Better Management of Major Underground Construction Projects (1978)

Pages
172

Size
8.5 x 10

ISBN
0309336155

Subcommittee on Management of Major Underground Construction Projects; U.S. National Committee on Tunneling Technology; Assembly of Engineering; National Research Council

Better Management of Major Underground Construction Projects

A Report to the

U.S. Department of Transportation
Urban Mass Transportation Administration
National Science Foundation

Of a Study Conducted by the

Subcommittee on Management of Major Underground Construction Projects

U.S. National Committee on Tunneling Technology
Assembly of Engineering
National Research Council

NATIONAL ACADEMY OF SCIENCES
Washington, D.C. 1978

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

SPONSORS: This project was supported by the following federal government agencies: National Science Foundation, Urban Mass Transportation Administration, and Department of Transportation—Office of the Secretary.

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Report No. NRC/AE-TT-78-1

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Printed in the United States of America

Foreword

In recent years expenditures by federal, regional, and local governments on underground construction of public transportation, water supply, and wastewater disposal systems have risen rapidly. At the same time, many of these projects have suffered from delays in completion. One strong bulwark against persistent increases in costs and serious delays in schedules is the application of better management procedures and practices by public bodies responsible for underground projects. Therefore, in 1976, three federal agencies requested the National Research Council to study how the management of such projects can be improved. Their objective was to obtain a set of guidelines that could be used to advance management efficiencies and construction economies. Further, the agencies requested that the National Research Council develop a descriptive model of a hypothetical urban underground transportation project that could be used to examine the ways that current procedures and practices influence the responsiveness, schedules, and costs of underground projects.

Within the National Research Council the study was undertaken by a specially organized Subcommittee on Management of Major Underground Construction Projects of the U.S. National Committee on Tunneling Technology. Early in the study the subcommittee concluded that underground construction costs are rising for the same reasons, in general, that other types of construction cost more from year to year.

Underground projects are among the most complicated and costly large projects being built today. This is true because most underground construction takes place in urban environments, because geotechnical considerations assume greater importance than in other types of construction, and because the nature of underground work requires special equipment, techniques, and skills. Accordingly, underground projects are particularly sensitive to management practices.

Whether to write a detailed project management manual or to concentrate on principles that would be broadly applicable was a considerable problem for the subcommittee. It decided to do the latter and to describe the application of the principles to the hypothetical Key City construction project. Because each new underground project is different from those that preceded it, the subcommittee decided that emphasis on principles would be more helpful than a manual, which might have limited applicability and could become quickly outdated.

In the end, better underground projects will result in improved public services and enhanced environmental conditions. The ultimate beneficiaries of better management practices will be the nation's taxpayers and the local residents.

The subcommittee hopes its report will be helpful to its users and meaningful in advancing the cost effectiveness of underground projects.

David G. Hammond, *Chairman*
Subcommittee on Management of
Major Underground Construction Projects

Preface

Some of the work of investigating management problems was done in 1973 and 1974 by the Subcommittee on Contracting Practices of the U.S. National Committee on Tunneling Technology. The results of the study were published in December 1974 in *Better Contracting for Underground Construction*[1], which noted that many of the problems encountered in the contracting and construction phases of underground projects result from actions taken in the development, pre-design, and design phases. The report called for a study to identify the procedures and practices in major projects that contribute to unnecessary increases in costs and to recommend improved procedures that will ensure more efficient and economical execution of major underground construction projects. The study reported here, therefore, is a sequel to the 1973-74 study. The subcommittee has accepted the Webster Dictionary definition of management—"the conducting or supervising of something, esp. the executive function of planning, organizing, coordinating, directing, controlling, and supervising any industrial or business project or activity with responsibility for results. Judicious use of means to accomplish an end."

STUDY OBJECTIVE

The objective of this study, as set out in the statement of task established by the sponsoring federal agencies, was to recommend actions that result in public underground projects that are completed on schedule, and at reasonable cost, and operate to design. The study also was to recognize that in completing any project, several goals are important—performing the work safely, minimizing disruption to the community during construction, and minimizing adverse environmental impact. Projects of the scale considered in the study have inherent risks, and all participants need to be prepared to accept their share of those risks.

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[1]National Research Council (1974), *Better Contracting for Underground Construction.* A report prepared by the Subcommittee on Contracting Practices of the U.S. National Committee on Tunneling Technology. Washington, D.C.: National Academy of Sciences. The report is available from the National Technical Information Service (NTIS), Springfield, Virginia 22161, under Order No. PB 236 973. The price code is A07 for paper copy and A01 for microfiche. The price schedule may be obtained directly from NTIS.

METHODOLOGY

The subcommittee consisted of owners' representatives, designers, contractors, geotechnical engineers, a management expert, a labor official, an insurance specialist, a lawyer, and a geologist. The members were selected on the basis of their knowledge and experience in planning, designing, contracting, and managing construction of underground facilities. To assure a broad balance of perspective, the members were selected from both the public and private sectors and from the universities. As will be described below, other individuals with competence in specific related areas were called on to assist the subcommittee during the study. Thus, the recommendations in this report are based on the judgment and experience not only of the members of the subcommittee but many other experts as well.

In planning the study, the subcommittee recognized that the major underground construction projects undertaken recently in the United States have been predominantly for urban mass transportation. Other major projects include the Chicago Tunnel and Reservoir Plan (TARP), which is intended to handle large amounts of wastewater. The subcommittee decided that because of the major expenditures for such projects, special attention should be given to them, but not to the exclusion of other projects.

The subcommittee noted that most major underground construction projects are primarily federally funded, either directly, as in the case of construction by a federal agency such as the Bureau of Reclamation, or indirectly, as highway tunnels, urban mass transportation systems, and urban sewerage systems such as TARP, constructed by state, regional, or local entities relying mainly on federal funding. In view of this, the subcommittee considered it important to examine approval and funding practices.

The subcommittee developed a study procedure that it considered useful in examining all aspects of management in underground construction. The procedure involved several steps.

The first step in the study was to develop a hypothetical model of a major urban underground transportation construction project. In this model it was possible to incorporate all actions required for such a large project as well as the critical social, political, physical, and technical considerations that might have a bearing on management. While such a project invariably commands more complex management than commercial or industrial underground construction, the model contains the essential management elements of private undertakings. So, most of the procedures or recommendations for a public project can be used for a commercial or industrial project.

The hypothetical project was named the Key City Model.

From the model the subcommittee developed a list of primary or critical project elements that could conceivably be faced in building an urban rapid transit system. These elements were placed into two categories—those within the transit authority's jurisdiction and those outside its jurisdiction. In all, 26 elements were indentified in the first category and 14 in the second. Each of the elements in the initial list was considered to be of importance to management, but the subcommittee did not attempt to rank them in significance at this time. Instead, it attempted to ensure that no important element was omitted.

Then, the subcommittee set about verifying its initial list of the primary elements and ranking the elements in order of criticality. The first step in this process involved a series of interviews of knowledgeable people with managerial expertise in underground construction. Appendix 1 lists the 35 people from universities, transit authorities, port authorities, sanitary districts, and engineering firms visited in July and August 1977 by the subcommittee's consultants and staff officer.

In the second step, a questionnaire listing the subcommittee's elements was sent to 104 persons experienced in underground construction. They rated the importance of each element and added any additional elements they considered necessary. Based on the responses, the list of elements was divided into three categories of importance. The comments, along with the completed questionnaire, revealed a consensus that the elements selected by the subcommittee were the most important. The questionnaire, the list of respondents, and an analysis of their responses are included in Appendix 2.

The third and final step in this process was the consideration of the critical elements by the subcommittee in its third full meeting, when the subcommittee approved the ranking of elements.

The subcommittee also examined whether the elements were generally applicable to major underground construction projects or only to transit projects and found that, with minor exceptions, they were generally applicable to all large underground works. The implications of the elements were considered for the conclusions and recommendations. As a result of the deliberations, the subcommittee decided to send out a second questionnaire that would lead to specific conclusions and recommendations, to develop tentative conclusions and recommendations, and then to subject the tentative findings to searching examination by a group larger than the subcommittee.

The second questionnaire, prepared and distributed in October 1977, was sent to all the respondents to the first questionnaire who had indicated a willingness to complete a second questionnaire, as well as to all members of the U.S. National Committee on Tunneling Technology, to all subcommittee members, and to certain other individuals who had been suggested by subcommittee members—a total of 113 addressees. Longer than the first, and not subject to simple arithmetic analysis as the first had been, the second questionnaire was broad in scope in order to encourage suggestions and ideas. The secondary purpose of the questionnaire was to determine the respondents who agreed to participate in a workshop at which tentative conclusions and recommendations would be subjected to careful examination. Appendix 3 includes the questionnaire, the list of respondents, and a summary analysis of the responses.

Both during and following the questionnaire procedure, specific tentative conclusions and recommendations were being formulated. While still tentative in nature and subject to revision after further consideration, these statements served as part of the basis of the workshop. These were sent, together with the summary analysis of the questionnaire responses, to the subcommittee members and to those who had volunteered to take part in the workshop.

The workshop conducted in Palo Alto, California, from February 15 to 17, 1978, was attended by 60 people competent in underground construction who represented government, universities, and industry. The participants reviewed

the subcommittee's work and the draft recommendations that had been prepared and distributed in advance. They agreed that the subcommittee's procedures and information gathering activities were valid and that the draft recommendations were generally useful and well stated. However, as a result of the workshop there were several changes in and additions to the draft recommendations. The subcommittee chairman invited all participants to write in further comments in the four-week period following the workshop, and several were received. The recommendations were then revised accordingly and reviewed and approved by the subcommittee.

The Key City Model was then completed to illustrate how the recommendations that were advanced in a general manner could be applied to a specific project. The organization adopted for the Key City Model is only one of several ways in which a project may be organized, and the subcommittee does not recommend it as the best way. However, the selected organization is considered appropriate for the Key City situation and for similar situations.

IMPLEMENTATION OF RECOMMENDATIONS

The federal agencies supporting the study requested a plan of implementation for use by government organizations and by industry and professional organizations concerned with improving the management of major underground construction projects. That plan will be submitted separately. The subcommittee believes that the intention of the agencies to make sure that key government officials and underground construction industry leaders are made aware of the recommendations will be helpful in improving management of underground construction projects. Sometime in the future, after these individuals have been informed of the recommendations and have considered them, it would appear appropriate for those agencies to examine the changes made as a result of the recommendations and the effects of those changes.

Acknowledgements

While this study was conducted by the Subcommittee on Management of Major Underground Construction Projects of the U.S. National Committee on Tunneling Technology (USNC/TT), many others in the underground construction community assisted by providing information, expert opinion, and suggestions through interviews, questionnaires, and participation in a workshop. The subcommittee acknowledges with gratitude the contributions of these individuals whose names are listed in Appendices 1 (Persons Interviewed), 2 and 3 (Respondents to Questionnaires), and 4 (Workshop Participants).

The study was supported by three government agencies—the National Science Foundation, the Office of the Secretary of Transportation, and the Urban Mass Transportation Administration. Their representatives, William W. Hakala, Russell K. McFarland, Gilbert L. Butler, Allen Chin, and Santo J. Gozzo, provided encouragement and suggestions along the way.

The subcommittee was assisted by two consultants, William A. Bugge and Franklin T. Matthias, both experienced engineers. The consultants developed the Key City Model, conducted the interviews, analyzed the responses to questionnaires, and prepared drafts of this report. Robert L. Bangert was staff director for the study. O. Allen Israelsen, former Executive Secretary of the U.S. National Committee on Tunneling Technology, furnished invaluable advice and assistance. Susan V. Heisler assisted in organizing the report and supervising its publication. Virginia M. Lyman provided the subcommittee with administrative support, and Carole B. Carstater typed the numerous drafts of the report and provided secretarial assistance.

The subcommittee expresses its sincere appreciation to all of the participants and to the sponsors for their interest in and support of the study.

Subcommittee on Management of Major Underground Construction Projects, U.S. National Committee on Tunneling Technology*

David G. Hammond, *Chairman*
Vice President
Daniel, Mann, Johnson & Mendenhall
Baltimore, Maryland

Walter J. Addison
Mass Transit Administrator
Maryland Department of Transportation
Baltimore, Maryland

William D. Alexander
Assistant General Manager for Transit System Development
Metropolitan Atlanta Rapid Transit Authority
Atlanta, Georgia

Charles H. Atherton
Vice President and Area Manager
J.F. Shea Company
Bethesda, Maryland

Bruce F. Baird
College of Business
University of Utah
Salt Lake City, Utah

+John C. Frye
Executive Director
Geological Society of America
Boulder, Colorado

*See Appendix 5 for membership of the U.S. National Committee on Tunneling Technology.

+Withdrew from subcommittee, August 26, 1977

John P. Gnaedinger
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Soil Testing Services, Inc.
Northbrook, Illinois

Thomas J. Hayes, III
President
International Engineering Company, Inc.
San Francisco, California

Edward B. Howell
President
Risk Analysis & Research Corporation
San Francisco, California

*J. Donovan Jacobs
Chairman
Jacobs Associates
San Francisco, California

Wendell E. Johnson
Consulting Engineer
McLean, Virginia
formerly Chief, Engineering Division
Directorate of Civil Works
Office of the Chief of Engineers, U.S. Army

Kenneth G. Knight
General Manager, Metro Construction Division
Niagara Frontier Transportation Authority
Buffalo, New York

Jack K. Lemley
Vice President, Special Projects
Morrison-Knudsen Company
Boise, Idaho

Harold E. Nelson
Senior Associate
Kellogg Corporation
Chicago, Illinois

Walter H. Paterson
Consulting Engineer
Toronto, Ontario
Canada
formerly Chief Engineer and General Manager of Subway Construction
Toronto Transit Commission

*Chairman of subcommittee until June 30, 1977, when he became
Chairman of the U.S. National Committee on Tunneling Technology.

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Laborers' International Union of North America, AFL-CIO
Washington, D.C.

Edward J. Ruff
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Thelen, Marrin, Johnson & Bridges
San Francisco, California

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Atlanta, Georgia

J. George Thon
Executive Consultant
Bechtel, Inc.
San Francisco, California

Eugene B. Waggoner
Consultant
San Jose, California

Kenneth N. Weaver
Director
Maryland Geological Survey
Baltimore, Maryland

CONSULTANTS

William A. Bugge
Olympia, Washington
formerly Director of Highways
State of Washington

Franklin T. Matthias
Danville, California
formerly Vice President for Heavy Construction
Kaiser Engineering Company

STAFF

Robert L. Bangert, *Executive Secretary*
U.S. National Committee on Tunneling Technology

Carole B. Carstater, *Secretary*

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Introduction, Summary, and Recommendations

This report is directed at a broad and disparate audience, primarily officials of federal funding agencies, heads and governing boards of public agencies and corporations, their engineers and managers, and their consultants, as well as executives in large construction companies. All of these people are responsible for carrying out major underground construction projects. Some have great responsibility for decision making, but limited experience in actual construction. Others are expert in one aspect or another—planning, design, construction, or operation. The report is organized to make it most meaningful to all readers of whatever background. Thus, following the short summary of conclusions and recommendations, the reader immediately is exposed to a hypothetical project into which the elements of many actual projects have been incorporated. The narrative describes how the Key City project was planned, organized, designed, and constructed. Readers with extensive background in underground construction may wish to compare their experience with the Key City Model or may decide to go directly to the discussion which follows.

A more generalized discussion of project phasing, organizational alternatives available for project management, and management problems ensues. The report concludes with detailed recommendations and supporting rationale.

The subcommittee observed during its study that there is a lack of uniformity within the underground construction community in the use of such terms as "consultant" and "project planning." Therefore, in an effort to standardize the usage of such terms, a short definition appears the first time each of several particular terms appears in the text.

Major underground projects are those multimillion dollar construction works in which all or a substantial part is built below ground level. They may be public or private in nature—though, for the most part, they are government undertakings such as rapid transit systems, tunnels for water supply and wastewater or flood water disposal, and subways for motor vehicles or trains.

The subcommittee came to the following three conclusions early in the course of its study:

- The management problems in major underground construction projects are similar to those encountered in other projects, but, in addition, have

"The motion to take immediate and decisive action was tabled until next meeting. . . ."

FIGURE 1 Cartoon reproduced from the *Wall Street Journal* with permission of the artist, Joseph Serrano.

some specific characteristics not generally found in other projects. Thus, the subcommittee's recommendations apply, to a large extent, to the management of major construction projects both privately and publicly financed, above ground or below.

- The characteristics of major underground construction projects vary according to urban, suburban, or rural location and purpose. They also vary according to depth, geology, and size. Because of such variables, the subcommittee decided to frame its recommendations in a general manner rather than attempt to provide a management manual. The hypothetical Key City Model was devised to illustrate how the recommendations can be applied to a specific project.

- The capabilities of the owner, which may be a private enterprise or, most often, a public body, such as a transit authority, sanitary district, or public works department, range widely from a newly organized entity created for a specific project to an established organization with experienced people. Many owners may not be experienced in the construction of large projects, even though they are experienced in the operation and maintenance of completed projects. The range of capabilities also persuaded the subcommittee to frame general recommendations that would be helpful to all owners.

There are many reasons for cost increases, construction delays, and performance defects in underground construction, and all aspects of these problems must be examined to determine what improvements may be required in policies, organization, and procedures. The most important cause of management problems, the subcommittee found, is delayed decisive action, illustrated in Figure 1 on the facing page.

Although the recommendations are stated in a general, rather than in a specific, how-to manner, there are places in the report where specific actions are suggested to implement the generalized recommendations. For instance, a number of recommendations center on the necessity for instilling a sense of urgency and high morale. Some of the means of achieving this are listed in Appendix 3, page 107.

Another instance: How can a "must-do, can-do" attitude be stimulated? Several actions are discussed in the supporting rationale for Recommendation No. 31, pages 81 and 82, and in Appendix 3, page 107. The actions include:

Setting the example (by the owner and his staff) of decisiveness and sense of urgency
Establishing well-defined goals
Encouraging and supporting other elements of the project management team
Assigning specific responsibilities and accompanying authority
Demanding, when necessary, prompt and decisive action within areas of authority and responsibility
Eliminating red tape

The subcommittee concluded that six major objectives are necessary to improve the management of major underground construction projects. Each of

the objectives led to recommendations that the subcommittee considered important to good management procedures and practices. Adoption of all the objectives is feasible and necessary to make the maximum possible improvement in management of a major underground construction project. The recommendations are directed at major public projects, which generally involve a larger number of participants than major private projects and, hence, are usually more complex to manage. However, most of the recommendations are considered appropriate to private projects as well. Each of the management objectives listed below is followed by the recommendations that will aid in achieving it. Each of the recommendations is explained in detail in the section beginning on page 63.

TO ESTABLISH THE PROJECT'S GOALS AND OBJECTIVES AND TO ORGANIZE THE PROJECT TO FACILITATE THEIR ACCOMPLISHMENT:

1. Define project purposes, goals, and policies.
2. Establish the owner's organization to direct the project.
3. Determine the management structure for the project.
4. Select consultants, if deemed necessary, to supplement the owner's staff.
5. Retain senior consultants, if necessary, to assist the owner in reviewing major decisions.
6. Act promptly to identify and solve problems.

TO PLAN THE PROJECT TO ACHIEVE THE OWNER'S OBJECTIVES:

7. Establish the owner's objectives to achieve project purpose.
8. Make realistic cost estimates.
9. Obtain public and political acceptance of the project.
10. Establish an understanding with agencies and organizations likely to be involved.
11. Expedite approval of the Environmental Impact Statement (EIS).
12. Establish the plan for financing the project.
13. Obtain firm financial commitments for funding the project.

TO ACHIEVE EFFECTIVE DESIGN ORGANIZATION, SUPERVISION, AND ACCOUNTABILITY:

14. Organize and coordinate project design.
15. Review designs to assure effective satisfaction of project goals and objectives in a cost effective way.
16. Freeze design criteria early.

TO ACHIEVE EFFECTIVE CONSTRUCTION METHODS, PROCEDURES, AND SUPERVISION:

17. Plan contract packages for efficiency and economy.
18. Minimize urban disruptions.
19. Establish problem solving procedures.
20. Develop a labor relations plan to assure continuity of work and to avoid labor disputes.
21. Establish sound contracting procedures.
22. Establish dispute settlement procedures.
23. Set up a review board to assist in the settlement of construction contract disputes.

TO ACHIEVE SOUND MANAGEMENT OF THE PROJECT:

24. Establish and adhere to a realistic budget.
25. Establish and adhere to realistic schedules.
26. Adopt sound management and financial reporting systems.
27. Exercise strict control of expenditures.
28. Grant agencies should revise practices to permit the project management to exercise appropriate authority.
29. Prepare a comprehensive risk and liability plan.
30. Establish adequate real estate acquisition organization and procedures.
31. Foster morale and productivity by strong leadership.

TO ACHIEVE SUCCESSFUL START-UP OF THE PROJECT:

32. Select key operations and maintenance personnel early.
33. Prepare operations plans early.
34. Allow ample time for a thorough testing program prior to scheduled operation.

Key City Model

CONCEPTUAL PLANNING

The Key City Transit Authority was established for the purpose of providing essential public transportation services for the people in the metropolitan area of Key City, a region that includes Key City and adjoining suburban and undeveloped areas. The region lies within three counties located in the states of Columbia and Gondor and includes the area within the boundaries of Key City (population 850,000), Eastfold (population 550,000) and surrounding incorporated and unincorporated communities, with a total of 2,228,000 inhabitants.

Earlier on, the planning agencies of the Columbia and Gondor Departments of Transportation (CDOT and GDOT), the three counties, Key City, and the incorporated suburban communities had collaborated in regional planning council transportation planning studies supported by local, state, and federal funding. The council recommended the construction of a fixed guideway system serving generally defined corridors, to be supplemented by bus or light-rail feeder lines. The objective was to provide alternative modes of personal transportation to private automobiles in order to alleviate the increasing congestion of street and highway traffic, help revitalize the decaying city centers, and guide future industrial and residential development to best meet environmental, economic, and social needs. The council also recommended the creation of a regional mass transit authority.

Accordingly, the Key City Transit Authority (KCTA) was chartered jointly by the states of Columbia and Gondor to integrate public transportation for the region and to design, construct, and operate the Key City Regional Mass Transit System (KCRMTS). The charter established the taxing district of KCTA to include the counties of Rohan, Anor, and Minas, each of which accepted the tax liability to fund the costs of the KCTA, the further development of the conceptual plan, and the preliminary engineering study. However, participation in the capital financing and operating costs of the KCRMTS required further approval by each county. The charter provided for a KCTA board of directors consisting of eight members—one each to be appointed by the Columbia Secretary of Transportation and the Gondor Secretary of Transportation, two from Key City, one from Eastfold, and one each from the counties of Rohan, Anor, and Minas. The members of the board elected their chairman from among their number. The charter required that board members be residents of the state, county, or community they repre-

sent. It also provided that, at local option, they would be either appointed by their respective community councils or boards of supervisors or elected by the voters.

Under the direction of the KCTA and with local, CDOT, GDOT, and federal DOT financial support, the system's general plan was enlarged into what is known as a "conceptual plan," a descriptive scheme of the project, prepared by planners to incorporate the perceived needs, but containing little or no engineering or architectural details. Key City's conceptual plan contained the general route alignments, general service criteria, and other features of the transit system related to the interfaces with other transportation modes in the region. Aesthetic, environmental, social, economic, and travel convenience values were used in shaping the conceptual plan. Because the plan was necessarily preliminary at this stage, approximate estimates of capital and operating costs and anticipated revenues were made. After public hearings were held throughout the service area, the conceptual plan was modified to incorporate feasible and desirable suggestions made at the hearings. The conceptual plan then was approved by the KCTA with the concurrence of CDOT, GDOT, federal DOT, and the three counties. Subsequently, a policy decision was made to proceed with the project for the Key City Regional Mass Transit System.

The conceptual plan called for three separate rail lines with passenger stations at each intersection and service connections for the movement of rail cars (without passengers) to the central maintenance and repair shops east of the central business district (referred to as CBD in Figure 2). Near one end of each line there was a car-storage, light-repair, wash, and train-makeup facility. The total guideway length was about 89 miles, of which 31 miles were likely to be underground and the rest either at, above, or below grade. Figure 2 illustrates the conceptual plan for the entire area.

The preferred vehicle system incorporated steel wheel vehicles on steel rail guideways and automatic train protection, operation, and control. The conceptual plan postponed the final decision on this until after more exhaustive system analysis and evaluation of alternates. Each proposed car was assumed to have about 70 seats and, with standing passengers, a maximum load of 120. To accommodate this type of vehicle, the system would need round tunnels about 17 ft in diameter and horseshoe tunnels about 14 ft wide by 17 to 18 ft high. These are inside finished dimensions.

DEMOGRAPHY, TOPOGRAPHY, AND GEOLOGY OF THE AREA

Demography

Key City is on the west bank of the Anduin River, a navigable stream which forms the boundary between the states of Columbia and Gondor. Directly across the river on the east bank is the city of Eastfold, containing the major industrial and manufacturing facilities of the region. A main-line railroad generally parallels the Anduin River on the east side, and the central passenger and freight stations for the area are in Eastfold, as are the inland waterway port facilities for barge traffic. The central business district for each city is near the Anduin River.

Housing in Eastfold, along the Anduin River on both sides of the railroad, consists of old, high density buildings of generally poor quality. The residen-

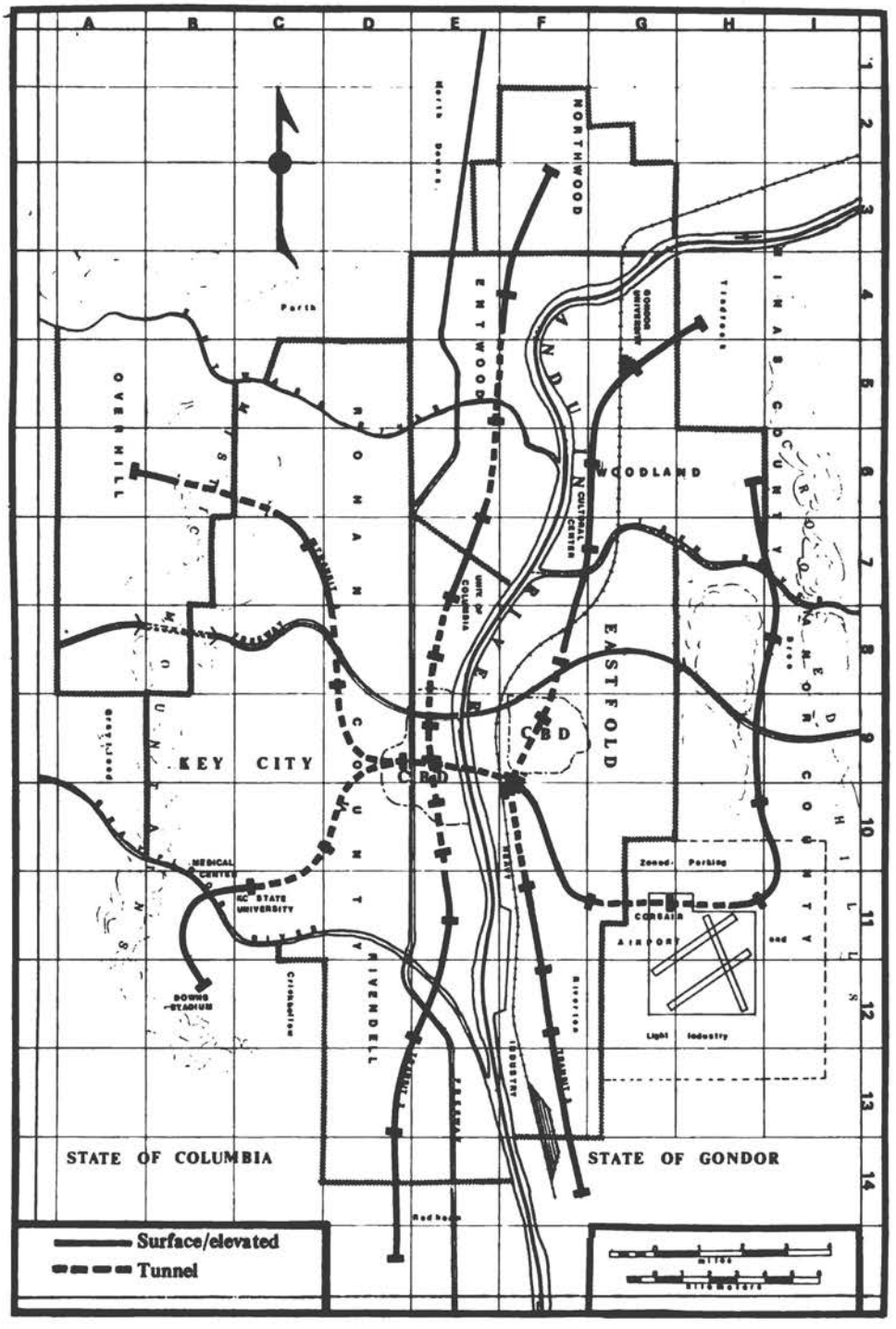


FIGURE 2 Conceptual transit plan, Key City Model.

tial section is interspersed with light industry and wholesale distributing facilities. Along the north and east fringes of the central business district, a number of good quality high-rise apartments have been built in recent years. Good quality, low density, well planned housing, in single-family, multiple-family, and apartment units, occupies the area along the hills east of the Isen River, the north boundary of Eastfold and Anor County, to the buffer zone for parking and light industry around the airport. The Riverton community, within the City of Eastfold, has high-density housing of poor quality along the railroad, with better planned, good quality developments under way to the south and beyond the city limits of Eastfold.

Woodland, the major city north of Eastfold, in Minas County, is primarily a "bedroom" community for people who work in Eastfold and Key City. Housing is high quality and low density, well planned and attractive. Substantial new development is under way in Woodland, extending into the unincorporated community of Tindrock. Bree is an attractive valley community in the Crooked Hills, consisting mostly of single-family houses.

Historically, in the development of the Key City region, the areas along the Anduin River and north of its central business district have been considered the choice residential locations, with many fine houses with spacious, well kept grounds. This area was incorporated as the City of Entwood. North of Entwood is the City of Northwood, in which Entwood-type quality development is continuing along more modern lines, reaching into the Tindrock community.

In its early development, Key City grew outward from the central business district area in an unplanned, crowded way, with a mix of fair quality homes and commercial buildings. Over the years, this area deteriorated. Recently, in the central business district, older buildings have been replaced by modern office and apartment buildings. Around the fringe of the business district, a strip of from one to two miles wide, dilapidation is still evident. Beyond this are residential areas that are better planned and of better quality, but still high-density. Along the lower slopes of the Mistic Mountains, high quality, expensive homes have been constructed. Well kept and attractive, this section is considered a highly desirable place to live.

The migration of residents from the decaying and crowded central city to the suburbs, and an influx of new residents to the metropolitan area, resulted in development of good quality, medium density residential sections in the northern part of Key City, which are now incorporated as the cities of Rivendell and Overhill. Development of similar residential areas also occurred in the communities of North Downs, Parth, Grayflood, Crickhollow, and Redhorn. All these cities and communities are still growing.

The entire metropolitan area of Key City is in Rohan County. Eastfold and the communities to the east and south of the Isen River are in Anor County, and the areas east of the Anduin River and north of the Isen River are in Minas County. Table 1 depicts the population of the political subdivisions of the entire region.

TABLE 1 Principal Cities and Communities, Key City Metropolitan and Regional Area

State of Columbia

	County	Population
Key City, Incorporated	Rohan	850,000
Entwood, Incorporated	Rohan	165,000
Northwood, Incorporated	Rohan	100,000
Overhill, Incorporated	Rohan	110,000
Rivendell, Incorporated	Rohan	210,000
Crickhollow, Unincorporated	Rohan	22,000
Grayflood, Unincorporated	Rohan	14,000
Northdowns, Unincorporated	Rohan	15,000
Parth, Unincorporated	Rohan	16,000
Redhorn, Unincorporated	Rohan	8,000
	Total	1,510,000

State of Gondor

Eastfold, Incorporated	Anor	550,000
Woodland, Incorporated	Minas	125,000
Bree, Unincorporated	Anor	11,000
Riverton, Unincorporated	Anor	12,000
Tindrock, Unincorporated	Minas	20,000
	Total	718,000
	TOTAL REGION	2,228,000

Topography

The Key City metropolitan area (Figure 3) lies in the Anduin River Valley in an area roughly 18 miles wide, east and west, and 25 miles long, north and south. Rolling hills run generally parallel to and on both sides of the river at a distance of about 5 miles from the river channel on both sides. West of the Mistic Mountains runs a parallel valley.

The right bank of the river in Key City is about 25 ft above normal water level and about 35 ft above the stream bed. The left bank is about 20 ft above normal water level. The ground surface rises gently from the banks on both sides to within about 2,000 ft of the hills at a general slope of 3 percent and rarely exceeding 5 percent. At these points, the slopes increase to about 15 percent and merge into the steeper slopes of the hills. The hills on each side rise to a general high of 500 ft above the valley floor. The slopes up the ridges are from 30 percent to 40 percent, except for occasional rock faces with talus accumulations spilling out over the relatively gentle slopes below.

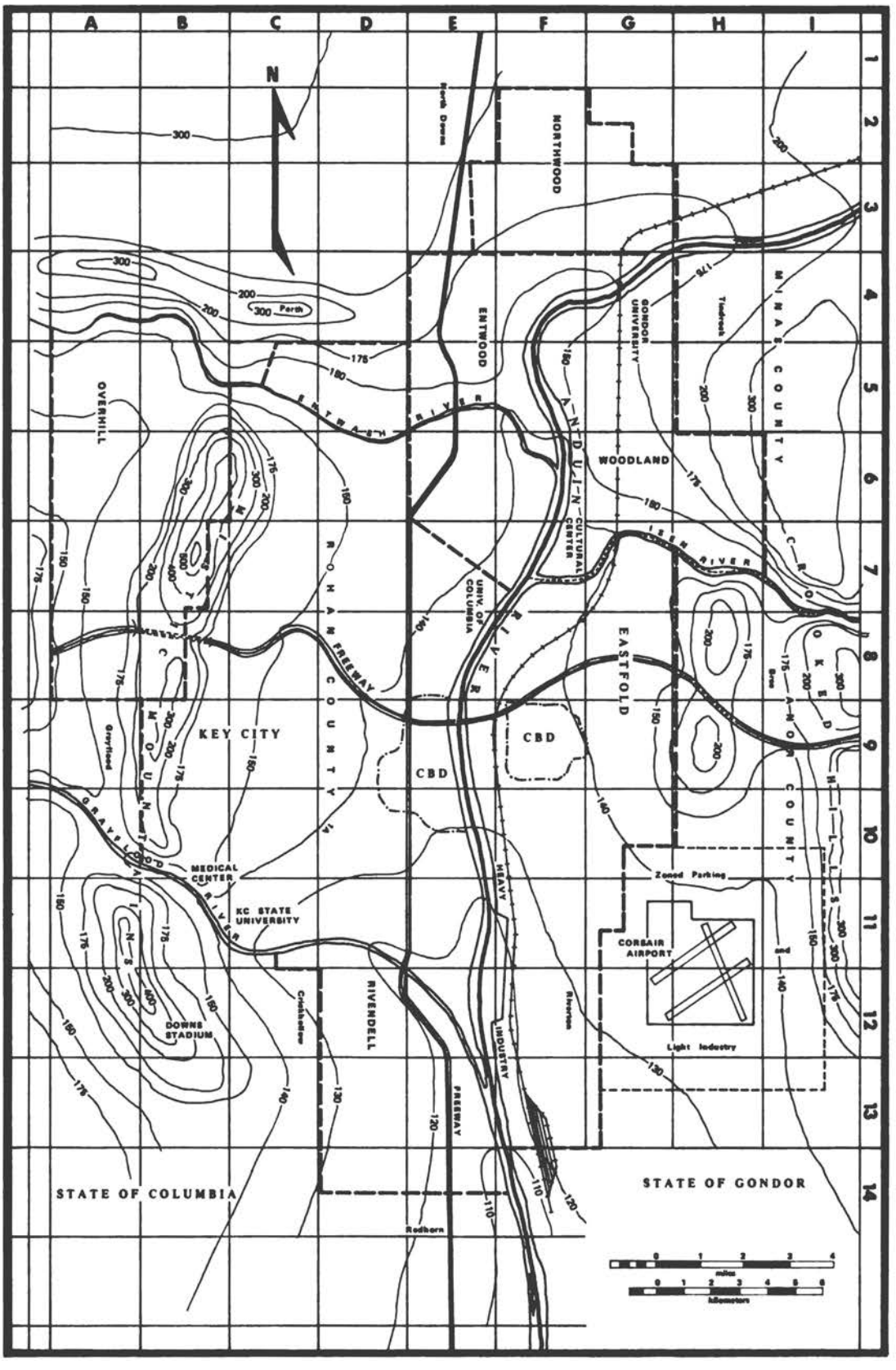


FIGURE 3 Topography, Key City Model.

The river bed is generally gravel, with occasional rock outcrops. The bedrock, into which the river has eroded its channel, is about 10 ft above normal water surface on the right bank and 5 ft above on the left bank. Near the river on the left bank, the overburden is mostly alluvium. Indications are that the bedrock slopes generally upward toward the hills on each side about parallel to the ground surface, but very large irregularities in the rock surface have been encountered.

Geology

The geologic formations described and the geologic map (Figure 4) and profiles (Figure 5AA-FF) represent interpretations of surface outcrops and available records of building, highway, and tunnel excavations, well drilling, and other indications. Subsurface geotechnical explorations were not carried out during the planning and conceptual development stage of the transit program.

The water table is located near the surface in all alluvium. There is artesian head in the sandstone layers of the Sandwich formation. The shale in this formation has no free water, except for a few fractures and joints, and has little head. Groundwater in granite, found in fractures and joints, has a static head equal to the surface elevation minus 20 ft.

Neptune Alluvium (Recent) is composed of sand, silt, cobbles, and boulders —uncemented, moderately compacted, generally fairly well sorted out, and very pervious. The water level is the river level. The material is composed of granite primarily, but is not suitable for aggregate without processing.

The Sandwich Formation (Cretaceous) consists of hard, dense, well compacted carbonaceous shale with interlayered beds and lenses of firm, moderately cemented , medium to fine grained sandstone. The shale ranges from massive and thick bedded to thin, platy, fissile layers. The sandstone beds are artesian aquifers and will make flowing wells in the area. Water tests have shown only small amounts of water in the shale. Shale and sandstone beds dip from 5° to 15°. Except where faulted or sheared, the sandstone and shale usually have joint spacing ranging from 3 to 5 ft. The formation unconformably overlies the Jurassic Roten schist.

The Roten Formation (Jurassic) is composed of slaty to sandy schist that is dark grey to brown. It is highly metamorphosed, closely foliated, and structurally deformed. It has weathered deeply but erratically, and has been found weathered to sand and clay as deep as 150 ft and found hard and fresh within 10 ft of the surface. As a residual soil it is generally clayey and highly plastic. The dip of foliation ranges from 15° to 90°, but most commonly is more than 45°. Although very competent when dry, it has low stability on slopes or in underground openings when wet. Jointing is prominent but wide spaced, 4 to 6 ft, except near zones of shearing or faulting. Predominant jointing is north to south, with a secondary system east to west. Rock failure occurs as commonly on foliation planes as on joints. Groundwater tends to be perched or pockety.

The Hades Formation (Miocene) consists of granite that is fine grained, hard, massive, and very moderately jointed. Weathering, except close to shearing or faulting, is shallow—1 to 10 ft. Fresh rock has a compressive strength of 20,000 to 30,000 psi. Joint spacing ranges from 5 to 10 ft. Groundwater in

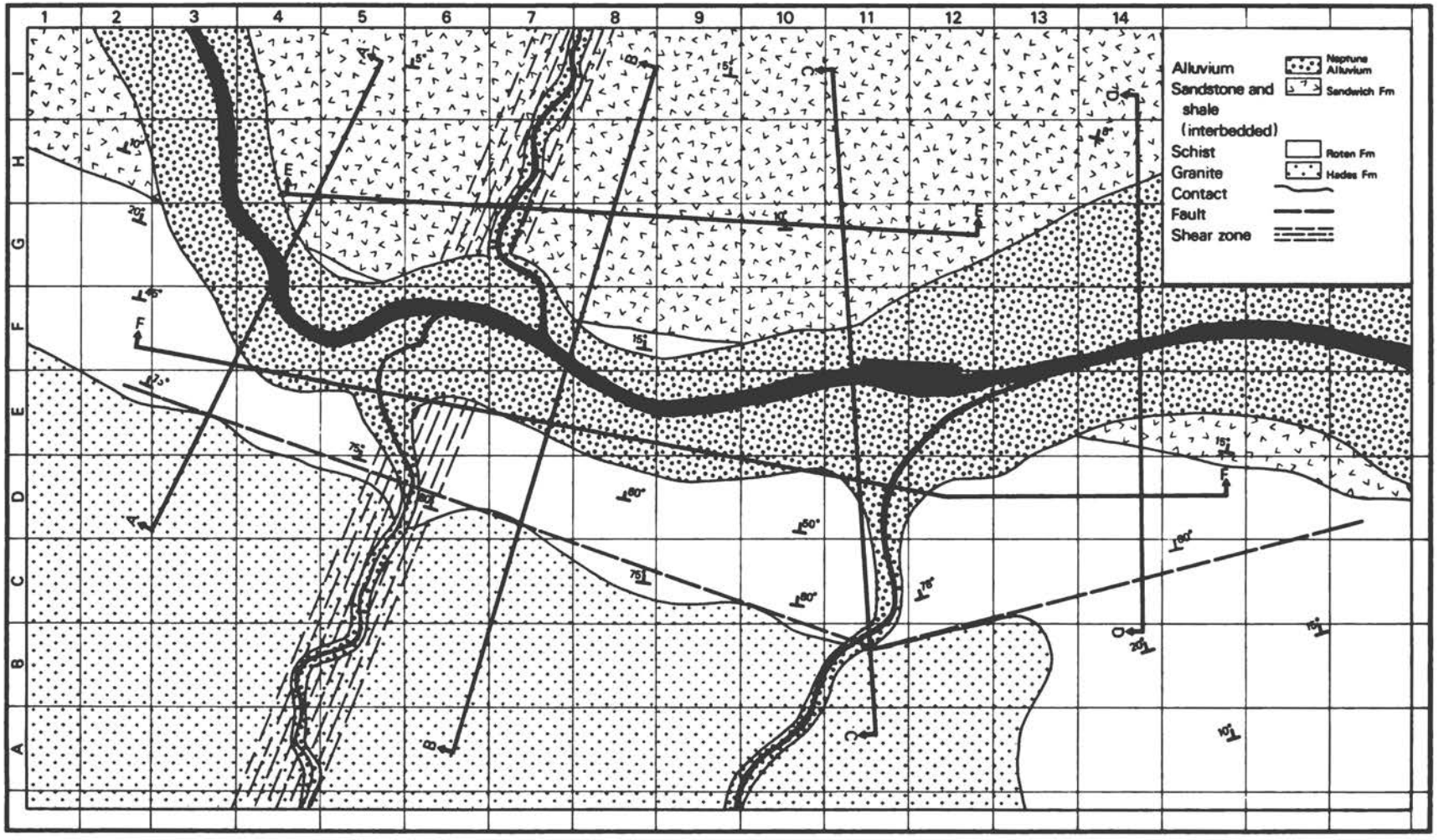


FIGURE 4 Geology and location of geologic profiles, Key City Model.

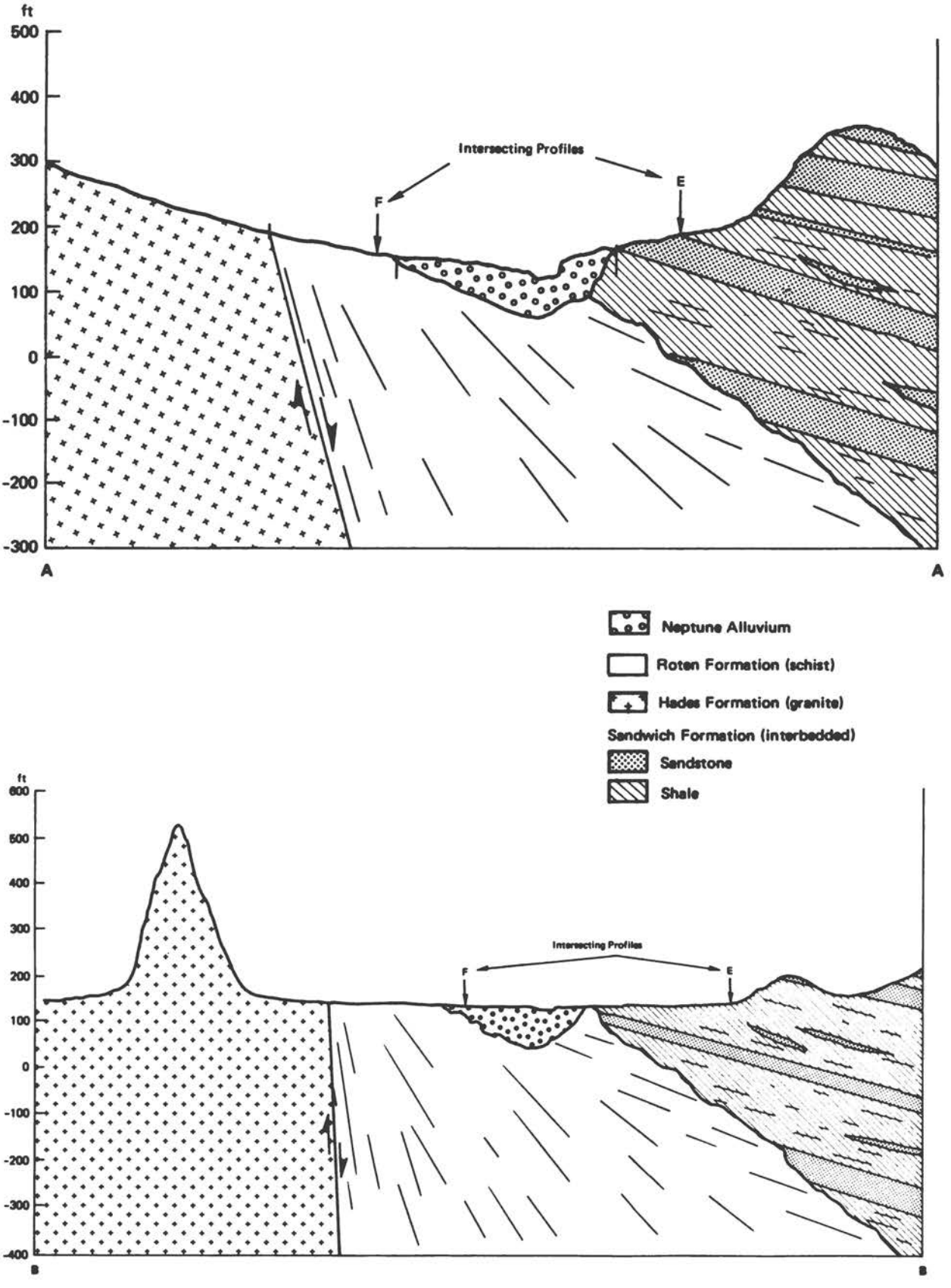


FIGURE 5 Geologic profiles, Key City Model.

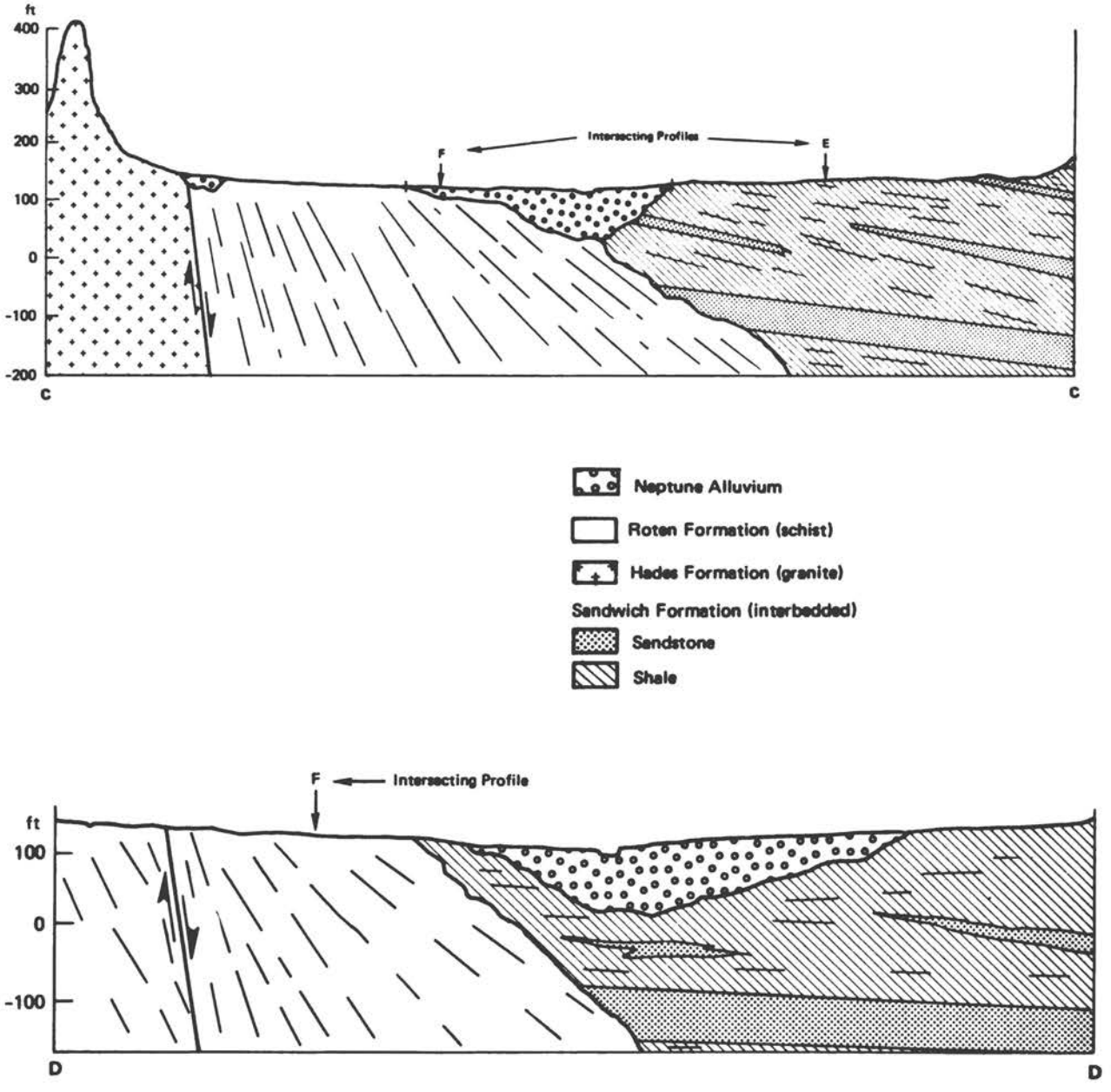


FIGURE 5 (continued) Geologic profiles, Key City Model.

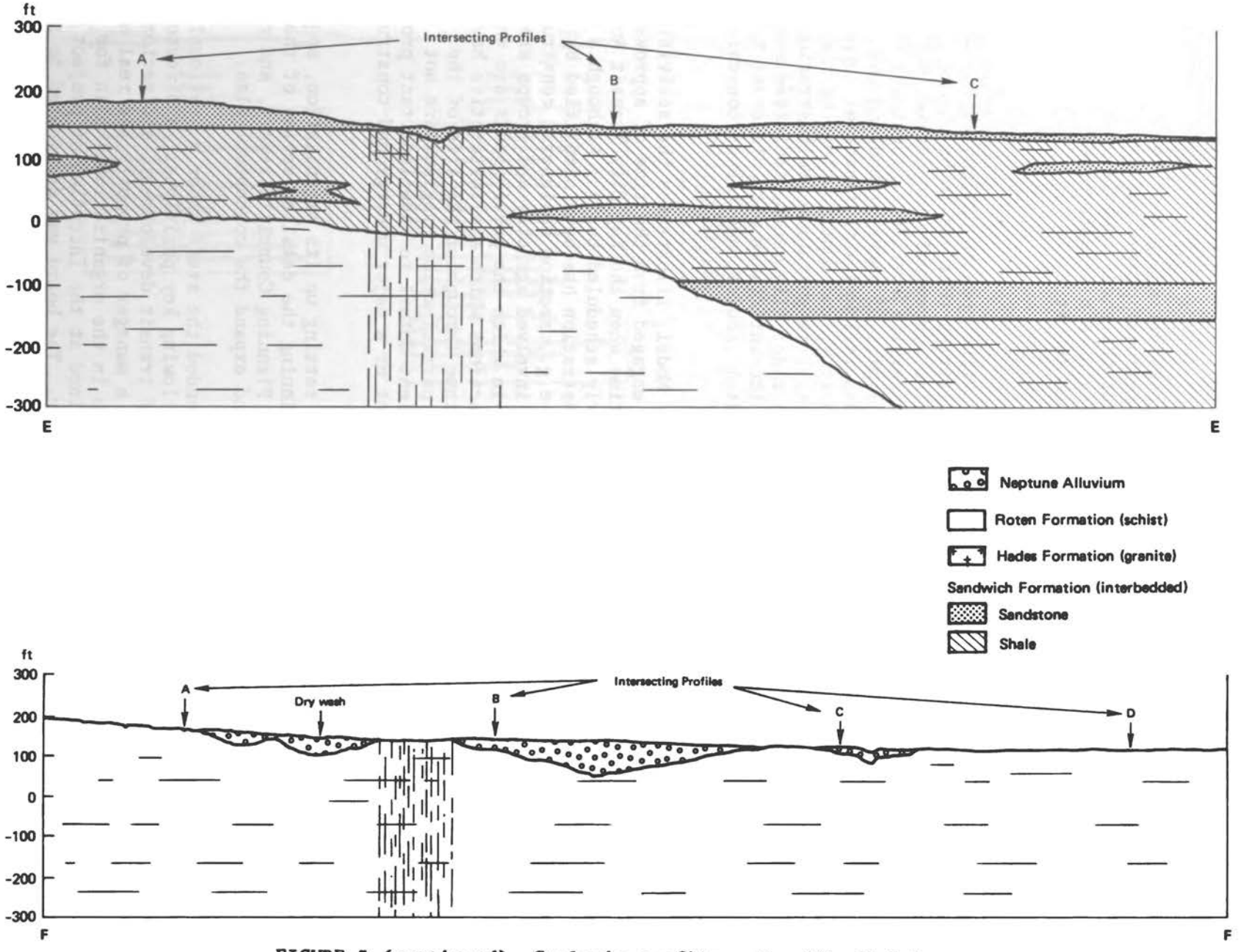


FIGURE 5 (continued) Geologic profiles, Key City Model.

the granite is negligible because most joints and fractures are tight. Sheared and faulted granite could carry water under head equal to surface elevations, but flows would not be sustained.

A very prominent shear zone has been mapped extending east to west from the Crooked Hills westward through the Key City cultural center and past the Overhill area. Displacement has not been measured, but the shear zone is up to 8,000 ft wide, and the shearing, jointing, and crushing have been extensive. Weathering in the shear zone has been measured as deep as 400 ft.

ORGANIZATION AND PLANNING

The recently established KCTA has been called upon to design, build, and operate a major transit system involving facilities that are to be underground, at the surface, elevated, and below grade. The conceptual plan devised by the Regional Planning Council had designated the service corridors, locations of stations, a favored vehicle system, and the limits of above ground and underground segments. The conceptual plan has been reviewed with financial support provided through KCTA's district taxing authority, and contributions by the states and the federal government's Urban Mass Transportation Administration (UMTA). The review confirmed the general corridor alignments, tentative service requirements, and other features related to the interfaces with different transportation modes and to aesthetic, environmental, social, and travel convenience values.

Figure 6, Program Development, Key City Model, illustrates the activities in which the major project participants are engaged from the time of approval and adoption of the conceptual plan to the time when the Key City Transit Authority is ready to move passengers on a regularly scheduled basis. Although a great amount of detail is depicted, the illustration has been simplified by limiting the number of participants shown——e.g., section designers, construction contractors, suppliers, subcontractors, and involved agencies and groups are omitted. Similarly, the list of activities in which the participants are engaged has been shortened somewhat and some actions which are reiterative have been shown only once. Activities that continue throughout the life of the project, such as the public information and participation program, are not shown. Nevertheless, the figure has sufficient detail to show important project actions and to make the point that management of a major underground construction project is a complex undertaking.

The initial actions of KCTA called for setting up its organization, acquiring the necessary administrative staff, beginning the detailed review of the conceptual plan recommended in the Regional Planning Council's report, and retaining professional services to evaluate and expand the conceptual plan.

The eight-member board of the KCTA expanded the staff under a previously appointed general manager to include the following key positions: a director of administration and finance, a director of transit development, a director of operations, a director of public relations, a manager of property and real estate, and legal counsel. Provision was made in the organizational plan for a board of engineering consultants to be retained at the inception of project planning, to serve under the general manager. The board was designated to review and advise periodically on developing concepts and on engineering and architectural work on the capital program of transit development.

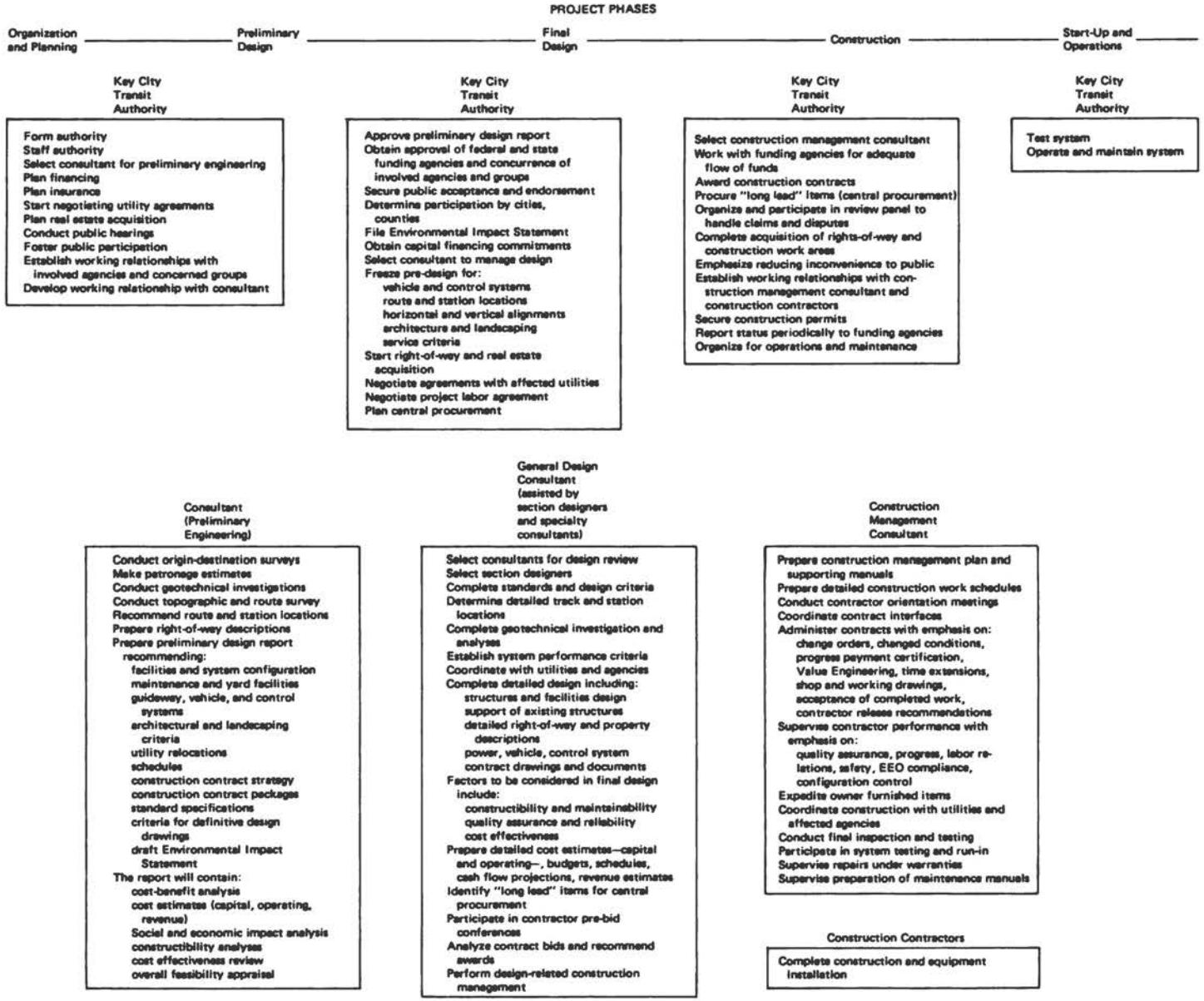


FIGURE 6 Program development, Key City Model.

Recognizing the complexity and extensive scope of the transit program, the staging need for multi-construction contracts, and the special problems of underground work, KCTA made a policy decision to utilize outside engineering consulting services for all engineering work, including construction supervision, system testing, and run-in. In addition, the consultants would be called upon to provide management services, in cooperation with the KCTA organization, in negotiations with the public utilities and involved agencies, as well as in community and public relations activities, financing, real estate acquisition, minimizing physical, institutional, and societal restraints, and identifying and coping with the critical elements of program management. The KCTA general manager, together with the director of transit development and one or more members of the board of directors, consulted with other transit authorities as to their organization, procedures, and management concepts in order to give KCTA the benefits of their experience in project planning and execution.

KCTA's planning for professional engineering and related services took the following general alternatives into consideration:

- *Full Construction Management.* Under this concept an engineering organization would be engaged at the preliminary stage to supervise engineering and construction activities for the duration of the project, with the construction manager acting as the agent for KCTA. The engineering firm would need to be experienced in transit system engineering and construction. It would be capable of providing all or some of the services, or obtaining the services from other consulting firms either by subcontract to the construction manager or by contracts with KCTA directly. It would provide support services to KCTA as required in all matters relating to the effective execution of the project. The construction contracts would be let either directly between the contractor and KCTA or between the contractor and the construction manager, acting as the agent for KCTA.

- *General Engineering Consultant.* Under this concept a professional engineering organization experienced in transit system engineering would be retained by the owner to perform or supervise all or part of the preliminary and final engineering and architectural design services, including design-related construction services and such support services as required by KCTA. Preliminary engineering would be performed by the general consultant with subcontract assistance of specialty consultants as required, such as geotechnical engineering, vehicle and vehicle control systems, and other necessary professional services for which the general consultant may lack experience and/or adequate capability. The general consultant would be engaged initially for project planning, the phase in which the conceptual plan is refined, and other services such as the development of physical and other necessary data, preliminary engineering and architectural studies, including the definitive description of the project facilities and their site locations, as well as the performance of cost-benefit analyses and the preparation of environmental impact statements. One of the selection criteria for the general consultant would be experience in design and construction supervision services because the contract would either include design and construction management or provide an option to include these services at a future date. The construction contracts would be between KCTA and the contractor.

- *KCTA to Act as Construction Manager.* Under this concept KCTA would engage consultants for each of the phases of the engineering and construction management services and would assume direct responsibility for the coordination and conduct of the program and for all interaction with involved agencies. In

effect, KCTA would act as its own construction manager as described in the first alternative.

- *Separate Consultants for Each Phase of the Program.* Under this concept, a consultant selection process would be carried out for preliminary engineering, for design engineering, and for construction management. Because each successive consultant or consultant group would not have the background of prior activities on the project, KCTA would not be able to rely on the same degree of consultant help available under the first two alternatives. Particularly affected would be project management assistance related to involved agencies, public relations, government agencies, and other project activities not directly part of engineering services.

The KCTA director of transit development, in the light of his analyses and the experience of other transit authorities, recommended the engagement of a general engineering consultant—architecture and engineering, which is usually termed the general consultant. The general consultant would be responsible for all preliminary and final design engineering, including design-oriented construction management, and for support and assistance to the KCTA in other matters of overall project management. At the option of KCTA, and after construction contracts were awarded, the responsibility for construction management, including the testing and run-in operations prior to revenue operations of the system, could be added to the general consultant's responsibilities.

The recommendations anticipated that the general consultant, as part of the management team, would:

- Remain responsible and accountable to KCTA for all professional engineering work for the project, possibly including construction management after the award of construction contracts.

- Advise and assist KCTA in developing financing and insurance programs, working out contracts with involved agencies and utilites, obtaining project agreements with labor unions, planning for public hearings and community participation, conducting central procurement activities, acquiring rights-of-way, obtaining building permits, complying with affirmative action programs, dealing with aesthetic, environmental, historical, and economic considerations, providing for traffic control during construction operation, and handling other matters for which KCTA was responsible by being in a better position or having more experience than other members of the team.

- Perform most of the preliminary engineering with his own forces, but retain the option to contract with professional firms for specialty services such as passenger use studies and estimates, geotechnical engineering, vehicle and control systems, architectural, acoustical, environmental, and other aspects of the project that need to be integrated into transit system design.

- Perform or contract with other professional firms for final design engineering. It was expected that facilities for this multi-contract project would be broken down into construction-contract-size packages and that the final design for each would be done by other engineering firms under contract with the general consultant. The final design of such systems as vehicle systems, control systems, power systems, and trackage would be done either by the general consultant or by other firms under contract with the

general consultant.

- Exercise post-contract construction management either directly or by contracting with a construction management consultant, if responsibility for this service is added to the general consultant's contract. The construction management consultant, if retained, is customarily engaged by the owner or general consultant to administer and supervise the construction contract and the installation of the system.

The following major reasons were given by the KCTA director of transit development for selection of the "General Engineering Consultant" method to provide professional services:

- It offers continuity of participation in the program by the general consultant through preliminary engineering, design engineering, and possibly post-construction contract management. The "Full Construction Management" alternative also provides this continuity but appears to divide professional responsibility and accountability with the design entity, each working under a separate contract with the owner. The general consultant, performing as contemplated during the preliminary engineering stage of the project, would develop an intimate knowledge of KCTA activities, policies, and interaction with state, federal, and local authorities, with local communities and citizens' groups, and with other involved agencies. This knowledge, together with detailed understanding of all of the professional and societal considerations leading to the end product of the preliminary engineering, which is the approved definitive design of the system, would be invaluable to the project management team through successive phases of the project.

- It centers professional responsibility and accountability in one organization.

- It offers the opportunity to utilize many engineering design organizations in the final design phase of the project, with all such design activities integrated into the project by the general consultant.

- It limits KCTA staff requirements to those necessary to perform the work that cannot be reasonably delegated to the general consultant, to administer the general consultant's contract, and to work closely with the general consultant's senior people, particularly with respect to critical or potentially critical problems.

- It allows KCTA, if satisfied with the general consultant's performance, to add construction management services through the construction and system start-up stages, thus keeping on tap the full background knowledge of the project development.

The recommendation to engage a general consultant was approved by the KCTA board of directors and the following general policy guidelines were adopted:

- KCTA staff would be kept at the minimum level required to perform that portion of the work that could not be reasonably delegated and to supervise the general consultant's work without duplicating it.

- KCTA senior staff members would promptly establish working relationships

with those federal, state, and local agencies that have approval authority of all or parts of the project and with those with a significant interest whose support would help the progress of the program.

- KCTA staff would prepare a public relations and citizen participation plan for the program.

- The preliminary engineering program would include conducting alternative studies of transit systems, vehicles, guideways, controls, alignments, locations, structures, and other features, and deciding on the adoption of specific alternatives. Once approved, the preliminary engineering report and supporting drawings would have to go through public information and environmental impact hearings. The report and its accompanying drawings would be a definitive description of the project ready for design without substantive change. Configuration or system planning would cease with approval of the preliminary engineering work, and any substantial variation would require approval by the KCTA board of directors. The preliminary engineering report and supporting information would be complete enough to meet all of the previously ascertained requirements of federal and state granting agencies and would be the basis of the capital grant application.

- KCTA staff would immediately analyze the authorities granted KCTA under the charter by the states of Columbia and Gondor, as well as the legal actions required in each state to exercise the right of eminent domain for real estate acquisition. The staff would also be directed to determine whether or not authority exists for KCTA to acquire property adjacent to transit stations considered favorable sites for business development and either build business facilities integrated with the stations or hold the property for future sale—in either case, to change a "cost-benefit" to actual money to defray the costs of the transit system.

- The KCTA General Manager would be directed to select the general consultant under procedures consistent with the requirements of state and federal sponsors—a procedure that permits selection of the consultant solely on the basis of qualifications, demonstrated experience, and commitment to the project of competent and experienced key personnel.

- The financing plan would call for study and capital grants from UMTA, with the local share to come from the two states and the counties of the region to be served.

PROJECT EXECUTION

Selection of General Consultant

Once KCTA had the concurrence of UMTA and a financing commitment from the agency, it advertised in professional engineering and architectural journals, inviting professional firms to vie for the position of general consultant to the Key City project. In addition, KCTA invited those firms known to have performed successfully in major mass transit programs to compete for the work. The invitation generally defined the scope of the Key City project and the professional services required, which included preliminary engineering and architectural studies and design, construction management, and supporting services. Team qualifications of joint venture partners and/or committed consultants would be

considered, providing that management would be by one sponsor. At KCTA's option, the engineering and architectural design of segments of the system, and possibly the systems for power, vehicle operation, and control, would be done by the general consultant or by consultants under contract to the general consultant. The initial contract commitment, limited by available funds, would be for project planning and development. There would be specific provisions for extending the contract to include design, by either the general consultant or consultants to the general consultant, and construction management and system start-up supervision. Construction management experience and knowledge of construction methods and procedures would be an important qualification requirement, because construction know-how would be essential to the preliminary engineering and design functions, as well as a positive influence on KCTA to retain the general consultant for construction management. A commitment to assign specific, experienced key personnel to the KCTA project would be a major factor in the qualifying procedure. Qualifications would be reviewed, and a limited number of applicants, probably not more than five, would be requested to submit proposals.

While awaiting responses to the qualification invitation, the KCTA staff prepared a request for proposal (RFP), defining in specific but not detailed terms the scope of work for the general consultant in the project planning and development phase. The RFP also described the kinds of concurrent work to be implemented by KCTA, with the support and participation, as requested, by the general consultant. It stated that an end product of the project planning and development phase would be a report that would meet all the requirements of UMTA for a capital grant providing federal funds that, along with local matching funds, would support the design, construction, and initial operation of the system. The report would also display to the public, involved agencies, concerned political entities, and others a comprehensive, definitive picture of the project and the plan of execution. The following items of primary significance would appear in the report and supporting studies:

- Vehicle; guideway; operating systems for power, train control, and safety; specific routes; station locations; and access to stations—all selected as a result of thorough studies of available practical alternatives.

- Estimated project costs, passenger use, revenues, and community benefits.

- Environmental assessments and steps anticipated to mitigate possible adverse environmental effects. (The environmental assessment and impact statement would be included as a task for the general consultant.)

- Schedules of project design, construction, and initial operation.

- Financing plan and cash flow estimates.

- Typical concept design of line structures and stations.

- Consideration of aesthetic, historic, and archeological preservation.

- Recognition of commercial developments in or around stations, consistent with urban planning goals.

- Contingency plan in the event that financial or other compelling limitations made it impractical to complete the entire project in one stage.

The proposers would detail the scope of work they considered appropriate for this phase. Items of work would be classified by indicating those for which KCTA or the general consultant would have the leading role within the management team for management and implementation. It would be understood that both would participate in all significant project decisions and actions. Proposers would describe their approach and implementation plan for the work in this phase and include a time-sequence diagram, showing in summary form the work to be done. The diagram would also indicate the milestones at which formal program reviews would be desirable to facilitate the necessary decisions and to inform the key members of the project team, including UMTA, of the progress and plans, as well as to give them an opportunity to comment on the progress of the project. Proposers would be requested to submit a sealed document containing an estimate of the cost of their services for this phase. The estimate by the consultant selected would be opened at the start of contract negotiations. In the event contract negotiations failed, negotiations would be initiated with the second-ranked consultant and his estimate could be opened for perusal.

Proposers would also be asked to provide a summary plan and time-sequence diagram for implementing the design, construction management, and system start-up phases, without giving any cost estimates. The quality of the plans would be evaluated as a factor in selecting the general consultant.

The purpose of an open proposal, as compared to including a detailed scope of work in the RFP, was to provide the proposer an opportunity to comment on the project. By excluding the cost estimate from the proposal, the KCTA would resist pressures to select the proposer with the lowest cost estimate. Approval of the selection procedure and the RFP by the ranking members of the executive branch of each of the concerned states and by UMTA was facilitated through close working relationships developed with the approving authorities by the chairman of the KCTA board of directors and the general manager.

Twelve groups responded to the qualifications request. After each respondent's submission had been reviewed by the KCTA staff, the KCTA director of transit development and the general manager recommended the selection of five respondents to be invited to propose. The recommendation was approved by the KCTA board and RFP's were issued to those five highest ranked respondents.

The completed proposals were evaluated by a task group of KCTA staff members, led by the director of transit development. Among the evaluation factors were the scope and extent of demonstrated professional competence and experience in all project phases, the record of cooperative working relationships with clients on major projects, the proposed organization for the project and the qualifications of key individuals to be assigned to the project, the quality of the implementation plan, and the financial status of the proposer. Based on this information, the task force ranked the top three proposers. The recommendations were examined by the selection board, made up of three members of the KCTA board of directors, the general manager, the director of transit development, a leading local professional engineer, a leading local architect, and a prominent community leader selected by KCTA. Each of the three contenders was given the opportunity to appear before the selection board. The choice of the selection board was confirmed by the KCTA board and UMTA, and the contract was negotiated. During the negotiations, it was jointly agreed that positive programs would be pursued in order to promote high morale and productivity in both the KCTA organization and the organizations of the general consultant and

the consultants operating under contract with the general consultant.

A consulting board was retained by KCTA to review the engineering and design when called upon to do so. Members of the consulting board were nationally known professionals with expertise in architecture, geotechnical engineering, foundation and structural engineering, construction, transit operations, and train operation and safety control systems.

In addition, a concept review team of leading local professionals was established to assist the management team in developing design concepts compatible with local practices and goals and to provide the professional community a convenient channel of communication with the management team. This review team included an architect, a civil engineer, a structural engineer, and a landscape architect.

Project Planning and Development Phase

A review of the joint charter of the two states that authorized the KCTA disclosed that there was no provision for the resolution of differences that might develop between the states with respect to project actions. At the instigation of KCTA, a board of three members was established to resolve such differences, if these arose. The board consisted of three members—one appointed by each governor and a third, a federal judge, acceptable to each governor. The board would meet and act only when differences between the states threatened disruption of project progress.

In contract negotiations, the general consultant developed a detailed scope of the project work and identified those items for which KCTA would have the main responsibility and those for which the general consultant would have principal responsibility for execution. The scope also identified those items under KCTA responsibility for which the general consultant would perform work to support KCTA actions, and provided that the general consultant would participate on other project work when requested by KCTA.

The initial work of the general consultant was to review and refine the conceptual plan. This included an assessment of project needs, analyses of resources, investigation of ground and subsurface conditions in critical areas, and general evaluation of previous origin-destination data and estimates of passenger use for segments of the transit system in the corridors designated in the conceptual plan. This work led to recommendations for changes in the conceptual plan and in the plan for staging the development in order to provide, in the initial stage, a system of rapid transit services likely to meet the most critical needs of the region, particularly where alternative transportation modes might not be economically or socially feasible. The recommended ultimate master plan included essentially the same general service areas as the conceptual plan but with some relocation of line and stations.

Changes to the master plan for the ultimate system included:

- Line A and Branch 1A west of the Anduin River were substantially rerouted. Branch Line 1A was relocated from Downs Stadium to the merge point with Line A to take better advantage of topography and subsurface conditions as well as to improve estimated patronage. Branch 1A became Main Line 1, and Line 1 west and north of the merge became Line 1A.

- An automated shuttle line between the Line 1 and Line 2 transfer station and the transportation center station (Line 1, Line 3, and the railroad station) was included in the master plan because of the extremely heavy patronage anticipated between the central business districts of Key City and Eastfold.

- The subway to Entwood, which was part of Line 2, was changed to surface or elevated because of the anticipated high cost of tunneling through the mile-wide major fault described in the conceptual plan and confirmed by drilling.

The initial project stage was part of the recommended master plan and included:

- Line 1 from Downs Stadium to Corsair Airport.

- Line 2 from the station in the north part of Rivendell, quadrant E-12, to the station in Entwood just south of the Entwash River, quadrant E-5.

- Line 3 from the station in Riverton, in the south part of the F-12 quadrant, to the station near Gondor University.

It was recommended that feeder bus service be initiated during this stage, concurrent with transit system operations start-up between Overhill and the north area of Key City to the transit station in the C-9 quadrant and from Northwood and north Entwood to the station in the E-5 quadrant in Entwood.

The revised master plan and the contemplated staging plan were the subjects of public hearings. While they were generally accepted, public objection was raised to removal of Branch Line 1A from the initial stage. Commitment by KCTA that this branch would be considered of first priority in the second project stage, and that feeder bus service would be operated from Overhill to the first stage system, satisfied most of the objections. Once the revised master plan and staging plan were accepted, the general consultant was requested to complete preliminary engineering and project development in detail for the initial stage. This included consideration of the extensions in later stages but only to the extent of providing viable interface with the proposed extensions for line structures, stations, and power and control systems.

The initial project stage and the master plan for the total project are shown in Tables 2 and 3. The shuttle would be two miles of subway with extension of two stations of Line 1.

TABLE 2 Initial Stage, Key City Transit Project

	Line 1	Line 1A	Line 2	Line 3	Total
Length (miles)	16	0	15	15	46
Subway (miles)	5	0	6	5	16
Surface/Elevated (miles)	11	0	9	10	30
Stations	8	0	10	9	27

TABLE 3 Total Master Plan, Key City Transit Project

	Line 1	Line 1A	Line 2	Line 3	Total
Length (miles)	30	12	25	22	89
Subway (miles)	12	4	10	5	31
Surface/Elevated (miles)	18	8	15	17	58
Stations	13	3	14	11	41

Early in the project planning and development phase, KCTA arranged a series of "brainstorming" meetings of the project management team. Those designated to participate included the KCTA general manager, the general consultant's official in charge of the project, and senior staff members of both organizations. The purpose of the meetings was to identify the joint management policies and actions that would minimize project delays by preventing identifiable problems from developing and solving serious unanticipated problems that arose, to find ways of developing efficient team-oriented working relationships between the two organizations, to suggest actions that would develop an environment in which morale and productivity would be sustained, and to identify other significant management practices that would help produce an efficient project. Management actions suggested at the meetings and considered of substantial significance to project success were summarized, and policy decisions and procedures were adopted and implemented.

Effective overall project management had to be exercised in two categories: (1) for those matters directly under the control of the management team and (2) for those matters requiring decisive actions, that are responsive and timely, by organizations and individuals not under direct contol.

Management of project matters dependent on the agencies, entities, organizations and individuals not subject to unilateral control by the project management team were considered of special importance. The entities certain to be involved, and others likely to be, were identified and plans made for early action to develop their constructive participation and prompt response to the needs of the project. The agencies and entities identified were:

Federal—DOT, EPA, Corps of Engineers
States, cities, and counties
Flood control districts
Port authorities
Water and sewage districts
Associations of government
Regional planning councils
Communities
Citizen groups and associations

The management team generally identified the potential constraints outside its unilateral control that could impact adversely on project execution and developed plans for mitigative actions that might be needed. Primary responsibility for dealing with the potential constraints and their possible adverse effects was assigned to specific members of the management team, as follows:

- The owner was assigned institutional constraints——e.g., imposed architectural treatments, building permits, acquisition of rights-of-way and construction work areas, financing, central procurement, and wrap-up insurance. The owner was also assigned societal constraints——e.g., environmental, aesthetic, economic, and historical matters.

- The engineering consultants were assigned physical contraints——e.g., topography, foundation and subsurface conditions, groundwater, weather, utility density and type, traffic controls, and protection of existing structures.

- The construction contractors were assigned institutional constraints —e.g., labor productivity, safety, and equal employment opportunity and participation by minorities.

The organizational project structures of the KCTA and the consultants were examined and restructured. For each major category of project activity responsibilities were assigned to counterpart individuals or organizational entities with delegated equivalent responsibilities and decisive authority at appropriate organizational levels. In general, work performance was assigned to the general consultant, with KCTA monitoring. A positive program to generate high morale and productivity was developed and implemented. Professional responsibility and decisive authority for engineering and architecture was assigned to the general consultant, subject to KCTA approval with respect to compatibility with owner and community goals but not with respect to structural integrity and public safety. The general consultant was accountable for engineering and architectural design.

A policy decision was made that KCTA have principal responsibility for the final execution of all management functions relating to funding agencies, to federal, state, and local political entities, to public utilities, to concerned federal agencies and regulatory bodies, to real estate acquisition, and to the public, all with support of and in close coordination with the general consultant. The general approach of KCTA was to establish contact with all of these groups and urge each one to designate a representative to work with a designated high-level KCTA official on all matters of interest to the group. The public relations program staff would work with citizens or citizens' groups and offer them an opportunity to be kept informed about the project and to participate in its development and execution. Early working relationships with utilities would develop preliminary commitments by each party for financing and timely performance of utility relocation. As the design progressed, details of the required relocation and construction schedules would be defined.

Procedures were developed for jointly streamlining the issuance of building permits and making sure of compliance with regulations. Condemnation of real estate for right of possession and acquisition would be done only through the executive branches of the respective state governments and authorized by state courts. Discussions with the key individuals participating in the condemnation process would result in accelerated action that would reduce the time required to obtain the right of possession from the usual two years or more to about one year.

At the request of KCTA, the secretaries of transportation of Columbia and of Gondor each designated a key official to maintain close liaison with KCTA.

For its part, KCTA obtained commitments from regional members of both state legislatures to assist in resolving legislative problems that could arise to adversely affect the project.

Financing and environmental approval procedures were specifically identified as critical project elements that potentially could delay the project's progress and increase costs. Positive action programs were developed to aid in timely, decisive actions that would advance the orderly and efficient progress of the project.

The management team of KCTA and the general consultant initiated a management plan, which was developed earlier in detail for the project planning phase and the work preparatory to final design, such as general specifications and design criteria. Studies were made of alternative transit modes, project configuration, and operating and control systems, along with patronage estimates for each major alternative. The alternatives to be studied were those considered practical by the general consultant and acceptable to KCTA and UMTA. Geotechnical exploration significant to the selection of alternatives, and to meeting other preliminary engineering, cost estimating, and concept development needs, was conducted according to a program developed by the general consultant and reviewed by the geotechnical engineer on the consulting board and KCTA.

The general consultant's experience was utilized in the study of alternatives to avoid in-depth studies of those considered obviously not promising or inconsistent with the owner's objectives. Detailed trade-off estimates were made by construction-oriented estimators on only those alternatives that met the project objectives. Detailed trade-off estimates, with life-cycle appraisals, were necessary to the decision for adoption. Preliminary engineering and design concepts were reviewed by experienced construction men in order to ascertain that everything would be done to advance construction economies.

Early discussions were initiated between the management team and the headquarters official of UMTA who had been designated as the focal point of project contact to establish the ground rules that would best serve the project without compromising UMTA responsibilities. The "go or no-go" decision for the project would be made formally with UMTA approval only after the project planning and development phase was completed and the report submitted to support a capital grant request. It was agreed that the recommendation for this fundamentally important decision would be made by KCTA only after review by appropriate members of the KCTA consulting board and a business and financial consultant to be retained by KCTA for that purpose. It could take considerable time, probably four months or more after receipt of the report and recommendation, for UMTA to approve the capital grant and to commit funding. However, preparation of general specifications and design criteria and identification of design consultant candidates had not been included in the project planning phase, and because this work would most likely take more than the four months needed by UMTA, the anticipated interruption would not seriously affect the progress of the project. The local share of funds to carry out this work and initial work in the design phases was available. Months before the completion of the report, it was reasonably certain that a "go" recommendation would be made. Starting the general specification and design criteria task during the latter part of the project planning phase and continuing it through the UMTA capital grant approval period would shorten the time needed to achieve project operation by an estimated six months or more, with substantial direct cost savings and without

incurring costs that would result from losing and regaining project momentum.

UMTA agreed to entertain this request and promptly approve it or, in the event UMTA could not approve it promptly, to authorize the work on a "no-prejudice" basis. The "no-prejudice" authorization would require KCTA to finance all of the costs until approval of a capital grant, at which time the costs incurred by KCTA would be allowed as part of the local contribution to capital grant funding. In view of the low cost risk and the substantial savings to be realized, agreement was made and the work started.

In the meantime, UMTA agreed to other procedures to advance the project. The regional UMTA representative and the designated UMTA project official in UMTA headquarters would be informed of project plans and proposed actions of major significance. UMTA would be able to monitor the project, rather than require prior approval for routine actions, including line item budget reallocation and assignment of appropriate contingency allowances to budget line items. Excepting requests for grants or increase in grants, UMTA agreed that approvals would be automatic if positive response was not made within three weeks from the receipt of the request. Under the circumstances, UMTA accepted contingency allowances in the budget above the basic estimates for real estate acquisition, professional services, administration, construction, and system testing and run-in. KCTA could utilize these contingency allowances as required within specified maximums. After the award of construction contracts, KCTA could commit contingency funds for contract adjustments up to 5 percent of the contract amount, without approval by UMTA. UMTA agreed to accept liability risk for the innovative design and construction techniques it had already approved in the same proportion as its capital funding.

Similar conferences with UMTA and other concerned federal, state, and local agencies led to specific guideline requirements for the Environmental Impact Statement (EIS) for the project. All needs for additional support or detail would be consolidated and requested within two months of receipt of the EIS. Rules not in effect at time of submission would not be imposed as a condition of acceptance. Concurrent review of the EIS would be made by all involved entities and a decision would be reached in conference with all entities that had problems with the EIS.

Project status reporting would provide information in detail about costs, schedules, expenditures, and progress. Exception reports would be made of problem areas and other salient features. The format of reports on information required by UMTA or other entities was designed to fit those requirements with little or no modification. Frequent, scheduled project reviews and briefings were conducted by the general consultant, and representatives of UMTA and EPA were invited to attend the meetings while the environmental assessment studies and preparation of the EIS were under way. Owner's representatives also participated, particularly those designated as responsible for operation of the system. Informal interaction of general consultant and owner representatives was encouraged as the project definition developed and decisive action was required to maintain the schedules.

The capital cost estimate for the project contained the basis for all estimates, including the calendar period that the estimated wage and material prices were in effect, and allowances for cost increases and schedule changes. It included a general statement regarding cost effects of delays at different

points in the project schedule.

KCTA and the consultants followed fair employment practices and utilized competent minority firms to a reasonable degree. Programs for developing morale and job satisfaction and providing job training and education were developed for use throughout the project.

The Key City public transit system would consist of a fixed guideway of steel rails, using cars with steel wheels, and with automatic ticketing and fare collection and automatic train control and safety systems—not different in general from the conceptual plan.

Design Phases

Under the "no-prejudice" commitment of UMTA, general specification and design criteria had been started in the project planning phase. On completion of project planning, the decision by KCTA was "go." This was endorsed by the region's political bodies and the two states. The local share of funding for the capital design, construction, and start of operation was committed. The capital grant application was submitted, expedited by KCTA through the UMTA project representative, and approved about on schedule. General specifications, general design criteria, identification of construction packages, and examination of the qualifications of design consultants were completed at about the same time.

Satisfied with the performance of the general consultant, KCTA exercised its option to extend his contract to include design and design related construction management. The definition of the scope of work by the general consultant for the design and construction phases had been prepared by the joint effort of KCTA and the general consultant, and contract negotiation was promptly completed, with concurrence of UMTA. The vehicle, power, operation, and control systems, maintenance facilities, and trackage would be designed by the general consultant with specialty consultant participation. Other facilities would be designed by engineering firms under contract to the general consultant for one or more of the construction contract packages.

All elevators, escalators, power transformers, vehicles, control systems, special maintenance shop equipment, fare collection systems, and similar common-use items that could be more favorably purchased in quantity were procured by KCTA in coordination with the general consultant. Construction materials and other permanent equipment would be purchased by the construction and installation contractors.

The design consultants were selected by the general consultant, with approval of KCTA, on the basis of their experience and competency. Each would be responsible, as a section designer, for the design of a defined section of the project.

Notices to proceed were spread over many months to fit the construction schedule. This schedule called for an early start of sections that would take the longest to complete, and early completion of a section of the guideway for testing. Among other scheduling considerations was fitting the design and construction sections schedule to such available resources as contractors, materials, equipment, design and construction work force, and cash flow.

The initial task of the section designer was to prepare detailed design criteria, configuration dimensions, and right-of-way and other real estate requirements in detail, to perform additional geotechnical exploration and analysis, and to provide other information needed to produce detailed design and working drawings for construction contracts. The preliminary design takes from 30 percent to 40 percent of the total design time. Changes made after the start of the detailed final design and production of working drawings usually require changes in a whole series of drawings. This is not only expensive, but results in delays and has a demoralizing effect on the design team. Accordingly, firm and final decisions at the completion of the preliminary design are important to the efficiency and cost of the design process. Of course, firm decisions call for exhaustive review of preliminary design concepts, drawings, and specifications when these are about 35 percent complete.

The KCTA staff, particularly the senior operating official, and the general consultant participated in frequent informal and formal reviews of the preliminary design. For the formal 35 percent design review, KCTA invited UMTA officials in order to give them first-hand understanding of the design. Following this review, the only design changes to be considered were those resulting from a real design breakthrough that promised substantive advantage to the project.

During the design stages, KCTA maintained active contacts with involved agencies, political entities, regulatory bodies, and UMTA. New information about utility relocation needs led to specific work orders and assumption of financial support, as generally covered in the agreement reached during the planning stage. Schedules were developed as the design for each section progressed, and a decision was reached determining whether the relocation work would be done by the construction contractor or by the public utilities. Real estate acquisition was started, timed to be completed to meet the contract award dates for each section. The public relations program continued, though its orientation changed from announcing project plans to dealing with problems arising during construction. It concentrated on the operation of the system, recognizing that it may take some time for the system to run relatively trouble free. The operations people continued to review the design and to suggest improvements that could benefit the operation, maintenance, and public acceptance. KCTA set up a task group to work with the designers to aid in the preparation of detailed work and maintenance manuals.

During the preliminary design phase, the general consultant worked with the section design consultants to prepare specific descriptions of all real estate needs for each section. KCTA proceeded with the acquisition program, using the expropriation procedures previously developed for all parcels on which price agreements could not be reached. Necessary rights-of-way and other real estate were acquired in all cases before awarding the construction contracts.

The general consultant directed special attention to anticipating and solving interface problems between adjacent design sections and between systems designs and section designs.

The final detail design included the preparation of construction contract drawings, specifications, and other required items for contract bid packages. Consistency in contract documents was achieved through careful supervision by the general consultant. The recommendations stated in *Better Contracting for*

Underground Construction were followed. Contract documents and specifications called for the protection of existing structures along the tunnel lines and other deep excavations, with specific design for critical conditions.

KCTA, exercising the option originally included, added construction management to the general consultant's contract. The scope of work, including system start-up and run-in, was defined and the management plan was expanded to cover these phases.

Notice of the acceptance of the EIS was received during the late stages of the final design of the first section that was scheduled for construction.

Construction and Initial Operation Phases

The first construction contract included the interchange station in the Key City central business district on Line 1 and the tunnel under the Anduin River to, but not including, the surface railroad—Line 3 interchange station. The second contract, awarded shortly after, was for a four-mile surface section north of the University of Columbia on Line 2, to be completed early for use as a test track.

Agreements were reached, prior to the award of the first construction contract, defining the responsibilities and authorities to be exercised by UMTA, the two states, the KCTA board, the KCTA general manager, and the general consultant with respect to construction contract administration. UMTA initially designated a contingency fund of 5 percent of the construction contract amount that could be used without its prior approval for contract changes that had been authorized by the KCTA board or by a group designated by the board. The states agreed to abstain from exercising contract administration over the KCTA board, but would be informed of actions taken through the regular project reporting systems. The KCTA board delegated most of its approval authority to the KCTA general manager, limiting his approval authority for any one change to an amount less than 1 percent of the contract. Delegations of approval authority for lesser amounts were given to the general consultant and the resident engineer. To facilitate prompt payment for contract progress, the KCTA general manager was granted controlling authority to make payments in amounts consistent with certifications of progress made by the resident engineer.

Established procedure required that all formal communication with the contractor would be between the resident engineer and the contractor's project manager. Communications from others would not establish contract obligations for either party to the contract.

Upon award of the first construction contract, KCTA, in collaboration with the senior members of the general consultant's construction management team, retained a panel of three members to function as a review board for claims by and disputes with construction contractors. The criteria for selecting this panel called for one member to be experienced in engineering and design, another to be experienced in contract construction, and the third in business administration or in construction contract law. The members of this panel would have no previous professional or business contacts with KCTA, the general consultant, or the construction contractors. They would be recognized in their fields and possess reputations for integrity and fairness. Their concurrent responsibilities would permit them to devote the necessary time, when called upon, to KCTA

problems. The same panel would act for all construction contracts, except when a panel member had a significant business relationship with a contractor within the past five years. In that event, a replacement would serve on the panel. The panel would recommend appropriate action on claims and disputes at the request of KCTA, but would not have authority to make binding decisions, unless by special agreement between the owner and contractor on a specific claim, dispute, or other contract problem. KCTA would convene the panel when necessary, not on a specified periodic schedule. The members would receive the construction status reports, including any "exception" or "trouble spot" reports and would be invited by KCTA to inspect work in progress from time to time, individually or together. The contract bid documents described the composition and function of this panel.

KCTA, together with the general consultant and the local representatives of the Associated General Contractors (AGC) and the National Constructors Association (NCA), initiated discussion with the Building Trades Council of the American Federation of Labor (A.F. of L.). They requested the cooperation of the union to enter into agreements with the construction contractors that would protect the project against strikes, promote prompt settlement of jurisdictional disputes, and generally relax jurisdictional rules in the interest of productivity and economy—both of benefit to the community and its residents. Specifically they requested that all categories of workers at the tunnel heading be permitted to perform work in any category.

During the construction phase, KCTA expanded its operation and maintenance staff by assigning key people, when required, to operation planning and participation in testing and run-in activities. The public-participation and support program continued, with emphasis on the handling of constuction disruptions and advancing the use and understanding of the entire transit system. Continuous contact was maintained with involved agencies and groups to avoid potential problems during construction and through the transition from construction to operation.

Project Phasing

Each major project, public or private, starts with the recognition of a need. The process of conceptual planning identifies the facility required to best meet the need. The conceptual plan describes the facility in general terms and, in the light of available information, compares the balance of economic, social, and other benefits against the estimated costs and any perceived adverse impacts. A favorable balance of factors should lead to a recommendation to go ahead and could help establish a mandate for the project. The agency or organization that would be responsible for executing the plan should also be identified or recommended in the conceptual planning phase.

The steps leading to completion and operation of the project are:

- Project Organization

- Project Planning, including review and possible revision of the conceptual plan; preliminary engineering. (The project organization and planning phases can be, and often are, combined.)

- Project Execution – Initial Phase
  – Preliminary Design Phase
  – Final Design Phase
  – Construction Phase
  – Start-up and Operations Phase

The boundaries between the conceptual planning, project planning, preliminary design, and final design phases are not fixed precisely and may not be recognized as separate phases in the execution of all projects. Conceptual planning and project planning phases may be combined, eliminating a "go or no-go" decision between these two functional phases. This is more common in major private projects than in public projects. The project planning phase may include functions frequently carried on in the preliminary design phase or may lose its identity as a phase if combined with the conceptual planning phase. Preliminary design may be combined with final design. This also is more common in major private projects than in public projects. Within most major public projects, sequencing of the work, as it relates to major geographic segments, will result in different segments proceeding through different development phases at any one period. However these phases are divided, the sequence

described here is a fundamental requirement to well-ordered project development and execution.

It is highly unlikely that any two major projects have followed the same course or sequence of phases with the same functions assigned to each. During each discrete phase the actions by financing agencies, political entities, other involved agencies, the public, owners, designers, and contractors, influence and possibly affect the progress of the project.

Because each large project is different from those that preceded it and those that will follow, it is impractical to select a particular historical example to illustrate the phasing of a major underground construction project. The Key City Model was developed to illustrate the variety of factors likely to be involved. Figure 7 shows the general sequence of project phases, from conceptual planning to start-up and operations, the major activities that take place in each phase, and the characteristic flow from one phase to the next. The bottom lines of Figure 7 display those activities that continue throughout the project, from the inception of conceptual planning through the start-up of operations.

CONCEPTUAL PLANNING

The conceptual plan is an overall master plan of the project developed primarily by the application of professional planning disciplines supported by engineering and architectural disciplines. In the case of a rapid transit project, such as the hypothetical Key City Model describes, the conceptual plan would generally identify the facilities to be built, the desired operating systems, the service areas and corridors, the supplemental support elements, such as feeder lines, and the manner in which the project operation would be integrated with other transportation modes and systems in the area, those both existing and planned. Of necessity, the plan would include an assessment of needs, maximization of favorable social, economic, environmental, and aesthetic impacts, minimization of unfavorable consequences, and both initial and continuing costs. Important factors that need to be considered in the plan are public and political support, approximate costs, economic feasibility, financing alternatives, ridership estimates, the direction and character of community growth, physical conditions, institutional influences, and other factors of general or local significance. The conceptual plan provides a general description of facilities and systems that are calculated to best meet the needs of the community and presents a favorable balance of impacts. The conceptual plan also recommends the type of agency or specifies the existing agency to be charged with the responsibility of carrying out the project under a defined mandate.

The starting point for this project management study is after the completion, acceptance, and approval of the conceptual plan and the establishment of an authority responsible for the implementation and control of the project. While project management during the conceptual planning phase is not part of this study, it is patently clear that the quality of management during this phase as well as the quality of the conceptual plan will have critical bearing on the project in all subsequent phases. Concepts that are not realistic at the outset require revisions that could cause delays and modifications of the project.

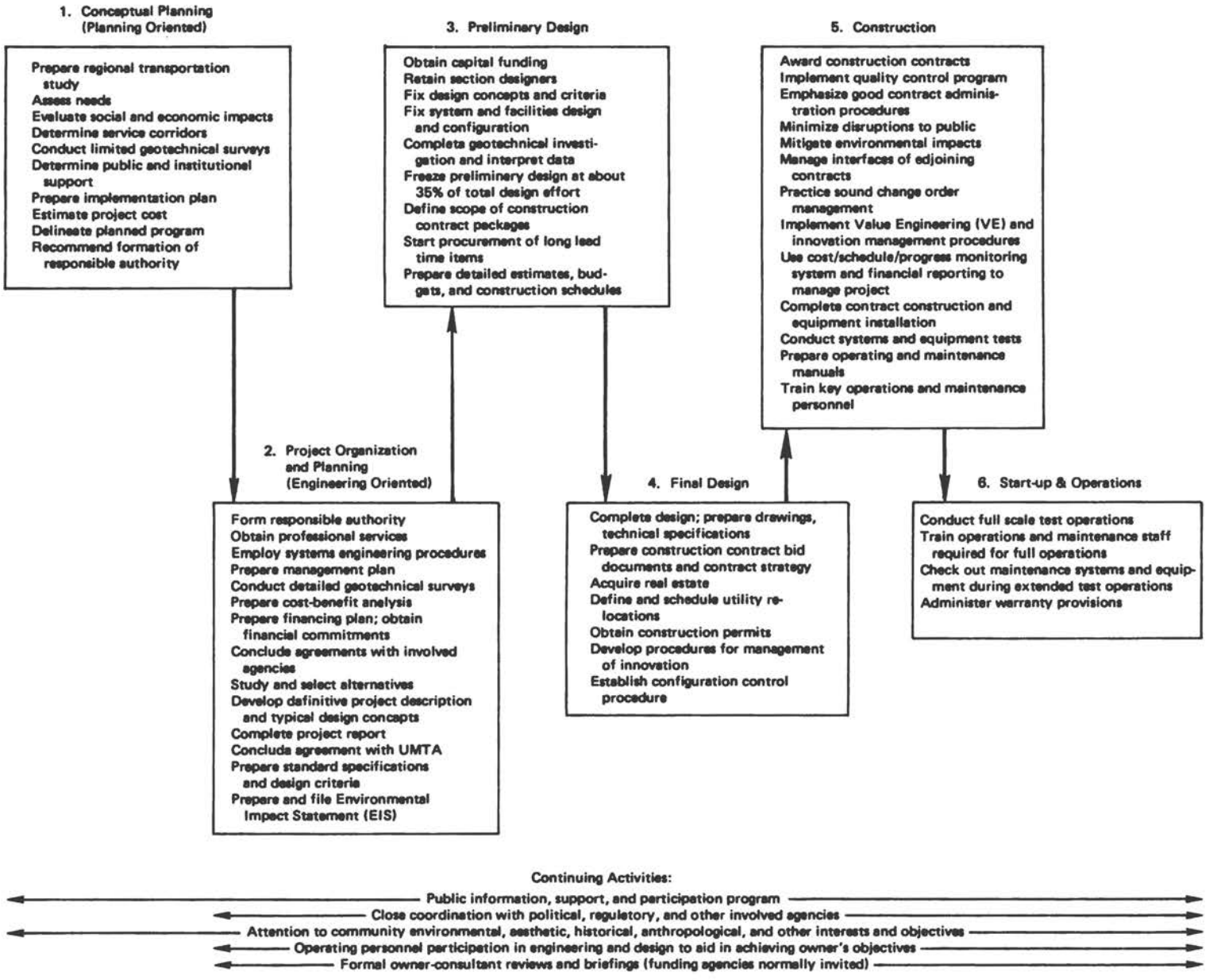


FIGURE 7 Typical project phases (major functions).

PROJECT ORGANIZATION

For effective management, the owner's staff should be organized to participate in and supervise the project activity no later than the start of project planning and should set general policies early as guidelines for the conduct of project development and execution. The owner should establish the project management and the project team concept and decide what use to make of outside consulting services. The effectiveness of the team concept will be largely dependent on the owner's leadership. As the project progresses through subsequent phases and the number and complexity of activities increases, the owner will need to "fine tune" his staff to meet the leadership needs of managing an increasing number of organizations in the project team during the entire project. For instance, key operations and maintenance managers must be brought on board early so that they can assist in the planning and design to facilitate effective operation and maintenance of the completed project.

The success or failure of the project will be largely influenced by the owner's ability to develop a team spirit among project participants. All organizations involved in the design and construction of the project must be directed toward the common goal—successful project completion. Because the organization to manage the project is so important to the project's success, the organizational alternatives the owner should consider are discussed in a separate section starting on page 45.

PROJECT PLANNING

Work in this phase is heavily oriented to the use of professional engineering and architectural disciplines supported by planning disciplines—all operating under systems engineering procedures. This phase consists of development of the detailed scope of work and the definitive description of project facilities and systems. It also includes a preliminary estimate and schedule, a staging plan for construction, cost-benefit analyses, financing plans, typical design concepts of facilities and systems, selection of alternatives, systems operating criteria, initial policy agreements with involved agencies, utilities, and regulatory bodies, environmental and societal impacts analyses and provision for hearings, a public information program, and any other elements of significance to the decision to go ahead.

The report that culminates this planning phase, which includes preliminary engineering, will become the basis for obtaining capital grants for design and construction for the project, for public hearings and referenda, and for obtaining public and political support for local public financing or for a private owner to decide to finance the venture.

PROJECT EXECUTION

Initial Phase

The approval of the project and the availability of financing will trigger the initial phase of project execution. The first step is for the owner and the project team to refine the project plan, organize to meet current needs, and plan the details of future needs. Information and control systems for design and construction activities should be developed. Candidates for architect-engineer and systems design services should be identified and selections should be made. Then contracts should be negotiated for these services, whenever the

commitment authority is consistent with funding limitations. General project criteria, specifications, and drawings, if not done in the project planning phase, are completed in this phase to guide final design. To further the design, additional data collection, topographic surveys, and geological and geotechnical investigations of critical areas are accomplished. Real estate descriptions are prepared and acquisition procedures started. Specifications should be prepared for procuring permanent equipment that requires long lead time before delivery. Design and construction packages should be identified. Master agreements should be made with involved agencies, utilities, and regulatory agencies, with provisions for the accommodation of general conditions that may develop during the design and construction phases. The program of public information, participation, and support should be continued. Environmental assessments should be refined, and draft and final environmental impact statements processed. Institutional influences, both existing and potential, should be identified and steps taken to mitigate those that might adversely affect the project. Other activities required to prepare for the final design phase and construction phase should be pursued.

The initial phase normally does not have a separate identity for private projects. There may be a line of demarcation in public projects between the initial phase and preliminary design phase in cases where funding of the initial phase is for a specific defined scope prior to capital grant funding. Work in the initial phase flows into and intermingles with the professional work and the administrative activities that lead to the final design. Therefore, it is often preferable to combine this phase with the preliminary design phase in order to advance project efficiency and to avoid project delays resulting from any hiatus in the project normally experienced in progressing from one funded activity to the next. If this is a separate phase, every effort should be made to work closely with the funding agencies to obtain approvals of the work as it progresses and to expedite the transitional activities related to additional funding. The chart (Figure 7) on page 39 shows the initial phase as part of the preliminary design phase.

Preliminary Design Phase

The purpose of this phase is to establish detailed criteria for use in the final design and to conduct other activities that facilitate the smooth, uninterrupted transition to final detailed design. Major activities in this phase include development and activation of management and administrative systems, completion or updating of agreements with involved agencies, utilities, and regulatory agencies, ordering equipment requiring long leads, initiation of real estate acquisition, continuation of public information and support programs, completion of data collection, topographic surveys, and geological and geotechnical investigations, and updating, when required, the environmental impact statement, operating criteria, and project cost estimates, schedules, and budget estimates for each of the construction packages. The preliminary design phase is generally considered to be 30 percent to 40 percent of the total design effort. This phase leads directly into the final design phase.

To avoid the delays and substantial added costs that accompany changes in the detailed final design, the preliminary design should be frozen at the inception of final design. Changes should be permitted only for compelling reasons, such as new or different political and public attitudes, substantial economies through value engineering, accommodation of changed conditions in

construction, reductions in funds or changes in funding agency criteria, and other reasons when the consequences of refusal to change are substantially more adverse than the risk of delay and the increase in design costs.

Final Design Phase

The purpose of the final design phase is to prepare final drawings, technical specifications, and contract documents required to obtain construction contract bids. The quality of these drawings, specifications, and contract terms has a pervasive influence on the contract bids. By providing clear and specific assignment of risks, disclosing all engineering and geotechnical information gathered, providing for contract adjustments for differing site conditions, clearly identifying contract obligations of both owner and contractor, and clearly defining avenues for contract adjustment for delays resulting from action, lack of action, or delayed action, the owner will place prospective construction contractors in the best position to submit realistic bids. Normally, the design phase includes the preparation of the engineer's estimate and schedule, analysis of construction bids, and award or recommendation for award.

During the construction phase, revisions of the design or even redesign may be necessary to accommodate unanticipated site conditions that are encountered, accepted value engineering proposals, final manufacturer's drawings, errors, and other factors. In instances when design changes may affect structural integrity, it is best to call upon the original designer to make the alterations. The original designer is more likely to redesign to the same standards and criteria as for the original design and should be able to do the work more efficiently than anyone else. Further, no dilution of professional responsibility results from the redesign. It is therefore desirable that the original design contract provide for design support during construction. Design changes required by design error are the responsiblity of the designer; other changes are normally paid for under the standard agreement.

Prior to the award of each construction contract, all real estate necessary to the contract work should be acquired, including land that may be leased for construction plant and access. Unforeseen delays in acquiring real estate may necessitate construction activities to "step around" specific parcels in order to maintain construction schedules.

Changes in the preliminary design may necessitate the revision of the environmental impact statement and lead to additional public hearings that could delay the progress of the project. The political liaison and public information and support programs should continue throughout this phase. All practical means should be devised and adopted to minimize any adverse impacts of construction on the community. The project management team should continue to communicate and work closely with involved agencies, utilities, and regulatory agencies. Central procurement should be completed and deliveries should be scheduled to fit the construction timetable. Construction contract strategy should be developed and implemented.

Construction Phase

The construction phase starts with the awarding of construction contracts. For multi-contract projects, bidding should be scheduled in accordance with the contract strategy and spaced to get the long-term contracts started early. Offer-

ings should be spaced in such a manner so that prospective contractors have time to bid on successive contracts. Whenever possible, and particularly for underground construction projects, the sequence of offerings should be set to avoid dates that are close to bid dates of contracts for other major projects in the country. Contract sequencing is also important to avoid competition among contractors for construction materials and for work force, especially in regions where there is a limited, experienced labor pool.

The owner may retain a separate construction manager consultant (CM) to manage the construction and procurement contracts or he may assign this function to his staff or to a general consultant. In cases when a separate CM is retained, the CM joins the project management team, whose members already include the owner, his staff, and any consultants who have been retained previously. The contractors' managers also should become members of the project management team.

Close working relationships with other agencies involved, railroad, utilities, and regulatory and funding agencies need to continue. Activity should be continued on political liaison and public information and support programs. An expanded program of public information and support should be implemented to mitigate the inescapable community disruption resulting from construction operations. This program should be particularly oriented to owners and operators of commercial facilities adjacent to construction areas, and should seek out and mitigate to the greatest practical degree any adverse environmental impacts. The proposed mitigation must be implemented. The contractors should provide the primary interaction with labor unions, although the entire management team should be responsive to the contractors' needs in labor relations matters in order to help solve problems that may develop and to achieve an appropriate degree of consistency in labor practices throughout the project.

Start-Up and Operations Phase

The key people of the owner's planned organization for operations and maintenance of project systems and facilities have a significant role in the activities of earlier phases of the project. Their experience in the operation and maintenance of similar projects, utilized in collaboration with the staff involved in planning, engineering, design, and integrated system testing, will lead to the smooth transition from construction completion into project operation and substantially improve the quality of early operations. Their early participation will influence the design to better achieve the desired degree of system operability, maintainability, dependability, operational economy, service standards, and safety. It also will help them develop detailed knowledge of the operating systems and facilities.

For a mass transit project, integrated testing of operating systems and equipment should be done during the construction phase, preferably on a section of the project completed early in the construction period. Such tests are normally the responsibility of the owner's system engineers or the general consultant or, if one is retained, the construction manager, with substantial participation by the key people on the owner's operational and maintenance staffs. On completion of construction of an operable section and before revenue operations are possible, full scale test operations must be carried out under the owner's operations organization, with the support of the consultants and suppliers of systems and equipment. In a mass transit project, a business development and public information program conducted by the owner will go a long way

to encourage the traveling public to use the system. It also should inform travelers how to use the system and provide specific schedules of service hours, train frequency, and information about when extensions of different lines will go into regular service.

Normally, the consultants will be retained to assist the owner, as may be required during warranty period, to assure compliance with warranty provisions.

Organizational Alternatives

There are several alternative ways of organizing a major underground construction project, and success can be achieved by more than one organizational model. There are four salient factors which, when considered together, will assist the owner in establishing the best organizational arrangement for a particular project. The first of these is the objective (or objectives) of the owner in undertaking the project. The second is the present or projected management capability of the owner. The third is the set of laws and regulations governing the owner's actions. The fourth factor is the resources, including the funds, of course, that are available to accomplish the entire project. The owner should strive to organize the project for the maximum efficiency possible, taking all four factors into account. If the factors are carefully considered, the advantages and disadvantages of each organizational arrangement will be apparent, and the best can be selected.

The organization necessary to construct a major project can be described as the organization of organizations—or the management structure—necessary to complete the project. An example of the owner's organization and possible organization charts for three different arrangements for overall project management are shown in Figures 8-11.

ORGANIZATIONAL OBJECTIVES

The basic objective in organizing the management of a major underground construction project is to successfully complete the project. To accomplish this basic objective, there are several important specific actions the owner must take. These are:

- Designate specific responsibilities, coupled with commensurate authority.
- Assign to specific organizations functions necessary to manage the project. Dual assignment of functions must be avoided.
- Establish clearly defined and understood channels of communication.
- Set the legal requirements governing the actions of the owner and the

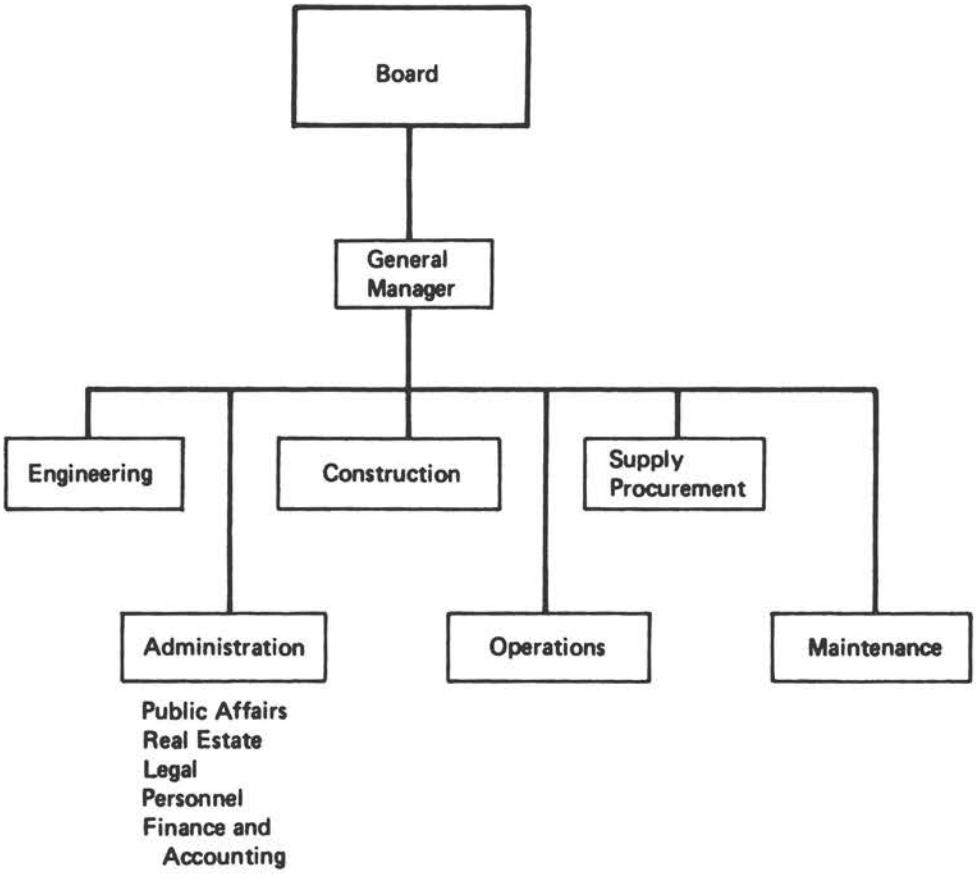


FIGURE 8 Typical owner organization.

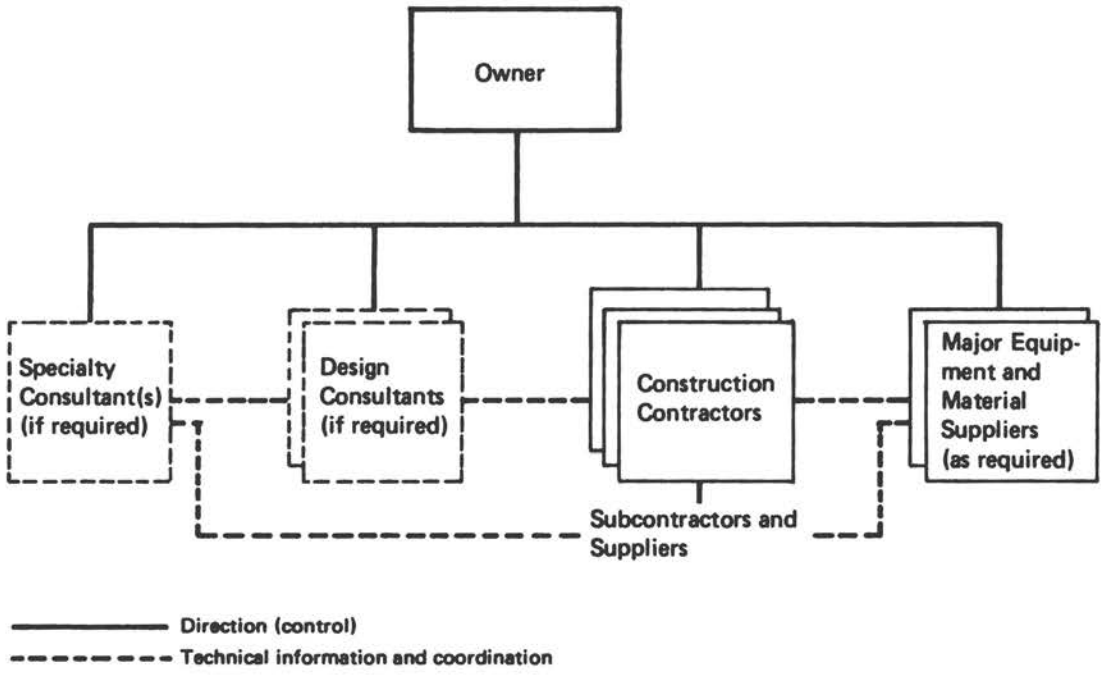
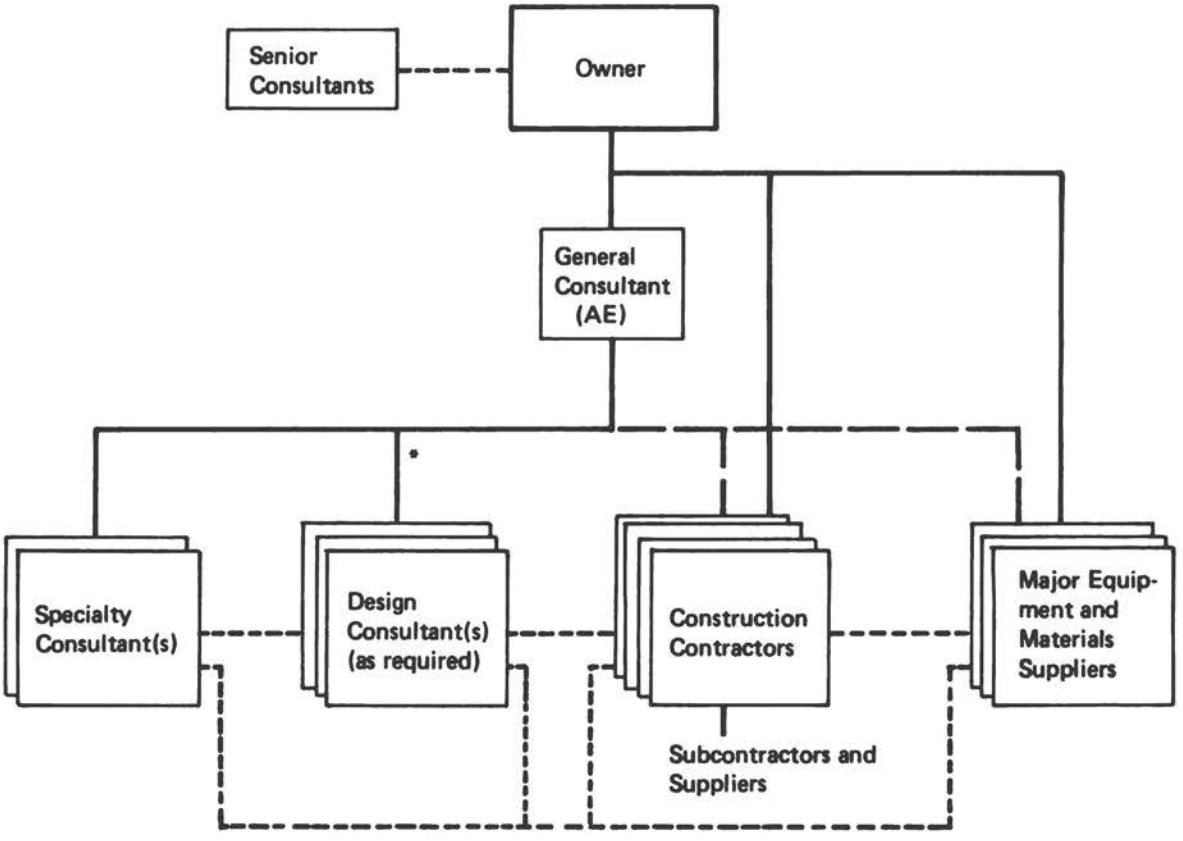
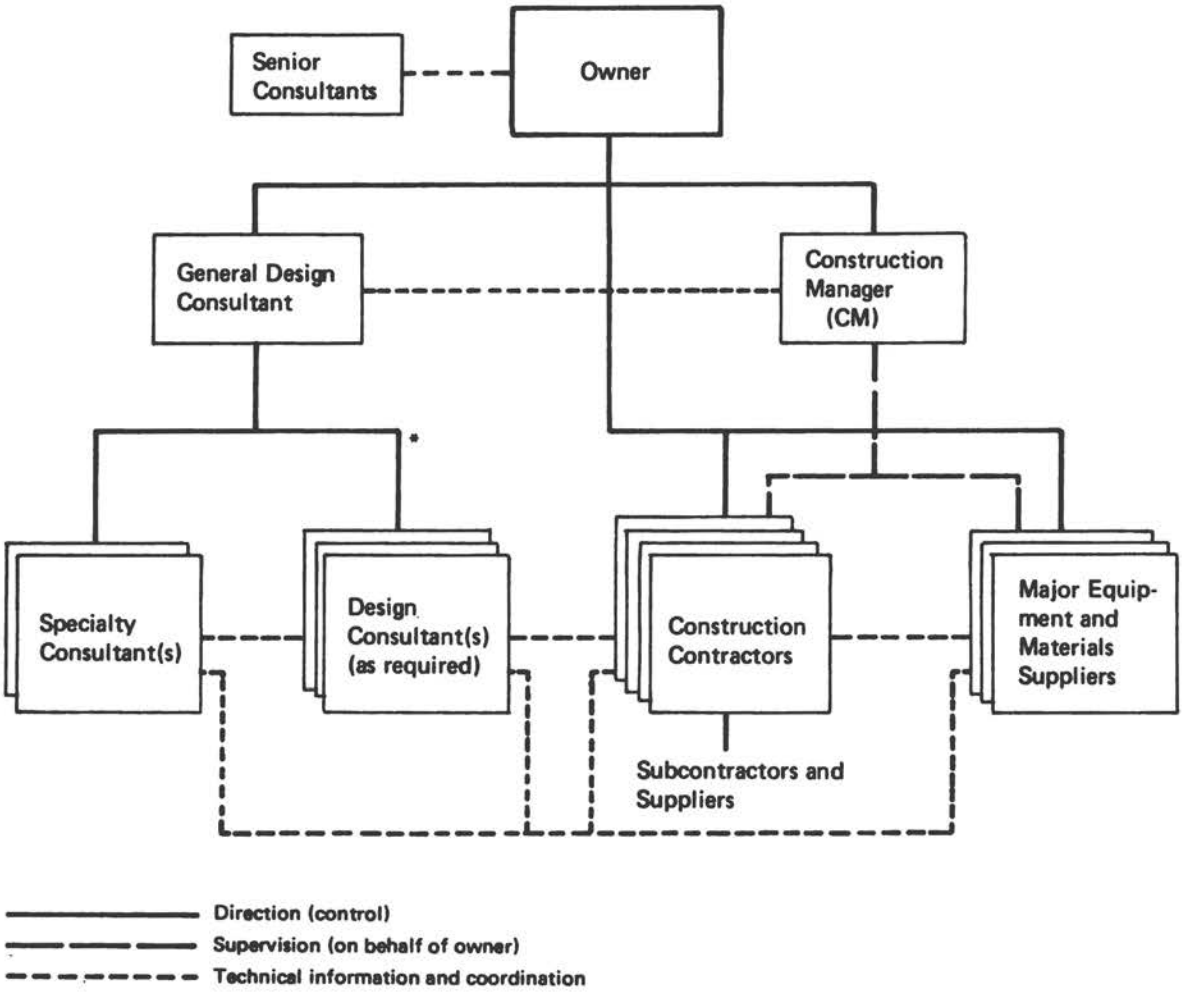


FIGURE 9 Project organization—established owner manages design and construction directly.



*This diagram shows design consultants as subcontractors to the general consultant. An alternative can be technical supervision of design consultants by the general consultant on behalf of the owner, to whom design consultants are under contract.

FIGURE 10 Project organization—general consultant manages design and construction for owner.



*This diagram shows design consultants as subcontractors to the general design consultant. An alternative can be supervision of design consultants by general design consultant on behalf of owner, to whom design consultants are under contract.

FIGURE 11 Project organization—general design consultant manages design and construction management consultant manages construction.

other organizations in the project management team. Once established, these must be adhered to.

- Staff the organizations with qualified individuals in the proper numbers to accomplish the assigned missions. At the same time, overstaffing must be avoided.

- Develop an objective means for the owner to review major decisions recommended by the project management team.

- Assemble an organization that is flexible and capable enough to come to grips with changes in emphasis as the project proceeds.

ORGANIZATION OF THE OWNER'S STAFF

The owner or authority is the organization with the overall responsibility for construction of the project. In a major underground construction project, the owner often is a public body, although a commercial firm can act as the owner in constructing projects for its own use. In this discussion, emphasis is on the public owner, but the principles and practices described may be readily adopted for use by a business firm.

Some agencies involved with underground construction have clearly defined and continuing missions, specific financing arrangements, and authority to administer the work effectively. In contrast, other agencies may be formed for a specific project. They begin with a general scheme that, once implemented, will have good and bad impacts on various elements of the community. In addition, the federal government usually provides a large part of the finances, but only after a preliminary plan has been developed and a political entity has been formed to carry out the plan. For such an agency to produce an effective operating system at a reasonable cost, it must clearly define its organization and the duties and responsibilities of its board and staff. This must be done early, with careful attention to detail in drafting the enabling legislation, taking advantage of the knowledge gained from earlier successes and failures. Later, grantors of financial assistance will need to review the legislation as well as the actual organizational structure and operating procedures of the agency, in order to determine that all these elements will effectively produce a successful project.

Owner (Authority)

The owner, whose charter is usually prescribed by the state legislature, consists of the governing board or commissioners who may be elected or appointed. Among the more important functions performed by the board in executing its responsibilities are:

- Establishing policy
- Assuring financing of the project
- Approving budgets and expenditures
- Approving contract documents
- Approving award of contracts

- Acquiring land

- Executing the project

The board is assisted in its functions by the general manager or executive director whose responsibility is the day-to-day operation of the authority. He is assisted by heads of such departments or divisions as engineering, construction, real estate, finance and accounting, procurement, legal, personnel, operations, and public affairs. Figure 8 (page 46) illustrates a typical owner organization.

The size and capabilities of the owner's staff will be influenced or determined in part at least by answers to the following questions:

- Is it a new organization or an existing one? What are its present capabilities?

- Will it be responsible for future construction projects or only the current one?

- How long is the project expected to take to complete?

- Will it become primarily an operating organization after completion of the present project?

- To what extent are qualified consultants available to provide technical and managerial services?

- Will a general consultant be engaged to perform or supervise the planning, engineering, and construction, or will these functions be performed by separate consultants or by the authority?

At this point, the owner must make a major decision with respect to alternative approaches, generally as follows:

A. To delegate responsibility to a general consultant for planning, designing, constructing, building, and equipping the facility or to delegate the management of design and construction to separate consultants.

B. To develop an in-house staff to undertake the whole project.

C. To develop an organization that takes advantage of the benefits of both A and B.

All three approaches have been used with varying degrees of success.

In making the decision, a major factor to be considered by the owner is that a knowledgeable staff is required to assure the owner of efficient and economical operation when the project is completed and to ensure that the lessons learned from operating and maintaining the project are fed back into the design process.

There are successful examples of owners performing the overall management function with a very small staff, relying on a general consultant for the

detailed work necessary. On the other hand, there are successful owners with sufficient staff to do the planning and most of the engineering design and construction supervision. Moreover, there are examples of a combination of these two approaches. By careful consideration of the alternatives, it is possible to make a rational decision concerning the amount of detailed involvement in project management by the owner's staff.

Whatever the organizational pattern, it is imperative that the owner make certain that the necessary mechanisms exist to permit prompt and final decision-making on all significant questions and that the various elements work together as a team.

ORGANIZATION FOR DESIGN (PRELIMINARY AND FINAL)

Three basic alternative means of organization for preliminary and final design exist:

- The owner's staff may do all design work. This alternative is usually appropriate when the authority is established and possesses considerable design experience and well qualified staff. A major underground construction project is often too large and complex for such an arrangement. In some instances, therefore, the owner's staff may supervise and manage the design by engineering firms retained to design sections of the project.

- A general consultant may be engaged to perform all design work if the project is not too large for one firm and if the time available for design is adequate. If a general consultant is engaged, the proper basis of selection is proven successful experience in similar work by that firm and a commitment to assign a manager and staff qualified to do the job.

- The third alternative is essentially a variation of the second. It entails the design of specific sections of the work by other engineering design firms and the overall management and coordination by the general consultant.

In the latter two alternatives the general consultant will perform the preliminary design of the entire system and prepare a preliminary construction schedule and estimates. After the preliminary design, schedule, and estimates have been approved by the authority, the general consultant will proceed with the detailed design of the system, consisting of a number of sections. These individual sections may be assigned to other engineering firms, which may be subcontractors to the general consultant or to the owner, with technical supervision provided by the general consultant.

Continuity in engineering services is essential and either the owner's staff or a consultant retained for that purpose should be available from the preliminary phase through final design and construction. An essential part of this role is the preparation and updating of schedules and estimates. When approved by the owner, these will be used as a basis for supervising the design and construction. Designers and design mangers will provide design services during construction.

ORGANIZATION FOR CONSTRUCTION

Construction of a project may be carried out by the owner's own construction forces or by contract. In almost all instances, major underground construction projects require construction capabilities greatly in excess of the owner's capabilities. Therefore, this study assumes that construction will take place by the contract procedure.

Several important organizational decisions need to be made to ensure that construction is accomplished efficiently. The first of these is the organizational arrangement involving the owner, his staff, the general consultant, if one has been retained, the construction manager, who may or may not be one of the parties listed above, and the construction contractors.

The arrangement most generally found consists of the owner acting as the overall contracting officer, letting contracts to several construction contractors. The owner is assisted in managing the construction and administering the construction contracts by an in-house or consultant construction manager. Unless the owner's staff is quite large and well experienced in construction management, as are such federal agencies as the Department of the Interior's Bureau of Reclamation and the Army Corps of Engineers, it is quite normal for the owner to engage a construction manager. If he plans to do so, his primary decision is whether the general consultant, if one has been retained to manage preliminary and final design, will act as construction manager or whether a different engineering firm will be engaged to manage the construction. There are valid reasons favoring each of the two arrangements. Major arguments for assigning construction management responsibilities to the general consultant include:

- Ensures continuity of effort from design to construction.
- Provides for knowledge of design intent by those charged with construction management.
- Provides owner with single point of contact.

On the other hand, arguments in favor of engaging another firm for construction management include:

- Provides for better construction supervision because there are few engineering firms well qualified in both design and construction management. Hence, a firm particularly qualified in construction management can be selected.
- Eliminates a tendency (or allegations of a tendency) to demonstrate "pride of authorship" in designs when questions are raised during construction.

The performance of the general consultant, as well as his capabilities in construction management, will be useful in deciding which arrangement to select for the assignment of construction management responsibilities. In any event, three guidelines may be followed with regard to the employment of the construction manager:

1. Select the construction manager early so that his specialized knowledge can be used in developing the construction plan.

2. Design clear lines of contractual authority so that no doubt exists among any of the parties.

3. Establish a workable management system that will ensure close cooperation and mutual support between design and construction forces.

ORGANIZATION FOR OPERATION

Generally, the continuing mission of the owner will be to operate the system after the construction project is completed. This continuing operational mission applies to transportation projects and to water and sewerage projects particularly, as well as to other major underground projects.

If the owner is an established organization already operating similar facilities, it can be expected to have sufficient experience to plan for operation of the current project when completed. Decisions concerning operational policies and procedures are not too difficult. On the other hand, some large projects are constructed by and for newly organized owners that do not have operational experience. In such instances there appears to be a tendency to defer operational matters during the planning, design, and construction phases of the project. While it may seem logical to do, because operations may be some years away, there is exceptional merit in making certain decisions concerning operations early in the project. The most important of these is to bring experienced operations managers on board early. Their knowledge can be most useful during the planning and design phases when it will help ensure that the system will efficiently accomplish the purpose for which it has been designed. Additionally, the maintainability of the completed system needs to be considered early, and experienced maintenance managers can contribute significantly in planning and designing a system for economical operation. Another major activity of operational managers who are assigned early is to develop an organization and procedure for operation and maintenance and to staff the organization as the date for operations approaches. During the system testing phase, the operations organization must be ready to test and assume responsibility for system components as they are accepted for operation.

Management Problems

The purpose of this section is to describe some of the most important management problems that arise in each phase of a major project. It is clearly impossible to list every possible problem, because each project is different from all others and because of the complexity of large underground projects. However, if the most likely problems can be foreseen and a means to respond to them established in advance, the problems are much less apt to result in poor performance, delayed schedules, and increased costs.

The problems that management faces can be categorized into three groups—those clearly recognizable in advance, for which solutions can be prepared in advance, those that can be foreseen, with problem-solving procedures prepared in advance, and those unanticipated problems that require prompt resolution by management when they occur.

It will become apparent as the discussion proceeds that few of the problems are of a strictly technical nature. The major problems are political, social, and economic, and in many instances they are the products of limited resources, conflicting social goals, institutional arrangements existing in our society, and general economic conditions. The project manager, who most generally is an engineer, will be called upon to exercise ingenuity and imagination in facing problems for which his training and prior experience may not be fully adequate.

By examining the major potential problems prior to experiencing them, the project manager can prepare to develop solutions. The alternative to good solutions is management breakdown, usually evidenced as a series of small failures caused by inadequate solutions to a series of problems. The cumulative result of these small failures may be a project that does not completely satisfy the needs for which it is built, delays in completion, significant cost overruns, litigation among the owner, consultants, contractors, and other agencies or public interest groups, and public perception of an inadequate project.

By contrast, good management achieves the opposite results: projects that meet the owner's requirements, completion on schedule and within the budget, and general public satisfaction with the project.

CRITICAL ELEMENTS

The problems likely to be encountered were identified from the list of critical elements compiled by questionnaires and interviews during the study. The list of 39 critical elements is broken into three groups in order of criticality:

I

Delayed decisive action
Project funding and cash flow
Imposed controls——funding and fund management
Dedication to timely project completion (authority)
Dedication of government and involved agencies to timely project completion
Transit authority organization
Transit authority legal authority
Public acceptance
Selection of consultants
Imposed controls, contracts, procedures
Acquisition of right-of-way and work areas
Schedule and cost management
Administration of and coordination with consultants

II

Environmental impact statements——approval
Construction contract strategy
Risks and liabilities (outside authority jurisdiction)
Risks and liabilities (under authority jurisdiction)
Claims and disputes——construction contracts
Government regulations
Testing, start-up, and run-in
Labor productivity
Contract agreements with utilities and involved agencies (outside authority jurisdiction)
Public and community relations and participation in system planning
Contract agreements with utilities and involved agencies (under authority jurisdiction)
Environmental hearings, analyses, and impact statement
Freezing project features and design prior to start of final design

III

Existing structures——protection
Operational organization and training
Political action and objectives
Citizen and class action lawsuits
Project labor agreements
Societal impacts

Public hearings
System cost-effectiveness analysis
Cost-benefit analysis
Special interest groups pressures
Wrap-up insurance
Equal employment opportunity program
Central procurement

Each one of these may be expected to affect the cost of the project and the time required for its completion. For further discussion of these problems, see Questionnaire Number 1, Appendix 2.

This list is generally applicable to most major underground projects, not only to public rapid transit projects. Some of the critical elements are important from the beginning to the completion of the project—e.g., delayed decisive action. Others occur at a particular point in the project—e.g., selection of consultants.

The problem of delay is so pervasive in a major underground project that it deserves special emphasis. Delays can be caused by action or inaction on the part of the funding agencies, the various project participants, and the other groups or organizations that have an interest in the project. It is a truism that "time is money" on such projects. Delays may range from days to years. Each delay may add costs to the project, disrupt orderly completion, and postpone the date when the completed project was expected to go into service. Therefore, throughout this report, emphasis is placed on actions that are intended to advance construction and avoid delays.

The problems described below are actual problems observed on major underground construction projects or other major projects. They are listed in essentially chronological order, from the organization and planning through the construction of the project.

ORGANIZATION

The problems facing management during the organization phase of a project are fundamental issues related to the overall project goals and how they will be achieved. The owner stands alone at the beginning of this phase, and he must assemble an organization of his own—often while concurrently assembling the organization of organizations to carry out the various parts of the overall effort. The opportunities are great while the slate is clean, and solutions to the basic problems listed below will affect the project's fortunes in a most profound way.

The major problems in the organization phase are:

- Defining the purposes and establishing the goals and policies of the project's owner.

- Organizing the owner's staff to ensure proper direction and control.

- Establishing an overall management structure of all the organizational elements to be included in the project management team.

- Selecting consultants who are qualified to do a major part of the planning, engineering, and management.

- Establishing means and procedures for unbiased, professional review of major decisions.

- Fostering a sense of urgency and a need for prompt action as the normal mode of operation from the inception of the project.

- Avoiding adversary relationships among the members of the project management team.

- Setting clear lines of responsibility and accountability for various project actions.

- Attracting the best qualified people available to fill key positions in the project management team.

- Ensuring that communications among members of the project management team are timely and accurate.

- Ensuring that the owner has the proper legal and administrative authority to do the job.

PLANNING

The problems associated with planning also are fundamental to the project. The decisions made in the planning phase will determine to a great extent the total cost and how well the project will satisfy the needs for which it is intended. Freedom of action is greater in the planning phase than at any later time, and therefore the greatest opportunity for control of the overall project cost and schedule exists during the planning phase. The speed at which the project proceeds to completion will be affected significantly by the solutions to problems that appear in the planning phase.

The major problems in the planning phase are:

- Establishing the owner's objectives for the performance of the project.

- Developing realistic estimates of the project cost.

- Gaining political and public acceptance and support of the project.

- Establishing understanding with the leaders of agencies and organizations affected by the project.

- Expediting development and acceptance of the Environmental Impact Statement (EIS) for the project.

- Preparing a sound financial plan for the project.

- Obtaining firm financial commitments from funding agencies.

- Providing means to ensure appropriate and timely action by other

entities that are not under the control of the project management team.

DESIGN (PRELIMINARY AND FINAL)

In the design phase the project's physical elements must be determined with precision. The opportunities for determining or altering the project's suitability and cost are fewer in this phase than in the planning phase, and these decrease even more as the design approaches the final form. Design progress paces the project because each successive phase depends on completed designs. In major construction projects, design is likely to involve several design firms, and management of their work is essential to ensure adherence to design criteria, interface of design, design schedules and budgets, and construction budgets.

The major problems in the design phase are:

- Eliciting innovative designs, for both a better final product and cost reductions.
- Avoiding costly changes in design.
- Coordinating the efforts of several design firms and managing the interface between design sections.
- Developing and using uniform design standards.
- Ensuring that designs properly meet the operational requirements of the system.
- Ensuring the "constructibility" of the design.
- Obtaining unbiased, professional review of major design recommendations and decisions.

CONSTRUCTION

In too many major projects, costs and schedules get out of control during the construction phase. The major problems during construction relate to obtaining quality work without losing control of costs and without suffering delays in the completion of the project.

The major problems in the construction phase are:

- "Packaging" construction for logical sequence and cost control.
- Obtaining realistic competitive bids for construction contracts.
- Rejecting unqualified contractors.
- Assuring good contractor performance.
- Avoiding adversary relations with construction contractors.
- Solving design and field construction problems correctly and quickly.

- Minimizing urban disruption and its consequent public dissatisfaction.

- Avoiding or minimizing labor problems.

MANAGEMENT

Strong management is necessary throughout the life of the project. Its scope and emphasis will change as the project proceeds from planning and design to construction and then start-up. But central to the life of the project is control of all actions. Some of the problems have been identified as important during specific project phases—e.g., prompt action in the organization phase—but are of such inclusive nature that they are repeated here to emphasize their importance.

The principal management problems are:

- Ensuring prompt management actions.

- Supporting and enforcing the authority and obligation to make prompt decisions at defined job levels and with regard to defined job problems.

- Ensuring accurate, speedy communications between all members of the project management team.

- Controlling costs and minimizing cost increases.

- Ensuring teamwork by the project management team.

- Completing the project on time.

- Avoiding stops and starts in the logical "flow" of the project.

- Imbuing everyone associated with the project with the spirit of getting the job done.

- Avoiding poor or inaccurate public perception of the project.

START-UP

As the project proceeds to the start-up phase, just before the service operations begin, action must be taken to ensure that all the parts fit together physically and functionally to make an operational system. It is during this phase that the project will be tested to make sure it performs the functions for which it was built. In this phase many major projects exhibit temporary failures and sometimes lasting deficiencies.

The problems at start-up are:

- Ensuring that the entire system performs well and satisfies the original purpose.

- Ensuring that the system's equipment is ready on schedule.

- Avoiding failures during testing and run-in.

- Ensuring that adequately trained operations and maintenance personnel, operating procedures, and equipment are ready on time.

- Ensuring public acceptance of the project.

Recommendations

The chief purpose of this report is to diffuse the experience gained from the sometimes costly lessons of completed major underground construction projects so that new owners and management teams can benefit from the experience and learn the best procedures and practices. Underground construction is not a pure or exact science. A critical factor in its success involves a great deal of art—the art of good management. In formulating its recommendations to improve on the management of major underground construction projects, the subcommittee concluded that six major objectives need to be established. Along with each objective, the subcommittee agreed on a group of recommendations that it considered central to attaining the stated objective. Adoption of all the objectives is considered to be both feasible and necessary to make the maximum possible improvement in the management of a major underground construction project, public or private in nature. While recognizing that each project is unique, the subcommittee has stated the objectives and recommendations so that they may be applied to any large underground construction work, most particularly public projects that generally involve a larger number of participants and more complicated funding and approval processes than major private projects. The recommendations suggest ways in which major or significant problems can be avoided, solved, or——when a full solution is beyond the means of the manager——managed in such a way that the project can proceed.

While effective management of major private company projects requires the application of most of the same management practices as for public projects, there are significant differences. Private projects are generally privately funded and escape the controls imposed by funding agencies at federal, state and local levels. Private projects can select professional consultants and utilize construction contracting practices without the restrictions usually encountered by public projects. Political and public requirements are less rigorous for private projects than for public projects. Even so, increasing political and public concern about potential societal and environmental impacts is narrowing the difference between public and private construction projects, and, in the future, private projects probably will need to be as responsive to such considerations as public projects are today.

The six objectives identified by the subcommittee are stated below. Accompanying each objective are the recommendations considered central to attaining it, together with the rationale supporting the individual or grouped recommendations.

TO ESTABLISH THE PROJECT'S GOALS AND OBJECTIVES AND TO ORGANIZE THE PROJECT TO FACILITATE THEIR ACCOMPLISHMENT:

Maximum efficiency can be achieved only if the objectives are firmly established and the project is organized effectively. Therefore, the organization needs to be evaluated and, if found necessary, modified appropriately throughout the life of the project.

Define Project Purposes, Goals, and Policies

1. The owner, the only active member of the future project organization at the time of project inception, should define realistic and attainable goals and guiding policies which will lead to successful completion of the project.

The owner should define the goals, guiding policies, and anticipated general structure of the organization of organizations required to manage and execute the project successfully. These need to take into consideration the size and mission of the owner's organization and the type and extent of professional engineering and other consultant services to be utilized. The owner should recognize the need to establish early a close working relationship with those federal, state, and local agencies that have approval authority over all or parts of the project, as well as those public or private agencies that have a significant interest and whose timely support would contribute to uninterrupted project progress. He should also provide for the early development and initiation of a public information and citizen participation program to generate public input into project planning and public support for the project. Other policies to provide overall guidance for future members of the project team in the execution of the project should be established by the owner at this time.

Establish Owner's Organization

2. The owner's organization should be a staff of highly competent managers and other professionals whose functions are to direct the project, to take the lead in gaining public and political acceptance of the project, to maintain close coordination with and obtain timely action from agencies participating in funding or responsible for regulatory functions, to assist and coordinate the planners, consultants, designers, and contractors in resolving local problems, and to identify and clear potential roadblocks.

The characteristics of a potent organization include:

- Clearly established lines of authority and responsibility.
- Broad legal authority (including right of eminent domain).
- Adequate staffing to do the job.
- Sound financial capacity.
- Public and political understanding, cooperation, and support. In addition, the authority should have forceful leadership, capable people, and adequate budget.

The most important function of the owner is to organize the overall effort and clear the way for continued orderly progress by all participants toward the economical and timely completion of the project.

In well ordered public and private organizations a governing board establishes policy and employs a chief executive officer, who is generally designated the general manager, charged with the responsibility to manage the company or project, but whose authority is limited by definition of those actions that require prior approval of the board. The extent of these restrictions depends to a large degree on the board's confidence in the general manager and also on controls that are usually imposed on public owners by law, charter, government regulations, or rules promulgated by funding agencies. The general manager is required to carry out the policies of the board, to keep the board informed of the project status and significant management actions taken, and to recommend the essential board actions on matters that are beyond his authority.

The general manager develops his organization and establishes a formal structure of authority through which work subdivisions are defined and coordinated to meet the defined objectives. He is responsible for the conduct of the project, including securing and utilizing the authority he requires to meet his responsibilities, concluding working agreements with involved agencies and utilities, obtaining consultant support, organizing, staffing, budgeting, reporting, and, most of all, leading, directing, and controlling all phases of the project. Because of his considerable responsibility, it is imperative that the general manager and his staff be well qualified and professionally experienced in the type of work involved.

Determine Management Structure

3. The owner's organization must determine the management structure for the project which should meet the following criteria:

- Clear lines of responsibility must be established.
- Responsibility should be delegated to the lowest possible implementing level.
- Authority commensurate with responsibility must be granted.
- Reviews should be made of how authority is exercised to ensure that timely action has been taken in reasonable and proper ways to meet project objectives.
- Duplication of functions must be avoided.
- Communications, both vertical and lateral, should be employed.
- Mechanisms for expeditious problem solving must be provided and known.

The participants in the project team consist of the owner, consultants, involved local, state, and federal agencies, the public, and the contractors. The participants in the project management team are the senior members of the owner, consultant, and contractor organizations, supported, as required, by senior members of involved public authorities and agencies. Owners and consultants should operate under the general principles of "organization by objectives," which call for general definition of the function and responsibility of each key person in the management complex, promote interaction across organizational lines, permit freedom of action in meeting assigned functions, and limit activity of each individual to those actions of real significance to the needs of the project.

Good working relationships, teamwork, and clear communication are all important in promoting successful project completion, and hence should be emphasized throughout the management structure.

Select Consultants as Required

4. The owner should select well qualified consultants to supplement his staff in the management and execution of planning, design, construction, and coordination. These may include, depending on his staff's capability, one or more of the following: a general consultant, design specialty consultant(s), and a construction management consultant. Consultants should be selected for both competence and successful record of performance in the type of project to be constructed. The work of each consultant should be reviewed periodically and, if found to be of superior quality, the firm should be retained. Consultants engaged in activities involving several aspects should be retained from the start of project planning through project completion and start-up of operations to ensure continuity.

A major underground construction project may take several years to plan, design, and construct. Beyond its expected completion date, the planners, designers, and construction managers will not be required. Therefore, instead of expanding their staffs to perform the required work and then reducing them at the completion of the project, many owners have decided that it is sound practice to engage consulting firms to perform all but the overall coordination task. A second important reason for engaging consultants is to ensure that the required expertise is available. Of course, some federal, state, and regional or local agencies that have operated for years have considerable expertise. Others, such as a newly organized transit authority, may have very little expertise. This report allows for such a range of expertise in two ways: first, the capability called for in the "general consultant-engineering and architecture" may already exist in a professional department of the owner's organization; second, the owner's staff capabilities may need to be supplemented by one or more of the various consultants mentioned in Recommendation 4.

The selection of consultants should be on the basis of experience, competence, and capacity, because the high degree of professional competence and experience they bring to the project can have a major effect on the quality

of the overall endeavor, as reflected in meeting project objectives, in reducing costs, and in completing work on or ahead of schedule. Most consultant contracts are cost-reimbursable, with a fixed fee adjustable only for a change in scope of services. This enables the owner to be flexible in adjusting the scope of services that require consultants to help meet unexpected problems. It provides for adjustments in the level of assistance by the consultant to cope with demands that call for assistance on tasks not covered by the scope of the contract. The only impact of the estimated cost submitted as part of the consultant's proposal is its influence in setting the amount of fixed fee, a small percentage of the cost of the services. This small percentage is insignificant relative to even a slightly higher level of experience and competence. When engineering is skimpy or inadequate, increased costs are sometimes hidden. Nevertheless, these can be substantially higher in the long run than costs for quality engineering. High quality engineering, construction drawings and specifications, and construction management can save the owner many times the total cost of engineering, because the difference in high quality engineering and inadequate or mediocre engineering can appear later in construction costs and operating and maintenance costs. Substantial advantages may accrue to a project when a competent general consultant is retained for project planning and continues through project completion and start-up.

Project planning, design, construction management, and operations start-up must be coordinated by management to establish continuity during the progressive stages of the project. It is essential that all of the participants in these activities perform as a team. The consultants' detailed knowledge of early project studies, of the organization, personnel, and management philosophies of the owner, of the business and political leadership of the region, of problems that developed and were apparently solved, some to recur in later stages, and of the organization and personnel of local, state, and federal involved agencies, can all contribute substantially to prompt and efficient performance in solving problems in the later stages of the project.

Retain Senior Consultants

5. The owner should consider retaining an independent group of senior consultants to provide advisory services that do not supersede the responsibilities of the project team but serve the important purpose of assisting the owner or governing board in making the go or no-go decision, in selecting consultants, and in reviewing major decisions throughout the life of the project. These consultants may function as a board or as a panel of individual experts, depending on the desires of the owner. Although the services will be required from the inception to completion of the project, the composition of the group may vary as the project progresses through various stages, provided that key members are retained to ensure continuity. The owner may request these experts to review major planning and engineering decisions, thus aiding in the development of a high degree of project credibility and support. In a project where a general consultant is retained, the general

consultant should also have the authority to retain senior consultants as required.

The owner and governing board have a continuing need for independent expertise to assist in selecting consultants and in deciding major issues concerning whether to advance, postpone, or abandon the project. On major projects it is customary to retain professional consultants of recognized competence in those fields of critical importance to the project in order to function as a board of consultants or panel of advisors to review the engineering work and confirm or recommend changes. Usually such a board is formed in the planning phase and retained until project completion. The engineering done during various project phases has a major impact and requires the attention of experts from several disciplines. In making major project decisions, use of the specialized competence and experience of such experts could contribute materially to a higher degree of public support and project credibility. In addition to the group of consultants, the owner should establish a project review board within the project team to ensure that all key managers participate in the periodic review of significant actions.

Act Promptly

6. The owner's organization must encourage and support and, when necessary, demand prompt identification of problems, problem solving, and decisions by each responsible member within the range of his responsibility and authority. All participants must be stimulated to have a "must-do, can-do" attitude!

Stimulation of such an attitude throughout the project management team requires several actions:

- Setting the example by the owner and his staff of decisiveness and sense of urgency.
- Establishing well defined goals.
- Encouraging and supporting other elements of the management team.
- Assigning specific responsibilities and accompanying authority.
- Demanding, when necessary, prompt and decisive action within areas of authority and responsibility.
- Eliminating red tape.

The consistent ability to take prompt and decisive action is a characteristic of good professional management. This management attribute is of paramount importance within the organization of organizations that is required to manage a complex project of large scope and dimensions. Equally, or possibly more important, the project management must be able to obtain prompt and decisive action from those local, state, and federal agencies involved in the project and from political bodies that have an interest in the project and whose participation in project matters may lead to delay or redirection of any part of the project. Delays or redirection often result in added costs because of price increases, extra work, and additional time for administration. Delays and

redirection also add incalculable costs related to the deterioration of morale, reduction of momentum, and possible adverse impacts on contractors that may result in claims, to cite just three adverse effects.

The leaders of the management team are responsible for demanding prompt decision making and problem solving actions by each responsible member, within the appropriate range of authority. The lack of prompt response is generally the result of an absence of clearly defined responsibility and delegation of authority, reluctance of the individual to assume responsibility without "hand holding" with people at higher levels of management, inadequate knowledge of the problem and alternative solutions available, or other reasons generally related to ineffective organizational and administrative leadership. A problem may be ignored in the hope that it will go away or, as Charles Dickens observed about his Mr. Micawber, that something will turn up. Both are unrealistic ways of managing a project and often make the achievement of project objectives difficult. Lack of understanding of all of the ramifications of a problem may call for dependence of the decision authority on lower echelon people. Delays in decision making may be due to efforts to satisfy fully the interests of all concerned parties. Such satisfaction is rarely attainable. The interests of a fast moving project are more often than not better served by a 60 percent ideal solution this week than a 95 percent perfect solution next month.

Decision and action by local, state, or federal agencies, or other entities over which the management team has no direct control are often more difficult to obtain than decisive action within the authority of the management team. Lacking the muscle to force prompt action, the management team needs to develop and utilize strategies and procedures to obtain the prompt and decisive actions from these entities that are needed to satisfy the project objectives.

TO PLAN THE PROJECT TO ACHIEVE THE OWNER'S OBJECTIVES:

Great opportunity for saving costs exists early in the planning phase when basic decisions determine the scope and extent of the project. Great latitude for changes also exists at this time. Therefore, the decisions taken during the planning phase have long-range importance in furthering the chances for success and controlling the costs of the projects.

Establish Owner's Objectives

7. The owner's objectives must be clearly set forth and these should become the criteria for project design. The project must be planned with an eye on the successful completion of the project purpose at the lowest cost for both investment and operation as well as for maintenance over the expected life of the project.

Make Realistic Cost Estimates

8. Realistic cost estimates, based on the best available information, must be used from project inception. Recognizing that early estimates are based on many uncertainties and variables, and therefore that costs may be overlooked or underestimated, realistic factors for uncertainties and contingencies should be taken into account during early phases. Particular attention must be given to realistic estimating during the

preliminary engineering phase because such estimates are usually the basis for project financing. Estimates should be revised periodically to accommodate changing circumstances.

Realistic cost estimates made when the early concept is being developed, during the project planning stage, and at the conclusion of the preliminary engineering stage bear directly on the go or no-go decisions. The reliability of project cost estimates is low at the early concept stage but increases with more detailed project definition, more detailed knowledge of geological conditions, real estate requirements and appraisals, labor and material cost trends, and other cost factors. The project management team needs to understand that early estimates tend to miss many significant cost factors and are much more likely to be substantially lower than ultimate project costs. A realistic way of dealing with this problem would be to allow for uncertainty factors by adding some 15 percent to 25 percent to the estimate at the preliminary engineering stage. This procedure, assuming the basic cost estimates were competently made, would produce more realistic estimates and reduce or eliminate the anxieties experienced by owners and managers when the need arises for substantially increased financing as the project proceeds. The cost increases caused by inflation are a significant factor in large projects that extend over a number of years and, therefore, all estimates should be expressed in terms of a base year. Each estimate should then be increased to account for actual or estimated inflation rates for any specific year. The importance of making a realistic estimate during the preliminary engineering phase is that this estimate usually provides the basis for capital grants for public projects, for financing plans for private projects, and for budgeting for both public and private projects. Realistic budgets will substantially reduce the trials and tribulations of the project management team and enable it to devote more attention to productive project activities. Each successive estimate should be accompanied by a cash flow estimate.

Obtain Public and Political Acceptance

9. The project management team must plan and execute a program to achieve and maintain the participation and support of citizens' groups and political entities in the planning, design, construction, and early operational phases of the project.

Public and political acceptance of a project is a fundamental requirement for success, particularly for public works projects. The project management team must conceive and execute a program to achieve the participation and support of citizen's groups and political entities in the project planning, design, and early operations phases of the program. Among the elements of a good public involvement program are:

- Keeping the public informed by providing the media with up-to-date and accurate information. Problems that can affect the public should not be concealed. In this connection, the corrective efforts under way should be emphasized.
- Soliciting and making use of citizen concerns in project planning.
- Maintaining liaison with public bodies and public interest groups.

- Promoting public acceptance by minimizing inconvenience to the public.

Leadership in obtaining project support should properly include collaboration with the general consultant, if one is retained. Route location, station locations, and service criteria need to be reviewed with local citizenry before final decisions are made. Specially organized citizens' advisory committees and already existing community associations ought to be sought out for citizen concerns. By working with such groups, the project management team can often prevent them from becoming antagonistic "intervenors."

Establish Understanding

10. The owner should identify those agencies and organizations that have the potential for either helping or hindering the project in order to establish an understanding with the leaders of these entities that will advance the project.

Early in the planning phase of the project, the management team should identify those agencies, railroads, and public utilities that are likely to be concerned with the project and have the potential of helping or hindering the project objectives. Appropriate leaders of the management team should seek cooperation from the leadership of those agencies to further the project. One method of achieving this is to encourage close working relationships among their respective staffs. Effective strategies applied by management teams in the past to obtain timely decisions and actions from these agencies include encouraging them to participate with the project team, inviting their participation in project planning and design, soliciting their assistance in formulating requests for approval to fit their policies and requirements, thereby minimizing controversies, and keeping them informed about current project status, plans, and dates when decisive actions are expected. Other useful approaches include taking a practical view of the relative positions of the established agency and its in-place facilities as well as of the owner developing the new project, negotiating firm agreements prior to the completion of the preliminary engineering stage, and maintaining the attitude of partnership throughout the project.

Removal and relocation of railroads and utilities are of prime importance to the construction schedule. All agreements with railroads and utilities should be consummated during the early phases of the project. If removal and relocation responsibilities of railroads and utilities are under franchise agreements with state or local jurisdictions, the owner should seek to exercise such rights in this phase of the work.

Expedite EIS Approval

11. Continued effort must be exerted and close contacts with appropriate agencies maintained to facilitate early approval of the project's Environmental Impact Statement (EIS).

Under current regulations, preparation of an EIS cannot be completed until about the time the preliminary engineering stage is completed. Significant changes made in the project configuration after the EIS is filed will necessitate its revision. Final action on an EIS can be expected to take 12 to 18 months—and a longer, sometimes indefinite period for an environmentally sensitive project. For federally financed projects, regulations prohibit the granting of capital funds prior to acceptance of the EIS. This can cause a delay to the

project progress that would seriously affect the schedules and costs, as well as result in a loss of momentum and incur other costs associated with delay and interruption. Close collaboration with local representatives and key officials in the funding agencies and other concerned federal, state, and local agencies in the preparation of the EIS as well as continuous personal contact can greatly shorten the time needed for approval. The project management team should strive to obtain relief from the financing agencies of all imposed controls that would prohibit application of grant funds for the ongoing activities of the project team that are required to meet schedules and reduce costs. The performance of interim reviews of portions of the EIS during the project planning stage cannot be overstressed.

The EIS becomes central when federal funding is a part of the financial plan. Procedures for processing the EIS call for concurrence by many federal, state, and local government agencies. Reservations relative to the coverage of the EIS or negative reaction to it can cause almost endless delays. Early discussions with the representatives of the agencies that require the EIS should help reveal the depth and detail of assessment normally expected.

Establish Financing Plan

12. Early in the project planning phase, the owner, assisted by his consultants, should develop and vigorously execute a comprehensive plan for financing the project.

Currently, virtually all public projects depend on a large proportion of federal grant funds. The remainder comes from local and state sources. Federal grants are generally available to support project planning as well as to provide capital funding for engineering, construction, and system testing——though each also requires matching funds from local sources. Therefore, early in the project planning phase, the project management team should develop and vigorously execute a comprehensive plan for financing that incorporates fall-back provisions to cope with those major elements of the plan that may be rejected by funding authorities or otherwise fall short of expectations. Contractual agreements with funding agencies may serve to reduce the amount of "ineligible costs" that may be determined retroactively by the agency.

Obtain Firm Financial Commitments

13. The project management team must make every effort to obtain early and firm commitments for complete funding by all participating agencies through constant attention to close working relationships, constant flow of information to key funding agency people, and issuance of frequent reminders of dates when necessary funds will be needed.

Uncertainties or changing amounts and rates of fund receipts are likely to have adverse effects, especially for staffing, contracts, costs, and loss of public support.

TO ACHIEVE EFFECTIVE DESIGN ORGANIZATION, SUPERVISION, AND ACCOUNTABILITY:

The success of the project purposes is to a large extent determined by decisions made during the design phase of the project.

Organize and Coordinate Design

14. The owner's staff, or general consultant in instances when one is retained, must provide the design firms with clear-cut design criteria that set forth standards of system quality and continuity that are to be met within prescribed schedules and budgets. Detailed coordination of section design and system wide design is essential. Economy of design, system continuity and safety, reliability, maintainability, and constructibility must be tested against budgeted construction costs and forecast operating costs.

Review Designs

15. A continuous review of all phases of design should be carried out jointly by the owner, consultants, and operational personnel to assure that the project goals and objectives are met in a cost effective way.

The overall obligation of the owner and his consultant team is to design and build a project that best meets the policies and purposes set at the beginning. Consistent interaction of the parties is necessary to discharge this obligation properly. The design should be supervised by the project management team to attain cost effectiveness, reliability, operability, maintainability, and safety, and to ensure cognizance of other factors significant to the successful and economical construction and operation of the project. Innovative elements that may introduce risks should be adopted only with full prior approval of the owner.

This question should frequently be asked: "Is this element really necessary?"

A continuous review of all phases of design should be carried out jointly by the owner, consultants, and operation personnel. Such review should be the basis of incorporating into the final design those features consistent with the owner's projected operating and maintenance needs.

Substantial economies can be achieved by facility designs oriented to economical construction methods and use of standard construction equipment. Participation in the design work by engineers experienced in construction methods, practices, and equipment, and aware of construction techniques and work force capabilities will lead to variations in design that can substantially simplify construction without jeopardizing structural adequacy or architectural unity. Some design engineers may not have experience in orienting their designs to simplify the construction process, and this needs to be considered in the design process.

Freeze Design Criteria

16. During the preliminary design phase of the project, design criteria should be developed to a stage that the design of basic elements of the system can be firmly established for the final design. Deviations from the design criteria should be made for compelling reasons only, not whims or expediencies.

Changes in the design criteria should be resisted in the final design stage and should be permitted for compelling reasons only. Criteria changes that occur while the final design is in progress generally result in extensive revisions to final design drawings and in configuration problems for permanent equipment on order, thereby adversely affecting morale among design personnel, and duplicating previous engineering efforts—all tending to cause delays, extra costs, and inefficiencies.

TO ACHIEVE EFFECTIVE CONSTRUCTION METHODS, PROCEDURES, AND SUPERVISION:

Controlling cost increases, settling controversies and claims, and minimizing delays can be facilitated by sound construction management practices, procedures, and supervision.

Plan Contracting Packages

17. Contract package size and scope should be selected with proper regard for the resources available and greatest efficiency and economy in using the resources.

The size and scope of contract packages are affected by several factors, including the resources of the contracting industry, availability of a skilled work force, administration of the contracts, cash flow, interface between contract packages, extent of urban disruption, and requirements of the size of the contract in relation to the nature of the unit to be constructed. A public agency such as a transit authority must consider certain social factors consistent with public policy. For instance, the ability of minority-group contractors and small local contractors to bid competitively will be determined largely by the size and scope of the contract package.

Minimize Urban Disruption

18. The owner must closely cooperate and jointly plan with local political entities to minimize disruptions during construction and to gain public understanding and acceptance of those disruptions that must occur.

Local political jurisdictions know they need to deal with urban disruptions in the construction of a major project. It usually affects traffic patterns, relationships with adjacent property owners, and access to business properties. Close cooperation with the local political entities must be maintained to establish an understanding and acceptance of disruptions caused by the construction of the project. The assignment of fulltime liaison personnel to specific governing bodies may be necessary at times.

Establish Problem Solving Procedures

19. A procedure should be developed for solving design or field problems as they occur during construction. The procedures must be clear and capable of achieving results rapidly.

Great attention must be given not only to avoidance of changes but to settlement of change orders and potential or actual claims as well. Judicious delegation of monetary authority to approve change orders at the field level can expedite this process. Timely payment of claims is essential.

Develop Labor Relations Plan

20. The owner, working with his consultants, contractors, and local agencies, should develop sound labor relations including giving consideration to agreements with labor to ensure continuity of work and to avoid labor disputes.

The owner and labor, both union and non-union, need to reach understandings that will contribute to the progress of the work. Consideration should be given to developing general labor agreements between the owner and labor to ensure continuity of work and avoid long labor disputes, without pre-empting the construction contractors' responsibilities for the project.

Establish Sound Contracting Procedures

21. The contracting practices recommended in the 1974 report *Better Contracting for Underground Construction* should be adopted.

In considering the ways in which better construction procedures and supervision could be achieved, the subcommittee was strongly influenced by two earlier reports by the Subcommittee on Contracting Practices of the U.S. National Committee on Tunneling Technology. These are *Better Contracting for Underground Construction*, published in 1974, and *Recommended Procedures for Settlement of Underground Construction Disputes*, published in 1977. For the reader who wants to inquire more fully into the rationale supporting Recommendations 21, 22, and 23, these two reports will be useful. (Both are included in Appendix 6, Selected Reading List.)

While some of the recommendations of these reports—e.g., prequalification of construction contractors, and arbitration procedures—have not been universally adopted, their use has been increasing. The report, *Better Contracting for Underground Construction*, recommended improved contracting practices to reduce costs, controversies, and delays in construction. Some of the practices recommended are of special significance to project management, including contractor prequalification, types of construction contracts, and value engineering. In addition to the firm fixed-price contract, which is the most common type of construction contract, other such types as cost reimbursable, cost plus incentive fee, and cost plus fixed fee should be given consideration. Existing state laws may control which types of contract can be used.

All contractors should be prequalified in order to participate in the bidding process. Such qualifications should be based on the following:

- The organizational structure of the company, including the experience and length of service of the company and competence of personnel.
- Recent (within three to five years) operational history of the company and specific information on current backlog.
- Current audited financial statement of the company under consideration.

A value engineering provision should be included in all construction contracts, even when alternative bids are permitted. Contract provisions used by the federal government agencies, such as the Corps of Engineers and Bureau of Reclamation, form guidelines for value engineering provisions.

Establish Dispute Settlement Procedures

22. The owner should adopt the recommendations and use the procedures for the settlement of disputes found in the 1977 report *Recommended Procedures for Settlement of Underground Construction Disputes*.

Following the issuance of the 1974 report *Better Contracting for Underground Construction*, the Subcommittee on Contracting Practices of the U.S. National Committee on Tunneling Technology conducted a follow-up study through its Task Group on Arbitration. In 1977 it issued a report, *Recommended Procedures for Settlement of Underground Construction Disputes*, which provided a number of procedures for mediation and arbitration actions. The report recommends that the project management team incorporate in construction contracts the provision for some form of mediation or arbitration to be available if voluntary procedures fail to reach a settlement, provided that qualified personnel are selected and available. The report recognizes that there may be legal restraints that prevent acceptance of binding arbitration.

Set Up Review Board

23. The owner should establish and utilize a professional review board to assist in the settlement of construction claims and disputes that cannot be settled promptly by normal contract administration procedures.

The board should be independent of the basic operation of the project and consist of three to five members. It should consist of professionally qualified, well respected experts in their particular discipline who possess demonstrated characteristics of integrity and justice. Their responsibilities may include assisting the owner in the settlement of construction problems and potential claims and disputes, and, if agreed by the contractor, the power to make final and binding decisions on fault but not damages. The use of optional settlement procedures recognized in the report referred to above is considered appropriate.

TO ACHIEVE SOUND MANAGEMENT OF THE PROJECT:

Construction of a major underground project is big business, and proven management methods need to be employed to complete the project successfully at the planned cost and in the scheduled period. Leadership must be strongly asserted by those with direct responsibility—e.g., owner, project manager, consultants, and chiefs of supporting bodies—for achieving the project objectives—quality, scheduling, and budgets. A complete management plan should be established and then kept up-to-date as changes are required. The management plan and methods adopted should take advantage of experience proven in similar large projects, but they need to be structured to fit the specific project objectives, local situations, and resources available or to be reasonably expected.

Establish Firm Budget

24. The project budget must be realistic; it must establish attainable goals; it must be adhered to.

Establish Schedule

25. Realistic schedules must be established and maintained.

Adopt Management Reporting System

26. Project management should adopt cost/schedule/progress monitoring and financial reporting systems with sufficient detail to enable key managers to facilitate decision making. It should include an exceptions report, listing only current problems or items that appear to be causing problems. It should indicate prospective changes in material costs and labor rates, and actual cash flow compared to the estimated plan. Top managers should take part in the development of the reporting system to ensure that the system meets their needs. The monitoring system should be geared to identify problems or necessary actions before they become critical (or historical) in order that problems may be avoided or actions taken in proper time. In the act of establishing controls, management should structure them toward facilitating forward progress rather than toward preventing relatively minor actions being taken that might have been done differently.

Effective project management requires comprehensive systematic reporting to the management team of current project status, costs, progress, activities, actual and potential problems, significant near- and far-term plans, special reports that may be required by funding or regulatory agencies, and special reports of project activities to the public and involved agencies designed to enhance their attitude of team participation in the project. Regular reports for a major project are often voluminous and detailed. For management's immediate use, those items that indicate potential or developing problems or that call for management action should be reported with appropriate recommendations to the management team. Such reports are commonly called "exception" reports or "trouble spot" reports and serve to highlight those items for the convenience of management people.

Certain basic requirements are necessary for effective planning and control of the project. These include:

- A clear definition and agreement on the engineering scope of work.
- Early agreement on the engineering budget.
- Early agreement on the construction cost target limitations the designer must meet.
- Forecasting and scheduling.
- A reporting system providing early notification of deviations from the established scope, budget, and schedule.
- Clearly established responsibility for maintaining performance and, if deviations occur, for taking corrective action.

In order to establish an adequate reporting system of deviations and problems, rapid feedback of information is essential. Major consideration must be

given to replanning by utilizing current historical records of accomplishments and their evaluation. In this way, cumulative experience on the several phases of the project can be brought to bear, not on the next phase but on the later phases of the project. Rapid and accurate feedback of information is also essential to effective planning. Replanning based on current information allows experience to be brought to bear on the later phases of the project.

Schedule and cost reporting plays a major role in the management of the project. All data on work in progress should be available in the form of accurate, informative reporting. A vigorous and well managed schedule and cost unit gives management the necessary information on cost, budget, and the progress of the many entities of the organization.

A promptly issued cost/schedule/progress reporting system is an important tool of project management. It should relate by budget item, or in greater detail, periodic costs, cumulative costs, comparison with budget, relationship with schedule and progress, and variations in the defined scope of project work. The system should include reporting of engineering and administrative costs as well as construction and central procurement costs. It should include an exceptions report, focusing on current problems or items that appear to be causing a problem, and indicating perceived changes in material costs and labor rates as well as actual cash flow compared to an estimated cash flow.

Control Expenditures

27. Strict control of project expenditures is an inherent obligation of the project management team. The management team must have adequate delegated authority and flexibility in the management of expenditures, and the determination to use and control them.

Controls imposed by the project management team can be effective in advancing progress, because such controls are administered by on-the-job people with an intimate knowledge of the project and an appropriate sense of urgency of decision to maintain project progress——a fundamentally important ingredient in the achievement of project economy. Controls commonly and currently imposed by state and federal agencies delay many necessary day-to-day and week-to-week decisions, are expensive to administer, generate project administrative costs often in excess of the amounts controlled, require approvals at levels not related to the size and complexity of the project, and result in delays in waiting for approvals. These types of controls do not help the project; they are detrimental to the efficient conduct of the project and increase costs rather than reduce them. An effort to negotiate management improvement procedures that reduce red tape and delegate more authority locally should be made. This has been successful at two major rapid transit projects. It has been said that an individual's sense of urgency in solving project problems is inversely proportional to the distance from his headquarters to the project site. Therefore, remote control of project management does not appear to be the way to go.

Revise Grant Agency Practices

28. Practices of granting agencies in controlling contract awards, contract forms, and contract changes should be examined in depth by those agencies with the goal of revision to permit the project management team the level of decision authority required to take prompt,

> responsive action in contract matters. Funding agencies, federal or local, should establish the amount and type of their support—e.g., a fixed dollar limit regardless of end cost or by percentage formula with a ceiling. Thereafter, the implementing agency should have the flexibility to prosecute the project promptly, efficiently, and economically within the established limits, subject only to "audit" reviews for eligible use of funds. These reviews should not be for second guessing but be for the purpose of ensuring that the agency is taking prompt action in prosecuting the project and in identifying and solving problems, and that these actions are in general adherence to project goals and prescribed methods.

To achieve a high degree of success in the conduct of a major project, the management team must have adequate delegated authority and flexibility in the management of expenditures. Within overall approved budget limitations the management team requires authority to adjust budget line items to fit expenditure needs and to utilize contingency allowances in the budget as required without prior approval of the grantor. Reporting any such adjustments in transmitted project reports should meet the needs of the grantor and still leave the management team free to perform efficiently. Current requirements for prior approval of minor changes cause delay in the orderly conduct of the project and can generate administration costs and project delay costs far in excess of the planned expenditure. The temptation and the tendency to use requirements for multilevel approvals of relatively small actions ($10,000 on a $1,000,000,000 project is small) as a means of preventing or postponing action are neither logical nor economical.

It is a common requirement of federal grant agencies to retain prior approval authority over the selection of consultants and the appropriate terms of consultant contracts, to require their prior approval of construction contracts and change orders to construction contracts, and to exercise a degree of control over construction contract terms. These requirements restrict the freedom of the management team to take prompt responsive action in the execution of the project and too frequently delay and/or redirect project activity. This type of control exercised by some granting agencies appears to be based on the assumption that Federal Procurement Regulations, established to control all contract work performed directly by federal organizations, should also rule the contract work performed by other entities for projects partially funded by federal grants. This philosophy is of questionable merit because the federal government is not the responsible manager of the project. The federal agency makes a grant to a project sponsor for a specific project after pre-grant investigations confirm that the project is sound. An alternative that would benefit the project substantially, as compared to current practice, would be to require approval before the award only of major prime contracts for consultant services, construction, and procurements—perhaps only of those that are valued at more than 5 percent of the total budget and of contract changes that are valued at more than 5 percent of the contract. It is vital that practices of the granting agencies in controlling contract awards and contract forms be examined in depth by the granting agencies with regard to enabling the project management teams to take prompt and responsive decisions and actions in contract matters. UMTA is aware

of this problem and is already working with one transit authority to test streamlined contracting procedures.

Prepare Comprehensive Risk and Liability Plan

29. The owner should develop a comprehensive risk and liability plan that includes allocation of risks. The owner should also consider the use of wrap-up insurance to protect all parties at a reasonable cost if this is found to be economically advantageous.

Risks and liabilities are both unavoidable in major underground construction. The owner needs to recognize this, especially during the construction phase. The advantages and disadvantages of establishing a wrap-up insurance program should be investigated during the evolution of a comprehensive risk management program, for designers and contractors are faced with risk insurance that is prohibitively costly or in some cases unobtainable.

Establish Adequate Real Estate Acquisition Organization and Procedures

30. The owner should determine the scope of real estate acquisition in the early phases of the project and establish an adequate organization to make acquisitions. Early in the project the owner should initiate close coordination with potential public and private developments adjacent to the project that could affect the owner's real estate acquisition program and could possibly lead to joint development. Areas that will be required by construction contractors should be identified by the project management team at the time other real estate requirements are established. The owner should give consideration to implementing a value capture program, which involves acquiring impacted properties in the vicinity of the project and holding them as an investment for future sale.

In order that the project proceed on schedule, it is necessary to determine the scope of real estate acquisition in the early phases of the project and to establish an organization or designate an existing organization for real estate acquisition and relocation of displaced businesses and households. It is imperative that acquisitions proceed through the progressive stages of design and be adjusted to the schedule of the project.

Adjoining property, particularly at transit station locations, is almost certain to increase in value as a result of the project. Therefore, consideration should be given to acquiring such properties as an investment by the owner for future sale after the project has been built and is in operation.

Near stations of a public transit system and along its route, construction operations may cause damage to buildings or facilities. These will have to be protected or acquired. Trade-off studies and estimates need to be made early in the project to allow the necessary time for acquisition if that is the decision.

Particularly in urban areas, sites required by contractors for construction offices and working areas should be identified by the owner's staff or general

consultant through construction planning during the final design stage. Access to these areas and right of possession or acquisition is an appropriate function of the owner and should be considered prior to taking construction bids.

It is essential that all matters involving real estate be coordinated closely with the local government and its comprehensive plan as well as with private developers in order to advance the full social and economic potential of the project.

Foster Morale and Productivity by Strong Leadership

31. Strong leadership is necessary to foster and maintain morale and productivity. Those who have been appointed to manage a project or major portion of it must exercise their responsibilities and act in a timely manner, taking the positive actions required to get the job done. The productivity of all participants and their role in the project must be emphasized by the leaders of the management team. The project management team must develop a definite program among all the participants to foster and maintain high morale and a sense of commitment to success. The demonstration of progress and achievement is one of the best morale and productivity boosters.

Productivity in all stages of the project is fundamental to the fulfillment of the objective to complete the project within the cost estimate and time schedule. One measure of project productivity is the ratio of what the collective individuals of the project team accomplish to further the project compared to what they are capable of accomplishing. High productivity among individuals at all levels of administration and engineering can be achieved through sound personnel management practices and leadership applied by responsible managers and supervisors on a continuing basis in a people-oriented organization.

Productivity does not increase automatically by promulgating harsh disciplinary rules. Many of the working practices incorporated in construction labor agreements, particularly with craft unions in underground construction, have serious adverse effects on productivity. Good management practices in all project phases include clear and concise work assignments, specific delegation of responsibility, clear instruction about what is expected of the employee, making sure the employee has the tools necessary to do the job, and informing the employee of his contribution to the success of the project. Other important practices include elimination of redundancy within and among organizational entities, use of special priority task assignments or groups of individuals in any of the organizational entities best qualified for the task, and avoidance of work assignments that obviously do little or nothing to contribute to the project. It is recommended that the leaders of the management team set an example by utilizing the personnel management practices listed here and making every effort to practice them at all lower levels of management and supervision in their organizations. Contractors, owners, and consultants should work with the unions to mitigate any labor practices that may have adverse effects on productivity.

Although an intangible quality relating to perceptions and emotions, morale generates tangible results to a project. High morale makes team efforts

effective. It generates positive attitudes towards work efforts, personal relationships, and job satisfaction. It stimulates thinking, planning, initiative and enterprise, and constructive innovation. In a high-morale environment people are inspired to seek the best. Low morale can lead to completely opposite results.

Morale generally starts from action and attitude of the top people of a management team and permeates down through organization levels to successive levels of management when leaders at all levels follow morale building practices and attitudes. The generation and maintenance of morale are leadership obligations. Good leadership is characterized by concern for employee welfare, fairness and impartiality, positive attitudes towards complaints and suggestions, giving credit when credit is due, open communication, respect for employee efforts, and impressing employees with their constructive contribution to the project. Morale makes for teamwork, and teamwork produces far more positive and productive actions than those resulting from individual actions. The project management team needs to develop a definite program for developing morale and motivation among the individuals of the project team, including not only those in the management organizations but also those in agencies that are significant in the execution of the project.

In recent years federal, state, and local authorities have promulgated laws, regulations, and rules, and have set objectives to employ individuals and organizations from minority groups in all phases of the project. Wholehearted efforts to meet or exceed those goals should be made for legal, social, and moral reasons. The project management team should develop and implement effective programs to meet equal opportunity and affirmative action objectives within every organization participating in the project.

TO ACHIEVE SUCCESSFUL START-UP OF THE PROJECT:

Major projects are extemely complex. Accordingly, proper attention must be devoted to preparation for start-up throughout the planning, engineering, and construction phases of the project.

Select Key Operations Personnel Early

32. Key operations and maintenance positions must be identified during the planning phase, and qualified personnel must be selected for these positions and brought on early to ensure that their expertise is used to plan and design the project.

Prepare Operations Plan Early

33. The owner and the other members of the project management team must develop and document operations and maintenance plans and procedures during the early part of the design phase. A complete family of test procedures, operating manuals, as-built drawings, and performance documents should be available prior to the final testing and acceptance.

Allow Ample Time For Thorough Testing Program

34. The owner and the other members of the project management team must initiate and schedule adequate time for a thorough program of testing, start-up, and run-in of the system, prior to the scheduled initial operation. Key operations and maintenance

personnel should participate fully and responsibly in the testing program to prepare for early and efficient system operation and to train and develop experienced personnel for operation and maintenance.

The successful operation of an underground project, such as a transit system, is dependent upon the relationship of all of its components. It is essential, therefore, that an adequate program of testing, start-up, and run-in of the system be initiated. This can be accomplished through the construction of a test track either independent from or part of the system. Prior to the initial operation, all phases of the system's operating components need to be tested on the test track and sufficient time allowed in the schedule for this most vital operation. This will provide an opportunity to make the necessary adjustments or changes to ensure a smooth transition to final operation. However, adequate time must be allowed for testing under full operational conditions. While this applies directly to a transit system project, virtually every new major project requires the testing of major and complex equipment and facilities as well as training of key operating personnel prior to full scale operations.

Operations plans and procedures should be developed starting during the design phase and completed no later than the construction stage. During the operation of the testing facility, key operating personnel can be trained to test and improve the operations plans and procedures. Moreover, operations personnel need to participate intensely and responsibly in the testing program to prepare for efficient system operation from the moment it opens for service.

Persons Interviewed

Name	Affiliation	Date
Boyd C. Paulson, Jr.	Professor, Civil Engineering Stanford University	July 11, 1977
John Fondahl	Professor, Civil Engineering Stanford University	July 11, 1977
Clarkson H. Oglesby	Professor, Civil Engineering (retired) Stanford University	July 12, 1977
Frank Wagner	Manager, East Bay Construction Bay Area Rapid Transit District San Francisco	July 13, 1977
Wilmot R. McCutchen	Manager of Design Bay Area Rapid Transit District San Francisco	July 13, 1977
Edward S. Olcott	Director of Planning and Development Port Authority of New York and New Jersey	July 19, 1977
Frederick E. Winter, Jr.	Deputy Chief Engineer Port Authority of New York and New Jersey	July 19, 1977
Daniel M. Hahn	Engineer of Design, Terminals, Tunnels and Bridges Port Authority of New York and New Jersey	July 19, 1977
Paul G. Nicholson	Manager, Construction Division Engineering Department Port Authority of New York and New Jersey	July 19, 1977

Fred N. Magrath	Assistant Construction Manager Bus Terminal Expansion Program Port Authority of New York and New Jersey	July 19, 1977
John T. O'Neill	Executive Officer and Chief Engineer New York City Transit Authority	July 20, 1977
George Ziegler	Executive Deputy Chief Engineer New York City Transit Authority	July 20, 1977
John F. Culhane	Deputy Chief Engineer Advanced Planning and Program Management New York City Transit Authority	July 20, 1977
Leon Rossum	Deputy Chief Engineer, Design New York City Transit Authority	July 20, 1977
Morris Loshinsky	Deputy Chief Engineer, Construction New York City Transit Authority	July 20, 1977
Thomas E. Diana	Assistant to Chief Engineer New York City Transit Authority	July 20, 1977
Sol Valenza	Engineering Audit Officer New York City Transit Authority	July 20, 1977
Bernard Adler	Public Agency Liaison New York City Transit Authority	July 20, 1977
Alan Kiepper	General Manager Metropolitan Atlanta Rapid Transit Authority	July 21, 1977
William Alexander	Assistant General Manager for Transit Systems Development Metropolitan Atlanta Rapid Transit Authority	July 21, 1977
Faust Ystueta	Chief Engineer Metropolitan Atlanta Rapid Transit Authority	July 21, 1977
Michael P. Mitro	Program Analysis Metropolitan Atlanta Rapid Transit Authority	July 21, 1977
Herbert M. Priluck	Construction Manager Metropolitan Atlanta Rapid Transit Authority	July 21, 1977

James L. Lammie	Project Manager Parsons, Brinckerhoff/Tudor (PBQ&D/T, Atlanta)	July 21, 1977
Milton Pikarsky	Chairman of the Board Regional Transportation Authority Chicago	August 16, 1977
Marshall Suloway	Commissioner of Public Works City of Chicago	August 16, 1977
Louis Koncza	Chief Engineer Department of Public Works City of Chicago	August 16, 1977
Frank E. Dalton	Assistant Chief Engineer Metropolitan Sanitary District of Greater Chicago	August 16, 1977
Richard D. Harza	Chairman Harza Engineering Company	August 16, 1977
David Novick	Consultant and Adjunct Professor University of Illinois, Chicago	August 16, 1977
Harry Sutcliffe	Manager for Engineering Bechtel, Inc. (Boston)	August 18, 1977
Frank Keville	Project Manager, NW Line Ext. Massachusetts Bay Transit Authority	August 18, 1977
Drew Hyde	Assistant to Director of Construction Massachusetts Bay Transit Authority	August 18, 1977
Martin Price	Massachusetts Bay Transit Authority	August 18, 1977
Robert R. Kiley	Chairman Massachusetts Bay Transit Authority	August 18, 1977

Questionnaire No. 1

Early in the study the subcommittee designed a questionnaire to rank in order of importance the critical elements faced by a transit authority in building an urban rapid transit system. The questionnaire, a copy of which appears on pages 100 to 102, listed 26 critical elements under authority jurisdiction and 14 outside authority jurisdiction. Addressees were requested to rank the elements on a scale from most important to unimportant. Space was provided for the addressees to list any additional elements they considered to be critical.

The questionnaire was distributed on August 5, 1977 to 104 addressees who had been selected for their experience in underground construction as well as for their range of viewpoints. The addressees, including subcommittee members, were categorized as follows:

Owners	22
University Professors	4
Attorneys	7
Engineers (designers)	32
Construction Contractors	31
Geotechnical Engineers	6
Labor Official	1
Insurance Specialist	1

Sixty responses were received, a 58 percent rate of return. Three of the responses were declinations to complete the questionnaire for various reasons, generally a lack of underground construction experience. The respondents who completed the questionnaire are listed on pages 94 to 99. A majority signified willingness to complete a later questionnaire concerning tentative conclusions and recommendations of the study.

The 57 completed questionnaires were tabulated to rank the critical elements. All elements listed in the questionnaire, except one, were determined to be valid on the basis of completed questionnaires. The one element not considered valid was "constraints," which was among those listed under authority jurisdiction. Because that element was unanswered or questioned by 16 respondents, the subcommittee concluded that it had not been stated with sufficient specificity. Accordingly, it was eliminated from further analysis.

The list of critical elements and their ranking in order of importance, as scored by the respondents, is displayed below. For convenience, the elements listed in the questionnaire as "under authority jurisdiction" and "outside authority jurisdiction" have been integrated into a single list that has been divided into three groups in order of criticality.

Of the 57 respondents completing questionnaires, 17 added other elements they considered to be critical. These added elements are listed on pages 91 to 93. Also, several respondents included amplifying letters with their completed questionnaires. Selected comments from these letters appear on pages 93 and 94.

The following conclusions were drawn from the responses to Questionnaire No. 1:

- An adequate number of responses was received to secure valid underground construction community evaluation of critical elements.
- The elements listed in the questionnaire were valid in the view of a majority of the respondents and were important.
- The relative importance of the elements was determined by an informed segment of the underground construction community.
- A sufficient number of interested, qualified people is available to test the subcommittee's tentative conclusions and recommendations by a second questionnaire.
- Questionnaire No. 2 should concentrate on those elements considered most critical.

CRITICAL ELEMENTS IN ORDER OF IMPORTANCE

I

1. Delayed decisive action
2. Project funding and cash flow
3. Imposed controls—funding and fund management
4. Dedication to timely project completion (authority)
5. Dedication of government and involved agencies to timely project completion
6. Transit authority organization
*7. Transit authority legal authority
*7. Public acceptance
8. Selection of consultants
9. Imposed controls, contracts, procedures
10. Acquisition of right-of-way and working areas
11. Schedule and cost management
12. Administration of and coordination with consultants

*Tie

II

13. Environmental impact statements— approval
*14. Construction contract strategy
*14. Risks and liabilities (outside authority jurisdiction)
15. Risks and liabilities (under authority jurisdiction)
16. Claims and disputes—construction contracts
17. Government regulations
18. Testing, start-up and run-in
19. Labor productivity
*20. Contract agreements with utilities and involved agencies (outside authority jurisdiction)
*20. Public and community relations and participation in system planning
*21. Contract agreements with utilities and involved agencies (under authority jurisdiction)
*21. Environmental hearings, analyses and impact statement
22. Freeze project features and design prior to start of final design

III

23. Existing structures—protection
24. Operational organization and training
25. Political action and objectives
26. Citizen and class action lawsuits
*27. Project labor agreements
*27. Societal impacts
*27. Public hearings
28. System cost effectiveness analyses
29. Cost-benefit analysis
30. Special interest groups' pressures
31. Wrap-up insurance
32. Equal employment opportunity program
33. Central procurement

ADDED CRITICAL ELEMENTS

Under Authority Jurisdiction

Element Description	*Respondent's Background*	*Scale***
Transit district under state legislative action rather than authority	Owner	4
Legislative rights to condemn with eminent domain		4
Legislative jurisdiction over cities and counties		4

*Tie

**5 = most important; 4 = of major importance; 3 = important.

Element Description	*Respondent's Background*	*Scale***
Delegation of authority	Owner	5
Organization of design/construction management	Owner	4
Responsibility flow during implementation		5
Alternative analysis	Owner	3
Procedures publications (e.g., construction management, construction engineering, safety, procurement, etc.)		3
Spelling out decision-making process and authority		5
Early efforts to standardize and control design criteria	University Researcher	5
Delegating sufficient decision-making authority to resident engineer		4
Cooperative team relationship between agency, consultants, and contractors		5
Development of type of contract not suited to all circumstances of the project	Attorney	5
Development of procedure for settling disputes that obviates, or at least minimizes court litigation		5
Cooperation and team approach to reduce costs, etc.	Engineer	4
Condemnation authority	Engineer	4
Responsive decision structure		5
Internal delegation of authority		4
Early approval/coordination—basis of design		4
Determination of number and scope of consultant contracts	Engineer	4
Construction contract staging	Engineer	5
Construction contract interfaces		5
Authority reputation as a system		5
Obtaining high quality personnel to administer construction contracts	Contractor	5
Lack of dedication to timely and economical performance at all levels of government agencies and organization of the program	Contractor	5
Construction reviews	Contractor	4

**5 = most important; 4 = of major importance; 3 = important.

Element Description	*Respondent's Background*	*Scale***
Timely settlement of claims	Contractor	5
Adequate contract documents	Contractor	5
Adequate budget		5
Adequate cost estimates		5
Flexibility in modifying design during construction	Geotechnical Consultant	4
Success in recruiting qualified professionals	Subcommittee Member	5
Conceptual planning; project planning		5
Fixed responsibility; good communication		4
Eliminating wasteful administrative procedures		4

Outside Authority Jurisdiction

Element Description	*Respondent's Background*	*Scale***
General planning agreement from local agencies for system as a whole	Owner	4
Approval of planning agencies	Owner	4
Physical aspects such as type and location of urban area, the geological and topographical conditions, type, extent and condition of existing structures	University Researcher	4 or 5
Changes (elections)—local jurisdictions	Engineer	3
National policy and priorities	Member	5
Local objectives and public acceptance		4

SELECTED COMMENTS RECEIVED WITH QUESTIONNAIRE RESPONSES

"The listed critical elements clearly reflect many of the problems faced by the agency responsible for such an undertaking and an attempt has been made to categorize them as requested. However, it is suggested that the ranking of these elements not be overemphasized. All are important and indeed any one of them through misfortune or mismanagement can delay or otherwise adversely impact the project at any given time, thereby assuming the status of 'most important'. Relative importance is also a function of political climate and many other factors which can vary from city to city."

"I do believe most strongly that the creation of a strong transit authority organization is the most important single factor in the process. Following

**5 = most important; 4 = of major importance; 3 = important.

that I would rate the early consideration of the risk, liability and insurance programs and practices to be observed, partially because of the importance of those elements in the overall process, but also because I am convinced that failure to resolve those issues at an early date will contribute to delays in project prosecution of a most serious sort."

"Please note that I have added one element to the Critical Elements Under Authority Jurisdiction. I believe that the current tendency to fragment the consultant effort on large urban rapid transit projects is a mistake in that I think that it ultimately leads to increased management difficulties and costs and, therefore, I suggest that the decision concerning this matter is one of the critical elements in the start of any such project....I also note that your questionnaire does not set a time frame for when the criticality of the estimates are to be judged. I have assumed that you intend that answers to the questionnaire reflect the degree of criticality as it exists at the very beginning of the project. I am sure you realize that some of the items listed become more critical as the project proceeds unless they are solved in the early days of the project."

"I regret that the designations of relative importance do not cover a wider range of scale but seriously believe all elements are virtually vital to the successful management of such efforts."

"I might say that all of the critical elements listed are important in my view and it was difficult to differentiate."

RESPONDENTS TO QUESTIONNAIRE NUMBER 1

William D. Alexander
Assistant General Manager for Transit Systems Development
Metropolitan Atlanta Rapid Transit Authority
Atlanta, Georgia

John P. Buehler
Consultant
St. Helena, California

J. Joseph Casey
President
Gordon H. Ball, Inc.
Danville, California

H. Cermak
Project Coordinator
Massman Construction Company
Kansas City, Missouri

Arthur P. Chase
President
A.A. Mathews, Inc.
Rockville, Maryland

Frank E. Dalton
Assistant Chief Engineer
Metropolitan Sanitary District of Greater Chicago
Chicago, Illinois

Elio D'Appolonia
Chairman of the Board
D'Appolonia Consulting Engineers, Inc.
Pittsburgh, Pennsylvania

Peter M. Douglas
Senior Associate Engineer
Shannon and Wilson, Inc.
Seattle, Washington

Munson W. Dowd
Chief Engineer
Metropolitan Water District of Southern California
Los Angeles, California

O.P. Easterwood, Jr.
McNutt, Dudley, Easterwood and Losch
Washington, D.C.

R.E. Fitzner
Manager, Marketing and Engineering
Dravo Corporation
Pittsburgh, Pennsylvania

George A. Fox
Executive Vice President and Chief Engineer
Grow Tunneling Corporation
New York, New York

E. Montford Fucik
Chairman of the Board
Harza Engineering Company
Chicago, Illinois

Dan Geary
Fenix and Scisson, Inc.
Tulsa, Oklahoma

Arland D. Gilbertson
Chief Engineer
Green Construction Company
Des Moines, Iowa

Seymour S. Greenfield
Vice President
Parsons, Brinckerhoff, Quade and Douglas
New York, New York

David G. Hammond
Vice President
Daniel, Mann, Johnson and Mendenhall
Baltimore, Maryland

Thomas J. Hayes, III
President
International Engineering Company, Inc.
San Francisco, California

Warren Higgins
Director of Construction
Massachusetts Bay Transportation Authority
Boston, Massachusetts

J. Donovan Jacobs
Chairman
Jacobs Associates
San Francisco, California

Douglas A. Johnson
Vice President
Al Johnson Construction Company
Minneapolis, Minnesota

M.G. Johnson
Counsel
Bechtel Power Corporation
San Francisco, California

Ernest Jonas
Head, Geotechnical Engineering Division
Tippetts-Abbett-McCarthy-Stratton
New York, New York

Thomas Kapsalis
Executive Director
Chicago Urban Transportation District
Chicago, Illinois

Frank M. Keville
Regional Project Manager
Massachusetts Bay Transportation Authority
Somerville, Massachusetts

B. Palmer King
Attorney-at-Law
Lincoln, Nebraska

Gail B. Knight
Area Manager
S.A. Healy Company
Camp Hill, Pennsylvania

Kenneth G. Knight
General Manager, Metro Construction
Niagara Frontier Transportation Authority
Buffalo, New York

James L. Lammie
Project Director
Parsons, Brinckerhoff/Tudor
Atlanta, Georgia

Jack K. Lemley
Vice President, Special Projects
Morrison-Knudsen Company, Inc.
Boise, Idaho

William N. Lucke
Consultant
Annapolis, Maryland

Theodore C. Lutz
General Manager
Washington Metropolitan Area Transit Authority
Washington, D.C.

George T. McCoy
Senior Vice President
Guy F. Atkinson Company
South San Francisco, California

Wilmot R. McCutchen
Manager of Design
Bay Area Rapid Transit District
Oakland, California

Norman A. Nadel
President
MacLean-Grove and Company, Inc.
New York, New York

Harold E. Nelson
Consulting Engineer
Chicago, Illinois

Richard H. Norair
President
Norair Engineering Corporation
Marlow Heights, Maryland

R.L. Olander
Chief, Transportation Engineering
Harza Engineering Company
Chicago, Illinois

Edward S. Olcott
Director of Planning and Development
Port Authority of New York and New Jersey
New York, New York

Robert S. O'Neil
Senior Vice President
DeLeuw, Cather and Company
Washington, D.C.

Walter H. Paterson
Consulting Engineer
Toronto, Ontario, Canada

Boyd C. Paulson, Jr.
Department of Civil Engineering
Stanford University
Palo Alto, California

Milton Pikarsky
Chairman of the Board
Regional Transportation Authority
Chicago, Illinois

Solomon Ribakoff
Attorney-at-Law
Encino, California

F.W. Ries
Senior Vice President
Stone and Webster Engineering Corporation
Boston, Massachusetts

Louis W. Riggs
President
Tudor Engineering Company
San Francisco, California

Lee Rowe
Vice President
Peter Kiewit Sons Company
Omaha, Nebraska

Edward J. Ruff
Managing Partner
Thelen, Marrin, Johnson and Bridges
San Francisco, California

Winfield O. Salter
Project Director
Parsons, Brinckerhoff, Quade and Douglas, Inc.
Atlanta, Georgia

Peter H. Smith
Chairman
Gibbs and Hill, Inc.
New York, New York

Marshall Suloway
Commissioner
Department of Public Works
Chicago, Illinois

Sven B. Svendsen
Senior Vice President
Daniel, Mann, Johnson and Mendenhall
Los Angeles, California

J. George Thon
Executive Consultant
Bechtel, Inc.
San Francisco, California

Erland A. Tillman
Project Director
Daniel, Mann, Johnson and Mendenhall
Baltimore, Maryland

Joseph C. Ungerer
Vice President, Underground Construction Division
Morrison-Knudsen Company, Inc.
Boise, Idaho

Eugene B. Waggoner
Consultant
San Jose, California

Chris F. Woods
Executive Vice President
Al Johnson Construction Company
Minneapolis, Minnesota

MANAGEMENT OF MAJOR
UNDERGROUND CONSTRUCTION PROJECTS

QUESTIONNAIRE NUMBER 1

Concerning Critical Elements Faced by a Transit Authority
in Building an Urban Rapid Transit System

Please rank the importance of the listed elements using the following scale:

Most important - 5
Of major importance - 4
Important - 3
Of some, minor importance - 2
Unimportant - 1

Blank spaces are provided for any elements you feel should be added. Please rank any element added.

CRITICAL ELEMENTS UNDER AUTHORITY JURISDICTION

Transit authority organization _____
Transit authority legal authority _____
Dedication to timely project completion _____
Project funding and cash flow _____
Cost-benefit analysis _____
Selection of consultants _____
Administration of and coordination with consultants _____
Environmental hearings, analyses and impact statement _____
Contract agreements with utilities and involved agencies _____
Freeze project features design prior to start of final design _____
Equal employment opportunity program _____
Acquisition of right-of-way and working areas _____
Public and community relations and participation in system planning _____
Public hearings _____
Construction contract strategy _____
Risks and liabilities _____
Wrap-up insurance _____
Existing structures - protection _____
Claims and disputes - construction contracts _____
Project labor agreements _____

CRITICAL ELEMENTS UNDER AUTHORITY JURISDICTION — cont'd.

Central procurement _____
Schedule and cost management _____
System cost effectiveness analyses _____
Operational organization and training _____
Testing, start-up and run-in _____
Constraints _____

_____

_____

_____

_____

CRITICAL ELEMENTS OUTSIDE AUTHORITY JURISDICTION

Government regulations _____
Imposed controls, contracts, procedures _____
Imposed controls - funding and fund management _____
Delayed decisive action _____
Dedication of government and involved agencies to timely project completion _____
Contract agreements with utilities and involved agencies _____
Environmental impact statements - approval _____
Public acceptance _____
Labor productivity _____
Risks and liabilities _____
Political action and objectives _____
Societal impacts _____
Special interest groups' pressures _____
Citizen and class action lawsuits _____

_____

_____

_____

_____

My experience has been as:

Owner	_____
Planner	_____
Designer	_____
Contractor	_____
Other (specify)	_____

I would _____ would not _____ be willing to assist the study by completing a second questionnaire concerning tentative conclusions and recommendations.

Signature_____ Address_____

Title_____ _____

_____

Questionnaire No. 2

The questionnaire was designed to assist the subcommittee in preparing recommendations for improving the management of major underground construction projects. It followed an earlier questionnaire which was used to determine the most critical elements of such a project—those under and outside the control of the authority (owner). The second questionnaire, a copy of which appears on pages 118 to 130, focused on specific problems and requested suggestions for solving or managing these problems.

Distribution of Questionnaire No. 2, which was forwarded to 113 persons, began on October 20, 1977. The recipients included members of the subcommittee, members of the U.S. National Committee on Tunneling Technology, respondents to the first questionnaire who had signified their willingness to answer a follow-up questionnaire, and other knowledgeable people in the underground construction community whose names were suggested by subcommittee members.

The questionnaire contained eight questions, each designed to elicit recommendations for improvements. The first question dealt with delayed decisive action, the single most critical element identified by the earlier questionnaire. Addressees were asked to identify delays caused by each agency or organization involved in a project and to recommend measures for prevention or reduction of such delays. The second question listed the 13 elements which had been determined by the earlier questionnaire to be the most critical ones faced by a transit authority in building an underground rapid transit system. Addressees were asked to indicate whether or not these elements were critical in other public projects and/or in commercial or industrial projects, and to list suggestions for dealing with the critical elements. The third question addressed the part played by the federal government in project approval, funding, environmental impact assessment, and any other areas of concern. Recommendations for changes in federal procedures were requested. The fourth question dealt with the owner's actions in a project and solicited recommended changes in owners' actions or additional actions which should be considered. The fifth question concerned the organization(s) employed for planning, design, and construction, and asked for reasons favoring each of the two most commonly employed organizational models—i.e., a single firm for planning, design, and construction management, or one firm for planning and design and another firm for construction. The subject of

the sixth question was contracting practices employed in major projects, and addressees were asked their opinions on fixed-price bidding and on certain contracting requirements imposed to meet special goals. The seventh question requested suggestions for improving productivity of all members of the project team (owners, designers, construction managers, contractors, construction employees, and others). Those making suggestions were asked to estimate the order of magnitude of the cost reductions which might occur if their suggestions were adopted. In order to ensure that no potential areas for improved management were overlooked, the eighth question requested any other suggested improvements not identified in the previous questions.

Seventy-five responses were received, 57 of which were completed questionnaires. (Substantive replies from 2 respondents who did not use the questionnaire form were included in the total of 57.) The subcommittee is indebted to those who took the time to complete the questionnaire, thereby providing valuable information and useful suggestions for management improvements. The names of these respondents are listed on pages 112 to 117. Those who did not complete questionnaires generally declined on the basis of lack of experience, or only recent experience, in the management of underground construction projects.

The subcommittee concluded that those completing questionnaires represented a valid cross section of the underground construction community. Several of the respondents have had experience in two or more roles in underground construction, and in the following classification they have been listed in the categories of their current roles. The categories and number of respondents in each are:

Owner's Representatives	12
Engineers (Consultants)	16
Construction Managers	4
Construction Contractors	12
Lawyers	4
Architects	2
Educator	1
Funding Agency Official	1
Geologist	1
Geotechnical Engineer	1
Construction Engineers	2
Supplier	1

The 57 completed questionnaires were analyzed in detail by the subcommittee's consultants and reviewed by the subcommittee. Then, a summary of the answers was prepared for use by the participants in the subcommittee's workshop. This summary follows.

SUMMARY OF ANSWERS TO QUESTION NO. 1, CONCERNING DELAYED DECISIVE ACTION

This question listed ten decision-making agencies which might be the cause of delayed decisive action. These included federal, state, and local/regional governments; authority (owner); general consultant; designers/specialty engineers; construction managers; prime and sub construction contractors; and advocacy groups. Space was provided for other agencies or organizations to be listed. Respondents were requested to identify types and durations of delays as well as the phase of the project in which specific delays occurred. They were also encouraged to recommend measures for prevention of delays or improvements in procedures.

The federal government was identified as the cause of major delays, generally ranging from one to three years. However, one delay of five years was cited. These delays generally occurred in the project approval phase but extended throughout the life of some projects. Major problems cited were antiquated agency procedures, lack of sense of urgency, lack of sufficient qualified people, and lack of goal orientation. The recommendations most widely made were: improve agency administrative procedures, reduce the amount of detail federal agencies require and delegate decisions to a lower level, reduce EIS requirements to essential information, develop a sense of urgency and a commitment to meet schedules, and retain more experienced and higher quality executives.

State governments were identified generally as causing delays similar to those caused by the federal government, so these have not been repeated here. Additional delays cited included a two-year delay in achieving consensus during the concept development phase, delays up to a year in approving matching funds, and a delay of a year in approving the consulting engineer for one project. Among the recommendations were development of early agreements with involved agencies and avoidance of competitive bidding in selection of contractors for professional services.

Local/regional governments were cited as responsible for significant delays, but generally shorter ones than federal and state governments. Delays usually related to agreements with involved agencies, gaining of political approval, and obtaining or granting permits. Major recommendations included setting up a group in the local government dedicated to project actions and being more aware of the need for public input in project planning.

Owners were reported responsible for delays ranging from weeks to four years during all phases of projects. Poor planning and management, lack of financing, and "buck passing" were all listed as reasons for delay. Recommendations for improvements included avoiding duplication of the authority staff and the general engineering consultant, using consultants to their full capacities, and accepting advice of the consultants. Also recommended was the use of better contracting practices, particularly recognizing and dealing with changed site conditions promptly. Establishment of good communications both to facilitate the work and to avoid adversary relationships was emphasized.

Delays attributed to the general engineering consultants included the tendency to "reinvent the wheel," failure to act on claims of construction contractors, failure to identify risks associated with introduction of new technology, and failure to secure adequate data to serve as a basis for design. The maximum delay reported was two years. Selection of the general consultant on merit was the major recommendation. It was evident that all parties expected prompt resolution of problems by the consultant.

Measures suggested to minimize design/specialty engineer-caused delays were selecting experienced and well qualified firms, de-emphasizing "defensive" engineering, and awarding multiple design contracts to the firms which perform best. Designer-caused delays were generally measured in weeks and in months rather than years.

The delays attributed to construction managers, also measured most often in weeks and months, were lack of sufficient attention to changed conditions, delay in approving contractor submissions, and failure to build an adequate staff

promptly. One incident cited was a 12-month delay caused by failure to "blow the whistle" on a contractor. A major recommendation of those responding to this question was to select a competent construction management firm with experienced, qualified people and then give them appropriate authority.

Delays attributed to prime and sub contractors generally appeared to result from the selection of unqualified or marginally qualified firms. Some prime contractors were cited for bid shopping and, on some projects, both prime and sub contractors were slow to mobilize and submit shop drawings. Delays mentioned ranged from a few days to six months. Prequalification of bidders to insure adequately financed, properly managed contractors was recommended by many respondents.

Project opponents were cited for delays of up to six months. Although environmental opposition was mentioned most often, opposition came from many segments of those affected. Long delays were encountered when opponents took problems to the courts, and various measures for limiting opponents' legal remedies were suggested. Respondents recommended more effective involvement in the planning phase of individuals and groups with a stake in the outcome. It was noted that the objective should be to plan a project well so that it will attract public support, and then pursue it while that support is strong.

Other groups reported by some respondents as causing delays included regulatory boards, insurance and bonding companies, labor unions, and equipment suppliers. However, the delays caused by such groups were generally considered to be minor as compared with other delays already described.

SUMMARY OF ANSWERS TO QUESTION NO. 2, CONCERNING WHETHER THE 13 PROJECT ELEMENTS DETERMINED TO BE MOST CRITICAL TO A TRANSIT AUTHORITY ARE CRITICAL TO OTHER PUBLIC PROJECTS AND TO COMMERCIAL/INDUSTRIAL PROJECTS

The answers to this question were summarized (Table 4) from the first 44 questionnaires received. Not every respondent answered each question, so total answers tabulated differ from question to question. In general, it can be stated that there is strong consensus that elements critical to a transit authority are critical to other public projects and, perhaps to a somewhat lesser degree, also to commercial/industrial projects. Consensus is not as strong on the latter type projects as it is on public projects.

SUMMARY OF ANSWERS TO QUESTION NO. 3, CONCERNING THE FEDERAL GOVERNMENT ROLE

Respondents were requested to list any recommended changes in federal requirements in five specific areas and were given an opportunity to recommend changes in other areas as well. The project areas, and a summary of recommendations concerning each, follow:

Project Approval

- Federal agencies should have small, experienced staffs to review projects.
- Approval authorities should have an appreciation of the tremendous cost of delays.
- Time limits for approval or rejection should be established and adhered to.
- Approval procedures should be simplified.

TABLE 4 Summarized Suggestions for Dealing With 13 Critical Project Elements

CRITICAL ELEMENT	IMPORTANT TO				SUGGESTED ACTIONS
	Other Public Projects		Commercial/ Industrial Projects		
	Yes	No	Yes	No	
Delayed Decisive Action	44	—	34	2	Get best qualified people for project. Delegate authority. Fix responsibility. Reduce number of agencies involved in project management. Eliminate red tape.
Project Funding & Cash Flow	39	1	23	1	UMTA should eliminate phased grants. Have assured funding source before starting project. Estimate costs realistically from the start. Provide for more flexible mobilization bid items.
Imposed Controls — Funding & Fund Management	32	1	19	9	Establish comprehensive cost control system prior to project initiation. Avoid over-regulation. Simplify approval procedures. Give responsible managers adequate authority
Dedication to Timely Project Completion	39	1	27	4	Develop team spirit. Impress all participants with sense of urgency. Make decisions promptly. Provide incentives. Disqualify bidders with poor records for timely completion.
Transit Authority Organization	30	2	12	7	Clearly define responsibility. Establish project team. Insulate managers from politics. Establish definite and clear lines of authority.
Transit Authority Legal Authority	28	4	12	8	Needs right of eminent domain. Authority must have broad legal authority. Must have appropriate legal advice.
Public Acceptance	37	2	22	11	Keep public informed. Develop public participation. Maintain liaison with public bodies. Use media to explain project. Minimize inconvenience to public.
Selection of Consultants	38	2	20	5	Avoid political influence in selection. Select on basis of ability to perform. Eliminate price competition. Experience and reputation for fairness and objectivity are key criteria.
Imposed Controls — Contracting Procedures	32	1	17	13	Delegate approval authority. Avoid multiple reviews. Avoid giving unknowledgeable bureaucrats too much authority. Devise means to bring problems to senior executives promptly.
Acquisition of Right-of-Way and Working Areas	35	5	24	5	Authority needs condemnation authority. Start in time. Provide sufficient work areas for contractors. Complete acquisitions before contract awards.
Schedule & Cost Management	33	6	29	3	Devise controls and schedules which fit the project.
Administration & Coordination with Consultants	31	—	25	1	Define responsibilities clearly. Emphasize good communications.
Approval of Environmental Impact Statements	36	—	30	2	Reduce requirements to essentials. Early approval is important. Allow adequate time for preparation. Involve public. Simplify without overlooking essential elements.

- Approval agencies should not attempt to conduct detailed engineering reviews.
- Approval functions should be consolidated into fewer agencies.
- After general approval, maximum authority should be delegated to local levels within general legal and accountability regulations.

Environmental Impact Statement (EIS) Approval

- Contents of the EIS should be reduced to essential information. Document preparation should be streamlined.
- Reviews should be conducted in reasonable time period. Deadlines should be established.

Funding Procedures of Grant Agencies

- Procedures for approval of capital grants should be simplified and streamlined.
- Grants for preliminary engineering should be increased.
- Funding agency should be involved at project formulation and continuously thereafter.
- Funding should be secured on long-range basis, not piecemeal.

Procurement Procedures

- All efforts to procure professional services by price competition should be resisted.
- Federal agencies should permit grantees to negotiate and process change orders for professional services without federal review.
- Recommendations in *Better Contracting for Underground Construction* should be followed.
- A more realistic approach to minority contracting should be developed.

Grant Agency Review and Approval During Design and Construction

- Controls should be based on budget only.
- Approvals to authority should be delegated and decentralized.
- Grant agencies should avoid getting involved in detailed control.
- Federal actions should be speeded up.

Others

- Federal agencies should set performance goals for grantees in concept stage.
- Federal procurement regulations should be revised to make them more applicable to standard construction practices.

SUMMARY OF ANSWERS TO QUESTION NO. 4, RECOMMENDATIONS FOR CHANGES IN OWNERS' ACTIONS OR ADDITIONAL OWNERS' ACTIONS

A prime responsibility of the owner is to gain the support of all levels of government and the public. The owner should have a management and technical staff capable of promptly and efficiently handling problems not delegated to the consultant.

The owner should:

- Solve utility problems prior to construction.
- Prepare the community for the upcoming construction.
- Coordinate real estate acquisition through design phase and complete as soon as possible.
- Arrange for necessary permits and secure jurisdictional concurrences.
- Schedule award of contracts with broad understanding of industry capabilities.
- Develop better ways of dealing with adversary groups.
- Reduce changes in scope during construction phase by better review of plans and specifications prior to construction.

SUMMARY OF ANSWERS TO QUESTION NO. 5, CONCERNING MANAGEMENT OF PLANNING, DESIGN, AND CONSTRUCTION

This question asked for a listing of factors favoring two different organizational approaches, both of which have been used for recent mass transit projects. One approach was management of planning, design, and construction by a single general consultant, and the other was design management by one firm and construction management by another. A total of 45 people responded to this question. It is notable that although respondents had not been asked which approach they preferred, 35 expressed an opinion. A significant majority (26 of the 35) stated a preference for the single-firm approach. It is interesting that of those expressing a preference for the two-firm approach, 4 were construction contractors.

The principal factors favoring management by a single consultant which were most commonly cited include:

- Facilitates phasing of planning, design, and construction.
- Minimizes coordination and interface problems.
- Provides for design intent to be understood by construction managers.
- Avoids designer/construction manager disputes.
- Provides for quicker responses to construction problems.
- Improves contract documents for later phases of the project by promoting feedback from field to design staffs.
- Provides for early participation in the design process by those who will manage construction, thus improving constructibility.
- Provides opportunities to streamline decision-making.
- Promotes better management control of entire project.
- Promotes continuity.
- Is probably more economical than two-firm approach.

The major factors favoring the two-firm approach include:

- Recognizes the existence of only a limited number of firms well qualified both in design and construction management.
- Eliminates "pride of authorship" as a factor in evaluating contractor-proposed changes.
- Provides check and balance between design and construction, therefore better end product may result.
- Provides owner with two viewpoints, thereby reducing dependence on a single consultant.
- Recognizes the political advantages in distributing the work to additional firms, and also recognizes the possible existence of legal

restrictions against one firm handling all phases.
- Reduces conflict-of-interest.

SUMMARY OF ANSWERS TO QUESTION NO. 6, CONCERNING CONTRACTING PRACTICES

This question had three parts: the first concerned fixed-price bidding versus other forms of contract; the second asked the effects of certain contract requirements, such as set-asides and minority contracting; the third requested suggestions for meeting the goals of these special programs.

Fixed-price ("hard money") contracts were favored by nearly half the 45 respondents to this question; the others favored some form of negotiated contract with incentive provisions. There were several comments recommending prequalification of construction contractors no matter what form of contract is employed. Generally, fixed-price bidding appears to be favored when design is complete and subsurface explorations are thorough. Negotiated contracts are preferred when risk is high, or new technology is to be introduced, or other special conditions prevail.

Varied replies were given to the question concerning the effects of such programs as minority contracting requirements, EEO, Buy American, small business set-asides, and local preference. Most respondents thought the programs had some cost, but none could quantify it. A few thought the added costs were negligible. The majority of respondents seemed to feel that the programs addressed social goals and that their added costs should be recognized as social rather than as construction cost escalation.

Recommendations concerning meeting the goals of such programs in contracting varied widely. Some respondents favored abolishment of the programs while others favored good faith efforts to meet goals but elimination of mandatory quotas. Several favored increased educational opportunities for minority citizens and elimination of existing barriers to entry into skilled trades. One thoughtful respondent commented: "National policy for most of these programs should be adjusted to avoid unrealistic expectations.... When one profession or element of an industry is selected to serve as a force for social change the consequence can be negative, especially when a few well-qualified minority firms become overcommitted. National policy should establish broad objectives with the manner of implementation delegated to the local level. Local programs in turn should be started on a small scale using the good offices of well established consultants and contractors."

SUMMARY OF ANSWERS TO QUESTION NO. 7, CONCERNING PRODUCTIVITY OF THE PROJECT TEAM

Specific suggestions for increasing productivity of members of the project team (owners, design engineers, construction managers, contractors, construction employees, and others) included:

- Devote strong efforts to fostering a "team" approach, the goal of the team being to do the job right.
- Provide strong central leadership for the team.
- Work hard to eliminate adversary climate and develop a spirit of mutual confidence.
- Communicate!

- Employ goal-oriented management techniques.
- Provide incentives for good performance.
- Get problems to the manager who can solve them.
- Assign risks fairly and reasonably.
- Keep all team members informed.

The second part of this question requested the respondents to estimate what percent reduction in costs might be expected if the suggestions made were adopted. Estimates ranged from 2 to 50 percent for various team members, with most answers in the 10 to 25 percent range. Although these estimates cannot be considered firm, they reveal that most respondents feel significant cost reductions can be achieved by increasing the productivity and efficiency of team members.

SUMMARY OF ANSWERS TO QUESTION NO. 8, CONCERNING SPECIFIC SUGGESTIONS FOR IMPROVEMENTS NOT COVERED IN THE PREVIOUS QUESTIONS

Specific suggestions received from five respondents serve best to summarize the answers to this question.

"Government regulations and requirements are becoming more numerous, complicated and time consuming. This has the effect of lengthening the total time required from inception of a project to completion. A halt to the proliferation of rules and requirements, and a complete overhaul of the review and approval process will contribute much to a more reasonable cost for underground construction."

"We are convinced that the Government's interests are best served when general guidelines are issued and detailed review by the Grant Agencies takes place at major milestones only. There is a disturbing tendency for more and more involvement by the Grant Agencies in details of implementation and associated requirements for time-consuming approvals at every stage, sometimes by individuals not really qualified to exercise such control. We understood that MARTA is being treated on a decentralized basis, but this appears to be experimental only. It should be the rule, not the exception."

"Our profession would profit from a better interchange of information regarding adverse experiences on a job which increase costs and/or cause delays. As a result of our adverse experiences we take steps to avoid them on future jobs. We learn from our mistakes and you learn from your mistakes, but neither of us learns from the others' mistakes. Our technical publications deal mainly with successful accomplishments, but they do not often mention the pitfalls in the plan-design-construct process except for major failures."

"Improvements in the construction industry require that the owner participate in the decision-making processes of the engineer and constructor and others involved with the project. The owner needs to increase his participation in the implementation of sound and prudent management techniques to project execution....

While organization charts and project management networks define specific responsibilities and interfaces for the efficient completion of a project, it must be remembered that the project itself is unaware of man's division of responsibility for his logistical, economical and political convenience. Interfaces between organizations exist only on paper, while the physical world

remains continuous and coupled. Relationships between organizational groups are the most difficult to consider correctly. The owner must be aware of this and must make every effort to improve the dialogue and communication between the various groups involved in the execution of a project.

Each project phase of planning, design, construction and operation plays a crucial role in the project success or failure; however, it is not their individual importance which determines the success or failure of a project, but their coupled effect as a smooth continuous flow and feedback of data and decisions across interfaces. Continuity of thought process throughout all project phases from inception to completion with interaction and decision-making at critical stages in the life of the project is the keystone of project success."

"Continued research into management, design and construction techniques and procedures.... Seek ways to work with union as well as non-union construction forces that are nondestructive."

RESPONDENTS TO QUESTIONNAIRE NUMBER 2

William D. Alexander
Assistant General Manager for Transit Systems Development
Metropolitan Atlanta Rapid Transit Authority
Atlanta, Georgia

Charles H. Atherton
Vice President and Area Manager
J.F. Shea Company, Inc.
Bethesda, Maryland

Michael B. Barker
Administrator, Department of Practice and Design
American Institute of Architects
Washington, D.C.

Peter G. Behr
Vice President
Bechtel Quebec Ltd.
Montreal, Quebec, Canada

William F. Brumund
Principal
Golder Associates
Atlanta, Georgia

Frank E. Dalton
Assistant Chief Engineer
Metropolitan Sanitary District of Greater Chicago
Chicago, Illinois

Elio D'Appolonia
Chairman of the Board
D'Appolonia Consulting Engineers, Inc.
Pittsburgh, Pennsylvania

Don U. Deere
President
Don U. Deere & Andrew H. Merritt, Inc.
Gainesville, Florida

O.P. Easterwood, Jr.
McNutt, Dudley, Easterwood and Losch
Washington, D.C.

E.E. Erlandson
Senior Construction Manager
Stone and Webster Engineering Corporation
Boston, Massachusetts

Arthur J. Fallon
Executive Director
Niagara Frontier Transportation Authority
Buffalo, New York

George A. Fox
Executive Vice President
Grow Tunneling Corporation
New York, New York

John P. Gnaedinger
President
Soil Testing Services, Inc.
Northbrook, Illinois

Donald Griffith
Project Manager
Norair Engineering Corporation
Marlow Heights, Maryland

J. Donovan Jacobs
Chairman
Jacobs Associates
San Francisco, California

Douglas A. Johnson
Vice President
Al Johnson Construction Company
Minneapolis, Minnesota

Ernest Jonas
Associate Partner
Tippetts-Abbett-McCarthy-Stratton
New York, New York

Thomas Kapsalis
Executive Director
Chicago Urban Transportation District
Chicago, Illinois

Frank M. Keville
Regional Project Manager
Massachusetts Bay Transportation Authority
Boston, Massachusetts

B. Palmer King
Attorney-at-Law
Lincoln, Nebraska

Gail B. Knight
Area Manager
S.A. Healy Company
Camp Hill, Pennsylvania

Kenneth G. Knight
General Manager, Metro Construction Division
Niagara Frontier Transportation Authority
Buffalo, New York

Louis Koncza
Chief Engineer
Department of Public Works
Chicago, Illinois

Thomas R. Kuesel
Senior Vice President
Parsons, Brinckerhoff, Quade and Douglas, Inc.
New York, New York

James L. Lammie
Project Director
Parsons, Brinckerhoff/Tudor
Atlanta, Georgia

Jack K. Lemley
Vice President, Special Projects
Morrison-Knudsen Company, Inc.
Boise, Idaho

William N. Lucke
Consultant
Annapolis, Maryland

Leroy Lundgren
Manager, Contracts and Costs
Dravo Corporation
Pittsburgh, Pennsylvania

Theodore C. Lutz
General Manager
Washington Metropolitan Area Transit Authority
Washington, D.C.

Wilmot R. McCutchen
Manager of Design and Construction
San Francisco Bay Area Rapid Transit District
Oakland, California

Norman A. Nadel
President
MacLean-Grove and Company, Inc.
New York, New York

Harold E. Nelson
Consulting Engineer
Chicago, Illinois

Satoshi Oishi
Senior Vice President
Edwards and Kelcey, Inc.
Newark, New Jersey

Robert S. O'Neil
Senior Vice President
DeLeuw, Cather and Company
Washington, D.C.

Thomas V. O'Neill
Executive Vice President
Lester B. Knight and Associates, Inc.
Chicago, Illinois

Walter H. Paterson
Consulting Engineer
Toronto, Ontario, Canada

Boyd C. Paulson, Jr.
Department of Civil Engineering
Stanford University
Palo Alto, California

Solomon Ribakoff
Attorney-at-Law
Encino, California

Lee Rowe
Vice President
Peter Kiewit Sons Company
Omaha, Nebraska

Edward J. Ruff
Managing Partner
Thelen, Marrin, Johnson and Bridges
San Francisco, California

Winfield O. Salter
Senior Vice President
Parsons, Brinckerhoff, Quade & Douglas, Inc.
Atlanta, Georgia

Peter H. Smith
Chairman
Gibbs and Hill, Inc.
New York, New York

Stephen E. Smith
Chief, Design and Construction
California Department of Water Resources
Sacramento, California

Arthur G. Strassburger
Supervising Civil Engineer
Pacific Gas & Electric Company
San Francisco, California

Harry Sutcliffe
Project Manager
Bechtel, Inc.
Somerville, Massachusetts

Samuel Taradash
Chief Consultant, Underground Supports Division
Commercial Shearing, Inc.
Youngstown, Ohio

E.L. Tennyson
Deputy Secretary
Pennsylvania Department of Transportation
Harrisburg, Pennsylvania

J. George Thon
Executive Consultant
Bechtel, Inc.
San Francisco, California

Erland A. Tillman
Project Director
Daniel, Mann, Johnson and Mendenhall
Baltimore, Maryland

Joseph C. Ungerer
Vice President, Underground Construction Division
Morrison-Knudsen Company, Inc.
Boise, Idaho

Eugene B. Waggoner
Consultant
San Jose, California

George B. Wallace
Principal Engineer
Bovay Engineers, Inc.
Spokane, Washington

Kenneth N. Weaver
Director
Maryland Geological Survey
Baltimore, Maryland

Ray E. Webb
Water Tunnel Contractors
Darien, Connecticut

W.E. Webb
Engineering Geologist
Austin, Texas

W.D. Wightman
Vice President
Underground Technology Development Corporation
Alexandria, Virginia

E.E. Wilhoyt, Jr.
Project Manager
Bechtel Associates Professional Corporation
Washington, D.C.

U.S. NATIONAL COMMITTEE ON TUNNELING TECHNOLOGY

NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES NATIONAL ACADEMY OF ENGINEERING
2101 Constitution Avenue, NW
Washington, D.C. 20418

MANAGEMENT OF MAJOR

UNDERGROUND CONSTRUCTION PROJECTS

QUESTIONNAIRE NUMBER 2

REQUEST FOR COMMENTS

NOTE: Information provided to the Subcommittee will be used in strict confidence for the purposes of the study only. No information will be quoted or otherwise incorporated directly in the report without the express permission of the contributor.

This questionnaire is being sent to addressees with experiences in several aspects of underground construction: planning, design, construction, legal matters, funding, and others. Some addressees' experience may enable them to contribute answers to all the questions; others may feel qualified to answer only a limited number of the questions. The Subcommittee, its consultants and staff will carefully consider every answer, and make judgements based on that consideration as well as on other pertinent and persuasive information.

Use the reverse side of the page or continuation sheets if necessary for a meaningful reply.

Replies may be hand written or typed. The Subcommittee's work will be assisted by readable replies.

In order to assist in ascertaining the views of the industry interest, it would be appreciated if you would identify your views as those of a _____[Please insert e.g., OWNER, GENERAL CONTRACTOR, SPECIALITY CONTRACTOR, SUPPLIER, ENGINEER (GEOLOGIST), or (DESIGN), (CONSULTING), (CONTRACT MANAGEMENT), EDUCATOR, LAWYER]. Other (specify).

Those providing replies will be furnished a copy of the final report when issued.

SUBMITTED BY:

_____
Name and Title

_____
Firm

_____
Street Address or P.O. Box

_____
City and State Zip Code

_____
Phone (including area code)

1. Responses to a recent questionnaire rated Delayed Decisive Action as the most critical element in management of major underground construction projects. The Subcommittee agrees that this is an extremely critical element.

Using the table below, please indicate at which decision points you have observed such delays and state your recommendations for improving the timeliness of the decision-making process.

Decision Making Agency/Organization	Type and Duration of Delay	Cause of Delay	Phase of Project in which Delay Occurred	Recommendation for Prevention or Improvement
a. Federal Government				
b. State Government				
c. Local/Regional Government				
d. Authority (owner)*				
e. General Consultant				
f. Designers/Specialty Engineers				

*Specify type, e.g. Transit Authority, Sanitary District, Etc.

Decision Making Agency/Organization	Type and Duration of Delay	Cause of Delay	Phase of Project in which Delay Occurred	Recommendation for Prevention or Improvement
g. Construction Manager				
Construction Contractors				
h. (Prime)				
i. (Sub)				
j. Advocacy Groups				
k. Other				

2. The most critical elements faced by a transit authority in building an urban underground rapid transit system, in the combined judgement of 53 respondents to Questionnaire Number 1, are listed below. The Subcommittee has discussed and accepted this list after considering experiences of the Subcommittee members.

Many of these same elements are critical in other public works type projects and in commercial/industrial projects. By completing the table below please signify the importance of each element in other public areas and in commercial/industrial projects. Please list any suggestions you have for dealing with each element.

Critical Element	Important to Other Public Projects?		Important to Commercial Industrial Projects?		Suggested Actions
	Yes	No	Yes	No	
a. Delayed Decisive Action					
b. Project Funding and Cash Flow					
c. Imposed Controls — Funding & Fund Management					
d. Dedication to Timely Project Completion					
e. Transit Authority Organization					

Critical Element	Important to Other Public Projects?		Important to Commercial Industrial Projects?		Suggested Actions
	Yes	No	Yes	No	
f. Transit Authority Legal Authority					
g. Public Acceptance					
h. Selection of Consultants					
i. Imposed Controls, Contracts, Procedures					
j. Acquisition of Right-of Way and Working Areas					
k. Schedule & Cost Management					

Critical Element	Important to Other Public Projects?		Important to Commercial Industrial Projects?		Suggested Actions
	Yes	No	Yes	No	
l. Administration of and Coordination with Consultants					
m. Approval of Environmental Impact Statements					

3. The Subcommittee believes that the Federal Government can play a part in reducing costs of major underground construction projects and the time required for their completion. Areas of consideration include procedures for project approval, Environmental Impact Statement approval, funding policies and procedures, the applicability of federal procurement regulations, and levels of approval during the design and construction of a project. Any suggested procedural changes to reduce costs and project completion time should be consistent with protection of the federal interest.

Do you recommend changes in Federal requirements in areas listed below? If so, please explain.

a. Project approval

b. Environmental Impact Statement approval

c. Funding procedures of Grant Agencies (both for preliminary engineering and capital grant)

d. Procurement procedures

e. Grant Agency review and approval during design and construction phases (leval of control and amount of detail)

f. Others?

4. Owners' actions may affect cost and project completion times significantly. For example, award of contracts in greater volume than can be economically undertaken by available contractor and labor resources; dilatory action in real estate acquisition and construction permits; ineffective relations with the public and other agencies; insistence on changes after start of final design; delays in key decisions have all, at one time or another, been cited as reasons for delays and cost increases.

What changes in actions of owners or additional actions by owners should be considered in an attempt to increase efficiency and productivity of underground construction projects? (If public owners and private owners differ, please identify)

5. Public owners (e.g. transit authorities) often appoint a general consultant to manage planning and design, and in some instances construction, of major underground construction projects.

a. What factors favor management of planning, design, and construction by a single firm (as opposed to separate firms for design and construction management)?

b. What factors favor design by one firm and construction management by a separate firm?

6. The Committee has discussed current practices in contracting for construction. While this subject has been recently studied and is the subject of a 1974 N.A.S. Report, Better Contracting for Underground Construction, certain questions have arisen which may be discussed in the current report.

a. Do you favor contracting procedures substantially differing from fixed price bidding and award to low bidder? (As now used by public owners). If so, please specify procedure favored and reasons therefore. [If you have made similar recommendations in connection with the study described above, please so indicate].

b. What effects have programs such as minority contracting requirements, EEO, Buy American, small business set-asides, and local preference had in contracting (or subcontracting) for underground construction?

c. What changes, if any, would you recommend with regard to meeting the goals of such programs in contracting?

7. The Subcommittee believes that the productivity of all members of the project team (owners, design engineers, construction managers, contractors, construction employees, and others) has a significant impact on the total cost of the project.

a. What specific suggestions do you have for increasing productivity of team members?

b. If your suggestions were adopted and each member of the team worked at optimum efficiency, what percent reduction in costs from current norms would you expect?

Team Members	% Reduction
Owners	_____
Engineers	_____
Contractors	_____
Construction employees	_____

8. The Subcommittee believes that achieving the goal of completing major underground construction projects which will fulfill the requirement for which they were built at reasonable cost and within scheduled times requires the best efforts of all parties who are concerned with the project: The public, all levels of government, owners, planners, designers, construction contractors, advocacy groups, and labor.

What specific suggestions do you have for improvements which have not been covered in the previous questions?

9. The Subcommittee is planning an intensive two and one-half day workshop of approximately 50-75 participants to review the study and the conclusions and recommendations proposed. The workshop will be held in February 1978 at a location to be selected.

The study budget does not permit reimbursement to volunteers who would participate in the workshop. However, we feel the opportunity to make a contribution to the solution of pressing national problems and to exchange ideas with a group of knowledgeable professionals will attract volunteers to the workshop.

Would you like to receive an invitation to participate in the workshop as a volunteer? _____

If so, please signify your availability by crossing off any dates in February on which you could not participate.

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28				

Workshop Participants

William Armento
Parsons, Brinckerhoff/Tudor (PBQ&D/T)
Atlanta, Georgia

Charles H. Atherton
J.F. Shea Company
Bethesda, Maryland

Bruce F. Baird
College of Business
University of Utah
Salt Lake City, Utah

Robert L. Bangert
U.S. National Committee on Tunneling Technology
National Research Council
Washington, D.C.

James Birkmyer
Bechtel Corporation
San Francisco, California

Tor L. Brekke
Department of Civil Engineering
University of California
Berkeley, California

Richard F. Brisette
D'Appolonia Consulting Engineers, Inc.
Chesterton, Indiana

William A. Bugge
Olympia, Washington

J. Joseph Cassidy
Gibbs & Hill, Inc.
New York, New York

G. Wayne Clough
Department of Civil Engineering
Stanford University
Stanford, California

Keith C. Crandall
Department of Civil Engineering
University of California
Berkeley, California

Carl J. Distefano
U.S. Army Corps of Engineers, Omaha District
Omaha, Nebraska

John E. Everson
Parsons, Brinckerhoff, Quade & Douglas, Inc.
San Francisco, California

Antonio Ferreira
Electric Power Research Institute
c/o NEPLAN
West Springfield, Massachusetts

John W. Fondahl
Department of Civil Engineering
Stanford University
Stanford, California

Richard Gallagher
Southern California Rapid Transit District
Los Angeles, California

John P. Gnaedinger
Soil Testing Services, Inc.
Northbrook, Illinois

Samuel L. Hack
Office of Construction and Facility Management
Department of Energy
Washington, D.C.

David G. Hammond
Daniel, Mann, Johnson and Mendenhall
Baltimore, Maryland

Thomas J. Hayes, III
International Engineering Company, Inc.
San Francisco, California

J. Donovan Jacobs
Jacobs Associates
San Francisco, California

Thomas Kapsalis
Chicago Urban Transportation District
Chicago, Illinois

Frank M. Keville
Massachusetts Bay Transportation Authority
Somerville, Massachusetts

Kenneth G. Knight
Niagara Frontier Transportation Authority
Buffalo, New York

Jack K. Lemley
Morrison-Knudsen Company, Inc.
Boise, Idaho

Bert Levine
Bureau of Reclamation
Farmington, New Mexico

Raymond E. Levitt
Massachusetts Institute of Technology
Cambridge, Massachusetts

Franklin T. Matthias
Danville, California

Joseph T. Mayer
Urban Mass Transportation Administration
Washington, D.C.

Terence G. McCusker
Perini Corporation
Framingham, Massachusetts

Wilmot R. McCutchen
Bay Area Rapid Transit District
Oakland, California

Russell K. McFarland
Office of Rail Technology
Urban Mass Transportation Administration
Washington, D.C.

Thomas Moran
Environmental Protection Agency
Washington, D.C.

Norman A. Nadel
MacLean-Grove and Company, Inc.
New York, New York

Forrest C. Neil
The Metropolitan Sanitary District of
Greater Chicago
Chicago, Illinois

Charles Nelson
University of Minnesota
Minneapolis, Minnesota

Harold E. Nelson
Consulting Engineer
Chicago, Illinois

Clarkson H. Oglesby
Department of Civil Engineering
Stanford University
Stanford, California

Dean L. Orcutt
Bechtel, Quebec
Montreal, Quebec, Canada

Walter H. Paterson
Toronto, Ontario, Canada

Henry W. Parker
Department of Civil Engineering
Stanford University
Stanford, California

Boyd C. Paulson, Jr.
Department of Civil Engineering
Stanford University
Stanford, California

Edward J. Ruff
Thelen, Marrin, Johnson & Bridges
Can Francisco, California

Winfield O. Salter
Parsons, Brinckerhoff, Quade and Douglas, Inc.
Atlanta, Georgia

Ralph Shankland
Envirodyne Engineers
Chicago, Illinois

Stephen E. Smith
California Department of Water Resources
Sacramento, California

Robert Snyder
Tekken Construction Company
Walnut Creek, California

Ben Sosewitz
Envirodyne Engineers
Chicago, Illinois

Zoltan Stacho
Kaiser Engineers
Oakland, California

H. Jack St. Clair
Metropolitan Atlanta Rapid Transit Authority
Atlanta, Georgia

Marshall Suloway
Department of Public Works
Chicago, Illinois

Harry Sutcliffe
Bechtel, Inc.
Somerville, Massachusetts

J. George Thon
Bechtel, Inc.
San Francisco, California

Erland A. Tillman
Daniel, Mann, Johnson & Mendenhall
Baltimore, Maryland

Joseph C. Ungerer
Morrison-Knudsen Company, Inc.
Boise, Idaho

Eugene B. Waggoner
San Jose, California

Kenneth N. Weaver
Maryland Geological Survey
Baltimore, Maryland

W.E. Webb
Austin, Texas

W.D. Wightman
Underground Technology Development Corporation
Alexandria, Virginia

George Ziegler
New York City Transit Authority
Brooklyn, New York

U.S. National Committee on Tunneling Technology, 1977-1978

OFFICERS

Tor L. Brekke, *Chairman*
Professor of Geological Engineering
Department of Civil Engineering
University of California, Berkeley

+J. Donovan Jacobs, *Chairman*
Chairman
Jacobs Associates
San Francisco, California

David G. Hammond, *Vice Chairman*
Vice President
Daniel, Mann, Johnson & Mendenhall
Baltimore, Maryland

*Ralph B. Peck, *Immediate Past Chairman*
Consultant
Albuquerque, New Mexico

DESIGNATED REPRESENTATIVES

Interagency Committee on Excavation Technology (ICET)
Don A. Linger
Structure and Applied Mechanics Division
Federal Highway Administration
Washington, D.C.

+Term of office as Chairman ended June 30, 1978;
now serving as Immediate Past Chairman.

*Term of membership ended June 30, 1978.

Associated General Contractors of America (AGC)
Chris F. Woods
Executive Vice President
Al Johnson Construction Company
Minneapolis, Minnesota

American Society of Civil Engineers (ASCE)
Eugene B. Waggoner
Consultant
San Jose, California

American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME)
George L. Wilhelm
Operations Advisor
Exxon Minerals Company
Houston, Texas

Geological Society of America (GSA)
Don U. Deere
Consultant — Engineering Geology and Rock Mechanics
Gainesville, Florida

Association of Engineering Geologists (AEG)
*Frank T. Wheby
Consulting Civil and Geotechnical Engineer
Evanston, Illinois

Victor L. Wright
Consulting Engineering Geologist
Placerville, California

INDUSTRY

Eugene L. Foster
President
Underground Technology Development Corporation
Alexandria, Virginia

Thomas A. Lang
President
Leeds, Hill & Jewett, Inc.
San Francisco, California

Terence G. McCusker
Wayne, New Jersey
formerly Manager, Tunnel Division
Perini Corporation

Vincent J. Murphy
President
Weston Geophysical Engineers
Westboro, Massachusetts

*Term of membership ended June 30, 1978.

Norman A. Nadel
President
MacLean – Grove and Company, Inc.
New York, New York

ACADEMIC AND RESEARCH ORGANIZATIONS

Michael B. Barker
Administrator
Department of Practice and Design
American Institute of Architects
Washington, D.C.

George B. Clark
Professor and Senior Research Associate
Excavation Engineering and Earth Mechanics Institute
Colorado School of Mines

G. Wayne Clough
Professor
Department of Civil Engineering
Stanford University

Edward J. Cording
Professor
Department of Civil Engineering
University of Illinois

*Delon Hampton
Professor
Department of Civil Engineering
Howard University

+Lymon C. Reese
T.U. Taylor Professor of Civil Engineering
Department of Civil Engineering
University of Texas, Austin

GOVERNMENT

*Walter J. Addison
Mass Transit Administrator
Maryland Department of Transportation
Baltimore, Maryland

Wendell E. Johnson
Consulting Engineer
McLean, Virginia
Formerly Chief, Engineering Division
Civil Works Directorate
Office of the Chief of Engineers, U.S. Army

*Term of membership ended June 30, 1978.
+Withdrew from Committee, October 1978.

Kenneth G. Knight
General Manager, Metro Construction Division
Niagara Frontier Transportation Authority
Buffalo, New York

*Harold E. Nelson
Senior Associate
Kellogg Corporation
Chicago, Illinois

Phillip R. McOllough
District Engineer — Tunnels
Colorado Division of Highways
Idaho Springs, Colorado

Walter H. Paterson
Consulting Engineer
Toronto, Ontario
Canada
formerly Chief Engineer and General Manager of Subway Construction
Toronto Transit Commission

*Milton Pikarsky
Chairman of the Board
Regional Transportation Authority
Chicago, Illinois

Homer B. Willis
Chief, Engineering Division
Directorate of Civil Works
Office of the Chief of Engineers, U.S. Army
Washington, D.C.

Sheldon P. Wimpfen
Chief Mining Engineer and Assistant Director — Field Operations
U.S. Bureau of Mines
Washington, D.C.

LIAISONS

Trasnportation Research Board (TRB)
John W. Guinnee
Engineer Specialist
Transportation Research Board
National Academy of Sciences
Washington, D.C.

Building Research Advisory Board (BRAB)
John P. Gnaedinger
President
Soil Testing Services, Inc.
Northbrook, Illinois

*Term of membership ended June 30, 1978.

SECRETARIAT STAFF

Robert L. Bangert, *Executive Secretary*
U.S. National Committee on Tunneling Technology
National Academy of Sciences

[+]O. Allen Israelsen, *Executive Secretary*

Susan V. Heisler, *Assistant Executive Secretary*

Virginia M. Lyman, *Administrative Assistant*

Carole B. Carstater, *Secretary (part time),*
Subcommittee on Management of Major Underground Construction Projects

Iris F. Spriggs, *Secretary (part time)*

[+]Served in this position until February 1, 1978.

Selected Reading List

This selected reading list has been prepared to assist the reader who wishes to gain a greater depth of understanding of the management of major underground construction projects.

The goal in preparing this list has been to identify specific references which bear on the subject matter of the report. There are many publications on management, a lesser number on management of construction, and very few on management of underground construction. The references in this list have been selected with this availability in mind—i.e., there has been no attempt to list all publications pertaining to management. Nor has there been an attempt to duplicate previous reading lists or bibliographies. For example, there are many publications concerning contracting for underground construction listed in the bibliography of the report *Better Contracting for Underground Construction* (National Research Council, 1974). This report is included in the list and the reader who is interested in obtaining more information on contracting practices should consult it.

Most of the major underground construction projects now under way in the United States, or contemplated for the future, are federally funded. Therefore, an effort has been made to list references dealing with the funding procedures of the U.S. Environmental Protection Agency and the U.S. Department of Transportation, two agencies providing a large amount of the funds for major underground construction projects. Because such federally funded projects must fulfill the requirements of the National Environmental Policy Act of 1969, appropriate references concerning that act have also been included.

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