III

DEPARTMENT OF THE TREASURY

Fiscal Service, Bureau of Government Financial Operations

■

CIRCULAR 570; 1975 REVISION

Surety Companies Acceptable on Federal Bonds

Names of companies and locations of principal executive offices	Underwriting limitations (net limit on any one risk) in thousands of dollars. [See note (b)]	States and other areas in which licensed to transact surety business. [See note (c)]	State or other area in which incorporated (in capitals), and judicial districts in which process agents have been appointed (letters preceding names of States indicate judicial districts). [See note (d)]
American Bonding Company, Los Angeles, Cal.	79	Alaska, Ariz., Ark., Cal., Colo., D.C., Idaho, Iowa, Kans., Miss., Mo., Mont., Nebr., Nev., N.Mex., Oreg., Utah.	NEBR.--Alaska, Ariz., Ark., nesCal., Colo., D.C., Idaho, Iowa, sMiss, Mo., Mont., Nev., N.Mex., Oreg., Utah, wWash.
American Casualty Company of Reading, Pennsylvania, Chicago, Ill.	3,159	All except C.Z., Guam, Virgin Islands--------	PA.--All except Guam, Virgin Islands.
American Credit Indemnity Company of New York, Baltimore, Md.	1,712	Cal., Colo., Conn., Del., Ill., Ind., Iowa, Me., Md., Mass., Minn., Mo., N.H., N.J., N.Mex., N.Y., N.C., Ohio, Okla., Pa., R.I., Vt., Wash., W. Va.	N.Y.--D.C.
The American Druggists' Insurance Company, Cincinnati, Ohio	173	Ala., Fla., Ga., Ill., Ind., Iowa, Ky., Md., Mich., Miss., N.Y., N.C., Ohio, Tenn., Tex., Va., W.Va., Wis.	OHIO--D.C.
American Economy Insurance Company, Indianapolis, Ind.	3,470	All except C.Z., Conn., Guam, Hawaii, Mass., N.J., Puerto Rico, Virgin Islands.	IND.--All except C.Z., Guam, Puerto Rico, Virgin Islands.
American Empire Insurance Company, Watertown, N.Y.	1,289	All except Alaska, C.Z., Guam, Puerto Rico, Virgin Islands.	N.Y.--Ariz., Cal., Colo., Conn., Del., D.C., eIll., sInd., nIowa, Ky., Me., Md., Mich., Minn., Mont., Nebr., N.H., N.J., N.Mex., N.Dak., nOhio, Pa., R.I., S.Dak., Tenn., Utah, Vt., wWis.
American Employers' Insurance Company, Boston, Mass.	3,665	All except Guam, Puerto Rico-----------------	MASS.-All except Guam.
American Fidelity Company, Manchester, N.H.	418	Conn., Iowa, Me., Mass., Miss., N.H., R.I., Vt.	VT.--All except C.Z., Guam, Kans., Puerto Rico, Virgin Islands.
American Fidelity Fire Insurance Company, Woodbury, N.Y.	524	All except Alaska, C.Z., Colo., Guam, Hawaii, Kans., Mo., Nebr., N.H., Virgin Islands.	N.Y.--Ariz., Cal., D.C., nGa., Idaho, nIll., La., Md., Mich., Mont., Nev., N. Mex., Oreg., Puerto Rico, Utah, eVa., Wash., Wis.
American Fire and Casualty Company, Hamilton, Ohio	739	Ala., Ark., Colo., D.C., Fla., Ga., Kans., Ky., La., Md., Miss., Mo., N.C., Okla., S.C., Tenn., Tex., Va.	FLA.--Ala., Ark., Colo., D.C., Ga., Kans., Ky., La., Md., Miss., Mo., N.C., Okla., S.C., Tenn., Tex., Va.
American and Foreign Insurance Company, New York, N.Y.	793	All except C.Z., Del., Guam, La., Oreg., Puerto Rico, S.C., Va., Virgin Islands.	N.Y.--D.C., Tex.
American General Insurance Company, Houston, Tex.	16,880	Mich., Pa., Tex.---------------------------	Tex.--All except Guam, Puerto Rico, Virgin Islands.

APPENDIX G

SCHOOLS CURRENTLY PROVIDING TUNNEL ENGINEERS

In our survey of 41 engineering firms and 105 contractors, we asked where and how they obtain their new engineers. This included questions about the schools from which their new engineers graduated, with emphasis on fairly recent graduates (approximately 0-6 years out of school).

It should also be noted that experienced engineers and contractors prefer bachelor-level graduates, preferring advanced study to occur after some years of experience. It is the contention of these industry people that the school faculties prefer to have the students continue graduate school directly after undergraduate years and that there is a growing communication problem between industry and the schools. We did not study this, as it was outside the scope of this report, but we do note similar industry allegations in several other fields where we are active.

On the following pages, the schools mentioned are listed in alphabetical order.

SCHOOLS PROVIDING TUNNEL ENGINEERS

	NO. OF ENGINEERING FIRMS*	NO. OF CONTRACTORS*
Polytechnic Institute of Baltimore	1	
Bradley University	1	
Brown University		1
John Brown University	1	
University of Buffalo	1	
U. C. L. A.	3	
California Polytechnic Institute	1	
University of California - Berkeley	7	
Carnegie Mellon University	3	
Case Institute		1
University of Cincinnati	2	
Clarkson University		1
Clemson University		2
Colorado School of Mines	3	3
Columbia University	2	
University of Connecticut	1	
Cooper Union College	2	
Cornell University	1	2
University of Delaware	2	1
University of Detroit		1
Drexel University	1	
Duke University		1
Erie Community College	1	
Fairleigh Dickenson	1	
University of Florida		2
Fordham University		1
Georgia Technical Institute	4	3
Harvard University	2	
Johns Hopkins University	3	1
University of Houston		1
University of Idaho		1
University of Illinois	6	1
Illinois Institute of Technology	2	2
Iowa State University	2	2
University of Iowa	1	
University of Kansas	2	

	NO. OF ENGINEERING FIRMS*	NO. OF CONTRACTORS*
Kansas State University	2	
University of Kentucky	1	
Lehigh University	3	3
Louisiana State University	1	
University of Louisville	1	
Lowell University	1	
MacKay School of Mines		1
University of Maine	1	
Manhattan College	5	5
Marquette University		4
University of Maryland	5	1
University of Massachusetts		1
Massachusetts Institute of Technology	5	2
University of Michigan	1	
University of Minnesota	2	3
Mirville University	1	
University of Missouri	4	1
University of Nebraska	2	
University of Nevada	1	
New Jersey Institute of Technology	2	
City University of New York	2	2
New York Polytechnic Institute	4	2
State University of New York	1	1
North Carolina State	2	2
University of North Dakota	1	
Northeastern University	4	1
Northwestern University	2	
Notre Dame University	2	
Ohio State University	1	3
Old Dominion University	2	
Oregon State University		1
Pennsylvania State University	3	2
University of Pittsburgh	2	
Pratt Institute	1	
Purdue University	5	1
Rensselaer Polytechnic Institute	2	1
Rolla School of Mines		2
Rutgers University	1	
San Jose State College	2	

	NO. OF ENGINEERING FIRMS*	NO. OF CONTRACTORS*
University of Southern California	3	
Stanford University	7	6
Southwestern Institute of Technology	1	
Stevens Institute of Technology	1	3
University of South Dakota		2
Syracuse University		1
Texas A & M University		2
Texas University		1
Tufts University	2	
Valparaiso University	1	
University of Virginia	4	
Virginia Polytechnic Institute	6	2
Virginia Military Institute	2	2
Villanova University	1	
University of West Virginia		1
West Virginia Tech		1
Washington University	3	
George Washington University	1	
University of Wisconsin	1	2
Worcester Polytechnic Institute	1	

*Numbers denote number of engineering firms and contractors hiring engineers for tunneling work, not the number of engineers hired.

APPENDIX H

INDUSTRY COMMENTS

During our interviews we asked contractors their opinions of OSHA and MESA and about the industry's needs for research and development.

OSHA AND MESA

These comments have to do with the impact or effect of the Occupational Health and Safety Act and its administration. The MESA references are to the separate Mine Safety group which is part of the Department Of The Interior, Bureau Of Mines. OSHA is part of the U. S. Department Of Labor.

Exhibit F-1 RANGE OF COMMENTS ABOUT OSHA

Number of contractors in each general category

Believe it is a good thing and working well	Some minor problems, but not serious	Believe it is causing major problems
41	21	6

Of 68 contractors who commented, 60% think OSHA regulations are a good idea. Nearly all of them felt that the inexperience of inspectors has been a problem but time and experience presumably will help that. Over twenty contractors felt that state inspection using the OSHA code would be an improvement but one spoke vociferously in behalf of federal over state.

MESA was blasted by several as having incompetent inspectors in most areas and there appears to be either confusion or contradiction between OSHA and MESA rules. Of the half-dozen who mentioned MESA, none was complimentary or neutral.

Several contractors who have long records of good safety practice felt that a positive aspect of the program is the control or elimination of the slipshod competitor who cuts costs and prices by gambling on safety. Several wished there was more emphasis on the safe worker rather than just the safe work place. Estimates of cost increases due to OSHA clustered at 3%.

RESEARCH AND DEVELOPMENT

Here is a summary of research and development needs for the tunneling industry developed from contractor firm executive comments during our interviews with 118 contracting firms.

Number of Contractors Who Requested It	Type Research & Development
19	Changed conditions contract clauses
18	Better geologic forecasts & full disclosure
16	Better teeth for moles
13	Combined primary and secondary tunnel linings
9	Better bearings for moles
7	High pressure water jets or lasers to assist moles
6	Improved moles
6	Improved muck handling
5	Improved shaft mucker and slope mucker
5	Research on precast segments like those in Europe
2	Standardization of design of small tunnels
2	Small, low-cost, easy-to-move mole
1	Chemical stabilizer for wet jobs
1	Improved noise control on moles
1	Continuous concrete with slip forms
1	Full face drilling for large shafts

AGENCY	NAME
City of Miami, Fla.	Acton, George, Director of City Planning
Office of the Mayor, Newark, N. J.	Bakke, Oscar, Special Consultant for Transportation
Metropolitan Water District of Southern California, Los Angeles, Cal.	Balcerzack, Richard, Principal Engineer
Planning Commission, Salt Lake City, Utah	Barney, Dean, Ass't. Director
Board of Water Commissioners, Denver, Col.	Batt, J. A., Chief Design Engineer
City of Department of Public Property, Philadelphia, Pa.	Belfi, Robert, Director of Architecture and Design
City Planning Commission, New Orleans, La.	Bell, Dean P., Chief Planner, Transportation Planning Section
Maryland Transporation Auth., Baltimore, Md.	Bender, W. F., Administrator, Toll Facilities
Department of Public Works, Rochester, N. Y.	Berger, Manfred, Principal Engineer
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Appendix J

REPORT OF NO PATENTS

U. S. Department of Transportation regulations require that a specific list of patents and inventions associated with, or resulting from one of its sponsored projects be included in every final report.

Because this project was a study of the organization, structure, descriptive economics, and current state of a segment of the heavy construction industry, there was no expectation that any patents or inventions would result as a by-product of the work.

That expectation was fulfilled. There are no present or prospective patents or inventions as a result of this work.

APPENDIX K

BIBLIOGRAPHY

American Public Works Association Research Foundation, Feasibility of Utility Tunnels in Urban Area, Draft Final Report, October 1970, Chicago, Illinois, for the Federal Highway Admin., Dept. of Transportation, Washington, D.C.

Associated General Contractors, Joint Venture Guidelines, AGC, Washington, D. C., 1975.

Baker, Robert F., et al, A Program For Improving The Effectiveness Of Underground Construction, Preliminary Report from the Underground Construction Research Council, American Society of Civil Engineers, to the National Science Foundation, Washington, D.C., February 29, 1972.

Baker, Robert F., et al, The Use of Underground Space to Achieve National Goals, American Society of Civil Engineers, December 31, 1972.

Berry, Donald S., et al, The Technology of Urban Transportation, Northwestern University Press, 1963.

Birkmyer, A. J., Richardson, D. L., Systems Analysis Of Rapid Transit Underground Construction Volume 1: Sections 1-5, Final Report, December 1974, Prepared for U. S. Department of Transportation and Urban Mass Transportation Administration. Report Nos. DOT-TST-75-72.I and UMTA-MA-06-0025-74-11.1, National Technical Information Service, Springfield, Va.

Bureau of Reclamation, Tunnels-Machine Excavation-Rate of Progress Machine Data, February 1972, Engineering and Research Center, Denver, Colorado, Report No. REC-ERC-72-9, National Technical Information Service, Operations Div., Springfield, Va.

Comparing Urban Travel Costs Essential For Metropolitan Area, Civil Engineering-ASCE, December 1973.

Cook, Earl, et al, The New Dimension - Rapid Underground Excavation, American Institute of Mining, Metallurgical, and Petroleum Engineers, New York, 1969.

Duncan, J. M. et al, Materials Handling For Tunneling, Final Report, May 1970, Prepared for Office of High Speed Ground Transportation. Report FRA-RT-71-57, National Technical Information Service, Springfield, Va.

ENR Directory of Contractors 1974-75, Engineering News-Record, McGraw-Hill, Inc. 1975.

ENR Directory of Design Firms 1974-75, Engineering News-Record, McGraw-Hill, Inc. 1975.

Fenix & Scisson, Inc., In Assoc. With Arthur D. Little, Inc., A Systems Study of Soft Ground Tunneling, Final Report May 1970, Report No. DOT-FRA-OHSGT-231, for the Dept. of Transportation, Office of High Speed Ground Transportation & Urban Mass Transportation Admin., Washington, D.C., Clearinghouse for Federal Scientific and Technical Information, Springfield, Va.

Fenix & Scisson, Inc., Conventional Tunneling Methods, Volume III, Feasibility of Flame-Jet Tunneling Report G-910560-10, May 1968, East Hartford, Conn.

Fondahl, John W., Bacarreza, Ricardo R., Construction Contract Markup Related To Forecasted Cash Flow, Department of Civil Engineering, Stanford University, Stanford, California, Technical Report No. 161, November 1972, Prepared for California Contractors Council, Inc.

Fox, George A., Subsurface Construction Contracts - A Contractor's View, Journal of the Construction Division, ASCE Proceedings, June 1974.

Gates, Marvin and Amerigo Scarpa, Reward-Risk Ratio, Journal of the Construction Division, ASCE Proceedings, December 1974.

Greenberg, Max E., Role Of Contract And Specifications In Foundation Construction, Journal of the Construction Division, ASCE Proceedings, June 1974.

Institute of Traffic Engineers, Capacities and Limitations of Urban Transportation Modes, Report by Technical Committee 6B(61) of the Institute of Traffic Engineers, May 1965.

Jenny, Robert J., "Soft Clay Tunnel and Caisson Construction", Tunnels and Tunnelling, Sept.-Oct. 1973.

Juergens, Ralph, "New Developments in Tunneling Machines", Construction Methods and Equipment, Mar.-Apr. 1966, McGraw-Hill, Incorporated, New York.

Major New York City Subaqueous Vehicular, Rapid Transit and Railroad Tunnels, Prepared by The Engineering Department, N.Y.C. Transit Authority, A. C. Maevis, Chief Engineer, April 1970.

Mayo, Robert S., Adair, Thomas, Jenny, Robert J., Tunneling - The State Of The Art, Prepared for the U.S. Dept. of Housing and Urban Development, Report No. PB 178 036, National Technical Information Service, U.S. Department of Commerce, Springfield, Va. 1968.

Mayo, Robert S., Practical Tunnel Driving (originally published in 1941 by McGraw-Hill. Revised and republished in 1975 by the author (Robert S. Mayo, Lancaster, Pa., 17604).

Mining Engineering, Volume 27, No. 7, July 1975, A publication of the Society of Mining Engineers of AIME.

Office of the Secretary of Transportation, Transportation Tunneling Program & Review, U.S. Department of Transportation, Washington, D.C. 1975.

Organization for Economic Co-operation and Development, Advisory Conference on Tunnelling, Springfield, Va. 1970.

Parker, Albert D., Planning and Estimating Underground Construction, McGraw-Hill, Inc., 1970.

Parsons, Brinckerhoff, Quade & Douglas, Construction Monitoring of Soft Ground Rapid Transit Tunnels, DOT/UMTA Report No. DOT-TSC-UMTA-75-9.I, November 1974.

Permanent International Association of Road Congresses, Tunnel Operating Survey 1974, Charles H. Taylor, Group Chairman, USA, Paris and New York 1974.

Pratt, H. R., Tunneling Technology, June 1973, Prepared for Defense Nuclear Agency, Report TR73-26.

Pratt, H. R., Tunneling Technology, Terra Tek, Inc., Salt Lake City, Utah, TR 73-26, June 1973.

Richardson, Harold W., Mayo, Robert S., Practical Tunnel Driving, McGraw-Hill Books, New York, 1941; Robert S. Mayo, Lancaster, Pa.

Sanders, D. B., Reynen, T. A., with assistance from Bhatt, K., Characteristics of Urban Transportation Systems - A Handbook for Transportation Planners, Report No. UMTA-IT-06-0049-74-1 dated March 1974, Prepared by DeLeuw, Cather & Company, Washington, D.C. with contributions from The Urban Institute, for Urban Mass Transportation Administration, National Technical Information Service, U.S. Dept. of Commerce, Springfield, Va.

Scannel, Daniel T. et al, Cut And Cover Method Of Subway Construction, New York Transit Authority, 1970.

Simon, Kenneth A., Frankel, Martin M., Projections of Educational Statistics To 1973-84, 1974 Edition, National Center for Education Statistics, U.S. Dept. of Health, Education, and Welfare/Education Div., U.S. Government Printing Office, Washington, D.C., 1975.

Solomon, Richard J., et al, Modes of Transportation, Sources of Information on Urban Transportation Report Number 2, American Society of Civil Engineers, 1968.

Spittel, Louis A., Willyard, James C., Tunneling Cost Analysis, March 1971, RMC Incorporated, 7315 Wisconsin Avenue, Bethesda, Md., Report No. FRA-RT-71-73, Washington, D.C. 1973.

Sverdrup & Parcel and Associates, Inc., Cut-And-Cover Tunneling Techniques, Final Report, February 1973, Prepared for Federal Highway Administration, Office of Research, Washington, D.C.

U.S. National Committee on Tunneling Technology, Standing Subcommittee No. 4 - Contracting Practices, Better Contracting For Underground Construction, National Academy of Sciences, Washington, D.C., 1974.

Van Dyke, William, Report On Planned Transit Tunnel Construction In The United States, Status Report, Prepared for U.S. Department of Transportation, Office of the Secretary, Washington, D.C.

Vetter, Betty M., Supply/Demand Imbalances Of Engineers and Scientists For Transportation and Other National Projects, January 1975, Report No. DOT-TST-75-73, for Office of the Secretary, U.S. Dept. of Transportation, National Technical Information Service, Springfield, Va.

Ward, Jack W., Construction Information Source and Reference Guide, Construction Publications, Phoenix, Arizona, Second Edition, October 1970.

Washington Metropolitan Area Transit Authority, Office Of Construction Bimonthly Reports, Office of Construction.

APPENDIX L

INDEX

INDEX

INDEX

INDEX

INDEX

INDEX

INDEX