Project Delivery and Planning Strategies for Public Owners

by

Stephen Edward Mahoney

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Signature of Author.....................
Department of Civil and Environmental Engineering
December 18, 1998

Certified by..............................
John B. Miller
Assistant Professor of Civil and Environmental Engineering
Thesis Supervisor

Accepted by..................................
Andrew J. Whittle
Chairman, Department Committee on Graduate Students

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Abstract

Current trends show that as the demand for infrastructure renewal and replacement has increased, Federal, state, and local government funding for infrastructure projects has decreased. It has become clear that the government will need to examine the potential of and implement other delivery methods in addition to design-bid-build. In order for the government to effectively use project delivery as a variable, the role of government in the capital planning process will need to be redefined.

This thesis examines the capital planning process used by public owners, i.e. the government. The identification of ideal project planning and management principles led to a new framework for capital planning, referred to as the Project Configuration Process. The proposed Project Configuration Process is based on the premise that a public owner can identify a realistic need, identify the objectives for the project, identify the project constraints or drivers, and select the most appropriate delivery strategy that aligns the project objectives with the advantages of the delivery strategy.

Two case studies are included to examine current project configuration practices. The Central Artery/Tunnel Project in Boston, Massachusetts and Tren Urbano in San Juan, Puerto Rico identify common challenges to the delivery of large-scale infrastructure projects. The Central Artery/Tunnel Project will widen and depress the existing elevated Central Artery, add a Third Harbor Tunnel, and improve highway connections within and around Boston. The Central Artery/Tunnel Project is a useful case study for it facilitates the examination of a large-scale infrastructure project utilizing traditional design-bid-build procurement methods in conjunction with a management consultant assisting the Department of Public Works. The Project's development history provides insight into the processes, challenges and limitations of the current project delivery process. Tren Urbano, an urban rapid transit project, is intended to reduce congestion in the San Juan Metropolitan Area. The objective of applying this research to Tren Urbano is to identify essential project management issues in a mixed delivery setting. Phase I of Tren Urbano posses a unique project management problem as it is divided geographically into seven alignment sections and contractually into a portfolio of contracts containing one design-build-operate contract and six design-build contracts.

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Table of Contents

List of Figures

List of Process Diagrams

List of Tables

1 Introduction

1.1 Research Objectives

Strategic project planning, by public owners, is a systematic process that involves the assessment of the organization's objectives, capabilities and resources. It is a managerial process designed to develop and maintain a viable strategy to deliver projects. In general, the project delivery process is the means by which projects are consistently and efficiently planned, executed, utilized, rehabilitated and replaced. The planning process for any project attempts to address two main questions: 1) Are we doing the right job? and 2) How are we to do the job right? For large public works projects urban planners, architects, designers, government officials, and the general public ultimately determine the answer to the first question. In response to the second question, this thesis adds to the body of knowledge developed by the academic community, consultants, construction managers and owners.

Currently, public sector project planning and management strategies are tailored to the design-bid-build project delivery strategy. As a result of the changing environment regarding project delivery, it is important to identify project planning and management strategies that are effective for all, or most, delivery strategies including design-bid-build, design-build, design-build-operate, and build-operate-transfer to name a few. The ideal is to develop a structured planning process and practical tools that address critical problems, objectives, and situations under conditions of uncertainty with all delivery methods.

The objectives of this thesis and the chapters that address them are listed in Table 1-1.

Table 1-1 Thesis Objectives

Research Objective	Chapter
Create a Project Configuration (i.e. planning) Process for public owners based on sound project planning and management principles and practices.	Chapter 2 & Chapter 3
Provide recommendations for the implementation of management tools, referred to as project configuration deliverables, by public owners	Chapter 4
Identify and evaluate project configuration and management issues on large-scale infrastructure projects.	Chapter 5 & Chapter 6
Evaluate the potential of the proposed Project Configuration Process and identify current barriers to its implementation.	Chapter 7

1.2 Research Assumptions

To properly understand the intention behind the development of such a process, it is useful to state the assumptions that were required to reach the results and conclusions.

The initial assumptions that are fundamental to the development of the processes to follow are:

- The belief that a direct relationship exists between the level of project planning and the success of a project
- The belief that project delivery options for the public sector will eventually be expanded from exclusive use of segmented design-bid-build processes to allow the option for all viable delivery methods, which include segmented, combined, directly financed, and indirectly financed strategies.
- The understanding that the particular legal framework and work environment of an area in which the owner is operating will have an impact on the use of any project planning process.

1.3 Research Intent

In the last decade, as the government has experimented with various project delivery strategies, the need for a standard configuration process has become apparent. Rigby states that a well proven and universally accepted project management (configuration) system will be an absolute necessity to control and manage the next generation of very large complex technical projects. It is widely recognized that large and complex technical systems need to be designed, developed, produced and maintained using a unified system of engineering concepts, policies, principles, processes, and terminology, which will be usable and understandable by all those involved (Rigby, 1998).

The term configuration, used in this context, may be new to most readers. It is assumed that an owner has the flexibility of selecting the most attractive organizational structure, design alternative, and the delivery, financing, and management strategies. The configuration process describes the evolution of these decisions and what must be accomplished before the private sector becomes involved.

The project configuration process and recommendations provided in this thesis are intended to improve the planning process and begin to establish uniform standards which can be used by public owners for the mutual benefit of owners and the design and construction community. It will increase the awareness of the relationship between individual effort and the broader goal of project success and will help develop consensus on objectives, strategies, success measures, and risk factors within the project team. The purpose of the process is not only to standardize the development of and expectations for public sector projects but also to allow designers and contractors maximum latitude on how to meet those expectations.

Well-executed project planning by an owner, prior to a project's release into the private sector, can provide many benefits. For example, the transparency of a consistent process will allow the private sector to know what to expect and better prepare to meet the owner's needs, the owner will be able to choose the best method to deliver the project, and the groundwork will have been established to manage risk and potential changes during the project. An owner can obtain these benefits through the development of a process that identifies common project configuration principles and practices. The goal or intention of the process is to provide an owner with strategic methods to obtain information, address risk, and commit resources to maximize the probability of a successful project. The general hypothesis of this research is based on the premise that:

- The delivery of public infrastructure in America; with Federal, state, and local governments as the owner, can be improved by the development of a project configuration process that can be consistently and efficiently applied for any delivery strategy.

Although results from testing the project configuration process are not available to support the hypothesis, its value is well supported in construction literature. The Construction Industry Institute (CII) has identified that strategic project organizing by owners and contractors offers the highest potential return for each dollar invested ("Assessment...", 1990). It is basically intuitive that good planning is beneficial to construction projects. If projects begin with good planning and are executed according to those plans, the potential for successful projects is increased.

In order for any new project configuration process to be fully accepted and implemented, attitudes and behaviors regarding project planning need to be aligned with the new philosophy. The development of a mission statement, an adaptation from the private sector, for public owners will help establish the overall goals that should be addressed.

- Collectively, the Federal, state and local government's mission is to maximize the resources available to provide the greatest infrastructure value, in terms of cost and service quality, to the public.

This mission lends support to the belief that public owners should be able to choose from multiple project delivery strategies, not just design-bid-build. The determination of the "success" of a project is inherently subjective and is strongly dependent on the point of view of the individual making the assessment. Typical metrics for measuring project success often include total design-construction cost and schedule compared with estimates as well as the performance of the facility compared with what was intended. Quality, for the most part, is considered an expectation and project success is reduced to favorable cost and schedule results. For the purpose of this research, project success is determined by a new definition:

- Success is determined by the level of satisfaction among the project participants toward the completion of a fully operational and functional facility, with the least number of changes, rework, cost overruns, delays, and disputes.

While traditional measures of project success focus on costs and schedules, the new definition of project success places emphasis on relationships. Strong, team-oriented relationships lead to shared objectives, fewer conflicts, and faster dispute resolution. The change in focus is an important difference for these factors typically have a large influence on the final project cost and schedule.

Although the project configuration process may seem valuable, it may not be clear why the process is developed from the owner's perspective. Project planning for public infrastructure is an owner-driven process that must be aligned with overall economic and social policies. It is essential to consider the future as well as the immediate implications of the project's financial obligation and social impact. Proper alignment requires consideration of design, construction, operation, financial support, and project management early in the project lifecycle. This research focuses on the owner's planning activities, for it is a widely held, accepted belief that the early phases of a project's lifecycle will have a much greater influence on a project's outcome than the later phases.

However, it should be noted at the outset that this research does not represent either a complete project delivery system or a comprehensive guide for the development of a project. Rather the emphasis is on the identification of common principles that lead to project success and the development of a fundamental project configuration process that effectively addresses these principles. The project configuration process and deliverables developed in this paper can serve as a checklist for owners to determine their needs to deliver their project successfully. Many of the principles are not necessarily new and have been in use for some time. However, their critical importance to project success has not been properly established within a common project planning, configuration process.

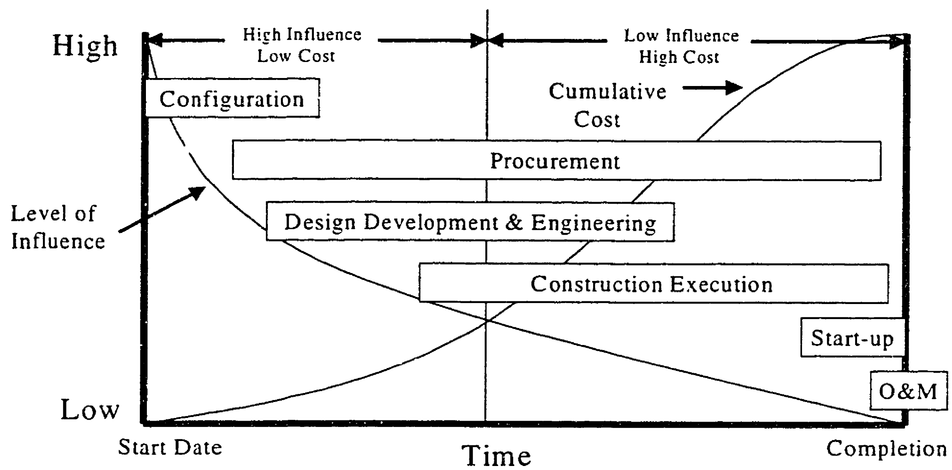
1.4 Thesis Structure

1.4.1 Problem Analysis

The state of infrastructure in America requires a change in the current method of public project delivery. Changes in current legislative statutes will be necessary to promote a long-term, stable commitment to private sector participation in the development of infrastructure. Different combinations of project finance, design, construction, and operations and maintenance, involving both the public and private sectors, offer the greatest potential to adequately serve the growing infrastructure demand. If this change is believed to be inevitable, as I have assumed, the central issue then becomes how should the government react to this change. What does the government need to do in preparation to operate effectively in this open environment? The choice among various project delivery strategies including; design-bid-build, design-build, turnkey, design-build-operate, build-operate-transfer, and other variations will provide the best potential value in terms of infrastructure quality, level of service, and development of technology. The government can satisfy its mission to the greatest extent, if effort and resources are focused on planning activities, which includes project delivery analysis, during the project configuration phase.

In support of this notion, Figure 1-1, first developed by Boyd Paulson, illustrates that it is easier to favorably influence a project's outcome during the project configuration phase, when expenditures are minimal, than it is to affect the project's outcome during construction execution or operations, when expenditures are more significant and work-in-place increasingly limits flexibility (Paulson, 1976b).

Figure 1-1 Phase Overlap and Level of Influence



1.4.2 Project Configuration Process

With the re-introduction of combined delivery strategies useful and successful project configuration will need to be redefined. Each project delivery strategy will have a different distribution of responsibility between the owner, designer, contractor, and operator depending on the level of integration between the phases, owner involvement, and owner expertise. An owner will benefit from implementing consistent project configuration methods to adequately prepare each project to progress through the remaining phases. The CII contends that up-front planning is a major key to a successful project. In a survey conducted by CII all designers agreed that project pre-planning by the owner and designer is a pre-requisite for a successful project (Diekmann et.al., 1987).

It is important that activities during the project configuration phase accommodate the various options available for project delivery, which includes the delivery strategy, finance, organization, and management in order to successfully address lifecycle issues of cost and service quality.

1.4.3 Project Configuration Deliverables

The project configuration process will identify specific project configuration deliverables such as a contracting plan, project management workplan, and project charter. These deliverables are resources that an owner can use to promote the delivery of a successful project.

The intent of each project configuration deliverable is expressed in a separate monograph. The monograph is a short text on a single topic that describes why the topic is important and what it contributes to successful project delivery. Each monograph describes common concepts regarding the intent of the project configuration deliverable and provides suggestions for its development.

1.4.4 Case Studies

The case studies are intended to illustrate how project planning, or configuration, is currently executed in a mixed delivery setting. The case studies will identify common challenges to the successful completion of large public projects, as well as, current barriers to the implementation of the proposed Project Configuration Process. The research for the case studies focuses on the existence of and reaction to project challenges, and not necessarily on the effectiveness of that reaction. That topic offers further potential research for each management and control program.

1.4.4.1 Central Artery

The Central Artery/Tunnel Project in Boston is the largest highway improvement effort ever undertaken within the core of an American city. The Project will widen and depress the existing elevated Central Artery, add a Third Harbor Tunnel, and improve highway connections within and around Boston. The Massachusetts Department of Public Works/Massachusetts Highway Department is the lead public agency of this nearly $11 billion project.

The Central Artery/Tunnel Project is a useful case study for it facilitates the examination of a large-scale infrastructure project utilizing traditional design-bid-build procurement methods in conjunction with a management consultant assisting the Department of Public Works. The Project's development history provides insight into the processes, challenges and limitations of the current project delivery process.

1.4.4.2 Tren Urbano

Tren Urbano, an urban rapid transit project in Puerto Rico, is intended to reduce congestion in the San Juan Metropolitan Area. The Puerto Rico Department of Transportation and Public Works (DTPW) and the Puerto Rico Highways and Transportation Authority (HTA) made the decision to construct Tren Urbano in phases. The first phase extends over 17 kilometers and will provide service for an estimated daily ridership of 115,000 passengers, at a capital cost of approximately $1.5 billion.

The objective of applying this research to Tren Urbano is to identify essential project management issues in a mixed delivery setting. Phase I of Tren Urbano posses a unique project management problem as it is divided geographically into seven alignment sections and contractually into a portfolio of contracts containing one design-build-operate contract and six design-build contracts. The Project's contract and organizational structures create multiple challenges to obtaining the HTA's project goals of obtaining a high quality transit system, completed on time and within budget.

2 Problem Analysis

2.1 Current Preferred Method

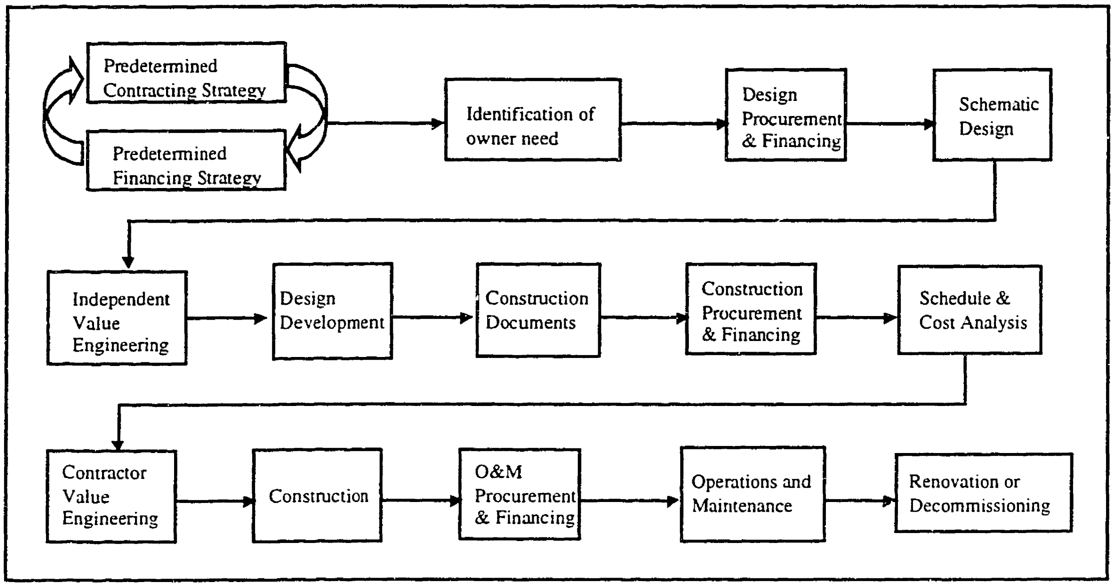
The current preferred public sector project delivery method and in general the most commonly used delivery method is design-bid-build. The implementation of the method is a sequential process, in that design is followed by a bidding process, construction, and then operations. Design-Bid-Build, also referred to as the traditional method, relies on an architect or engineer to design the project, a sealed bidding and public award process, construction by the lowest bidder, and financing secured and supplied by the owner.

Federal, state, and local governments have relied exclusively on the design-bid-build method of project delivery over the past few decades. After World War II, the EPA Construction Grants Program and the Interstate Highway System Program firmly entrenched the delivery of public infrastructure in the use of the design-bid-build strategy (Miller, 1997a). As a result of specialization within the industry and the statutory and regulatory requirements of both funding programs, the project life cycle was segmented, separating finance, design, construction, and operations and maintenance. In 1972 the Brooks Act required the segmentation of design from construction for public projects (40 U.S.C Sec. 541-544) (Miller, 1997a). This was done to allow the award of the design contract to be based on technical capability and the qualifications of the design firm, while the construction contract could be procured through competitive bidding with an emphasis on low cost. The consequence of limiting the government's project delivery options is that Federal, state, and local governments have been forced to assume direct responsibility for planning, designing, constructing, maintaining, and operating most major infrastructure projects (Miller, 1997a).

Currently, when a need is identified, the development of the project follows distinct stages. The owner selects a designer, typically based on qualifications over price. The design professional then develops 100% complete plans and specifications for the owner. The construction contractor is selected through a low bid process based on the completed design furnished by the owner. The contractor is then responsible to complete the project as specified in the design documents by the specified date and within the contract price.

It is important to note that the lowest bid is not always in the owner's best interest as it does not guarantee quality or the lowest total cost for the project. The current approach lacks any attempt to develop partnering relationships, and fails to provide incentive for project participants to work together for the benefit of everyone involved. Because there is no contractual relationship between the designer and the contractor all directives must come from the owner. Therefore, the owner is responsible for oversight of the construction process as well as any disputes or changes that occur. The typical lifecycle of a design-bid-build project is represented in Figure 2-1.

Figure 2-1 Typical Design-Bid-Build Lifecycle



There are benefits to the traditional method as through decades of use the private sector has become acclimated to the use of design-bid-build. Through better efficiency and project control the low bid process has been effective at reducing construction costs.

2.2 Why Treat Project Delivery as a Variable?

There are fundamental problems with exclusive reliance on any one particular project delivery strategy. The last couple of decades have proven that the sole use of design-bid-build will not provide an answer to the growing demand for infrastructure in America. This strategy relies on public funding to support infrastructure projects and current trends show increasing demand for infrastructure and decreasing public funds to support it. Use of the segmented design-bid-build method also excludes the incentives for innovation and incorporation of new technology that combined methods create due to access to the revenue stream and lifecycle cost and cash flow analyses during the design phase. Similarly, exclusive use of build-operate-transfer methods would not satisfy the demand for infrastructure. The private sector cannot be relied on to identify and satisfy all public needs. In this environment only those identified projects which produce favorable discounted cash flow results will be pursued by the private sector. All other needs, of which there are currently many, will remain unmet.

A fundamental element of a sustainable infrastructure delivery strategy is the notion that the method of delivery is a variable to be analyzed and managed. "More than one practical, viable project delivery option exists for most major public works projects" (Miller, 1997a). "Simply put, it is the mix of project delivery methods that are applied to a collection of desirable infrastructure projects that is becoming increasingly important. One of the clear teachings of the history of construction management in the United States is that no single form of project delivery and finance is preferable across numerous projects and sectors over time" (Miller, 1997a). The ideology behind allowing the public sector to use all of the available contract procurement strategies is based on the belief that the public and private sectors can collectively provide the best services to meet the growing needs of infrastructure in America. The public and private sector must together strive to improve the quality of the American infrastructure portfolio through proper allocation of financial risk and the encouragement of developments in technology and innovation throughout design, construction, and operation processes. If the government can push financially viable, large capital projects into the private sector, more public funds can be directed to a large number of smaller projects that cannot support themselves.

The advantages to the government of having the authority to select a project delivery strategy are clear. The government would be able to:

- Attract private sector investment in infrastructure
- Increase the introduction of new technology and innovation
- Increase infrastructure quality and service while controlling costs
- Conserve government resources to support public projects and services that only the government will perform

Although history shows that the public and private sector have delivered successful projects with the traditional method, a number of trends have emerged that do not support the continued exclusive use of design-bid-build to deliver all public sector projects.

2.3 Recent Trends

2.3.1 The Delivery of Large-Scale Projects

As current infrastructure systems continue to age, they will need to be upgraded or replaced. There is likely to be a significant number of large-scale infrastructure projects in the near future and we must recognize the challenges and develop processes to deliver these projects successfully.

Although each project is unique there are some common challenges and problems with the delivery of large-scale projects by the government. A few identified problems are:

- The government does not have the resources to support Federal programs indefinitely
- The use of government funding programs may lead to misguided objectives to obtain Federal money rather than fulfill a realistic need
- The structured delivery process may not be the most cost-effective solution to the mission need
- The design-bid-build process limits the potential of obtaining the best-value for public money

2.3.2 Inadequate Public Capital Resources

Current statutes and regulations predetermine the project financing and delivery strategy. Under the design-bid-build project delivery method the government must provide the financing necessary to complete the project. As the demand for infrastructure has increased, the Federal, state, and local government funding available for these projects has decreased. The combination of the current and growing shortfall of public funds available for infrastructure and the requirement of direct public financing associated with the design-bid-build process will inevitably cause the government to fail in its mission.

2.3.3 Misguided Project Objectives

A direct result of relying on and pursuing Federal financing support for public infrastructure is the misguided objectives of public owners. Public officials and legislators at the Federal, state, and local level currently support infrastructure programs that are funded by specific public appropriations and that require a variety of Federal, state, and local agencies to administer guidelines, rules, and qualifications for the receipt of public funding. This strategy can result in an infrastructure planning process that is focused on obtaining program funds instead of meeting the current and long-term public infrastructure need (Miller, 1997a).

2.3.4 Project Drivers

Typical project drivers are cost, time, and/or quality. In today's business environment quality work is an expectation and pressure to reduce the project duration has increased. The potential for revenues from operation of the completed facility often outweighs the design and construction cost. Good examples are high technology industries where profit margins are high and large infrastructure projects that will improve the surrounding economy, protect the environment, and/or fill a social need. Because of the segmented nature of the design-bid-build strategy, it is typically recognized as having a longer project duration than combined strategies, which can take advantage of fast-track methods that overlap the design and construction phases.

2.3.5 Lifecycle Value

A consequence of using the traditional method is that lifecycle cost principles are not presently considered to be the method of determining the value of a project. The low bid process reflects an attempt at the lowest initial cost not the lowest cost of ownership. A fee-based selection process for A/E's typically results in standard designs that do not guarantee maximum efficiency, least operating expense, or even lowest initial cost. However, the importance of low initial cost has caused the development of project management and control techniques to focus on cost and schedule control during the construction phase.

Most public agencies have a limited amount of funds and they are under political pressure to produce short-term results. Most investments are therefore made on the basis of initial costs without any consideration of lifecycle costs (Arditi and Messiha, 1996) (Novick, 1991). The traditional method inherently focuses on short-term sequential goals concerning design, then construction, and finally operations and maintenance. This short-term view has resulted in the belief that design and construction for public projects often end in cost overruns. There is substantial support for the notion that the segmented approach is largely responsible for these cost overruns as the government has not been as successful at integrating the results as they have been at segmenting the tasks (Miller, 1997a).

Under the design-bid-build process it is difficult for public owners to involve contractors in the planning and design processes. If a contractor were compensated for involvement during the design process, that contractor would most likely be excluded from bidding on the job due to the potential conflict of interest and perceived unfair advantage (Gibson et. al., 1996). Along the same lines, prior to the bid, contractors are reluctant to suggest ideas on improving the project or reducing cost because of the fear that competing contractors will also use that information (Warkol, 1997).

Figure 2-1 shows that the government has been involved in multiple contract agreements with public or private entities without the capability of obtaining the best value, cost and service quality, over the entire lifecycle. The design-bid-build strategy used today ignores the implications of the fact that a majority of a project's cost resides in the operations phase. "Initial design and construction ought to be expressly aimed at long term operations, maintenance, and finance – particularly since initial design and initial choice of technology commit the owner of the facility (public or private) to the resultant cost of maintenance and operations for three to five decades" (Miller, 1997a).

In certain areas of public works projects at least the value of lifecycle cost analysis, if not its effective implementation, has been recognized. Section 1024 of the Inermodal Surface Transportation Efficiency Act of 1991 requires that any organization depending on Federal funds for infrastructure investment perform some sort of lifecycle cost analysis to satisfy funding requirements.

2.3.6 Barriers to Innovation

Prevailing construction technology generally restricts innovation by designers. Under the public bidding process used for design-bid-build, the designer cannot foresee who the contractor will be. Consequently the designer is not aware of the technology available to the contractor. This lack of information forces the designer to create designs feasible for construction by many firms. The obvious consequence of this practice is that the designer is reluctant to innovate, fearing that contractors will either refrain from bidding or will submit high bid prices (Nam and Tatum, 1993).

Under the design-bid-build method the contractor and designer are in separate worlds: the designer's world of reputation and the contractor's world of price competition and cost reduction. This divergence of goals typically leads to a lack of cooperation or even an adversarial relationship between the designer and constructor. Although new ideas in design can often be introduced with new materials or methods of construction, continued coordination between these two occupations in the whole process is difficult. This helps make a potentially dynamic industry technologically rigid (Nam and Tatum, 1988) (Nam and Tatum, 1992).

2.3.7 Increased Private Sector Involvement

The private sector is already involved in the design, construction, and operation of public projects. Current regulations require that public owner's procure each of these services separately with public financing. However, there is great potential to obtain private financing to assist in the completion of needed infrastructure projects by allowing the integration of design, construction, and operation services. The key to alternative delivery strategies that combine the responsibility for these services is the potential for private financing. "Private sector entities recognize the lack of government funding and understand its implications on their work – fewer projects, increased competition and lower margins. Potential involvement by the private sector is certainly driven by economic motive, but provides an additional source of capital with which to complete additional projects" (Dieterich, 1998).

2.3.8 Legal Constraints

Current statutory regulations and subsequent legal challenges may prevent the use of alternative project delivery methods. The Brooks Act prohibits the selection of design professionals using price as the only selection criteria. In some areas of the Unites States Federal acquisition regulations may exclude design firms from receiving construction awards. " In the case of the Commonwealth of Pennsylvania, the Pennsylvania Law Governing Architects challenges the notion of design professionals not working directly for the owner" (Potter, 1994).

The design community's greatest concern, about the increased public use of alternative delivery strategies, focuses on the potential emphasis on low cost to the detriment of the proposers' technical qualifications. However, public procuring agencies control the weight given to different evaluation criteria and can give further emphasis to technical considerations.

2.4 Project Delivery Phases

In some fashion, all project delivery systems address the definition of scope; contractual requirements, obligations, and responsibilities of the parties; interrelationships among the participants; mechanisms for managing time, cost, safety, and quality; forms of agreement and documentation of activity; and the actual execution of design and construction. The project configuration process identifies the necessary principles and practices to successfully manage the entire project. Therefore, it is useful to establish the lifecycle phases that follow the configuration phase.

Strategy

The phases, which describe the lifecycle of a project, generally fall into broadly consistent groups of activities. However, the timing and degree of emphasis on each phase, or group of activities, will vary from project to project. The number of phases selected should vary with the owner's desired level of control. More phases will increase the need for specific, well-defined tasks; provide more review and quality checkpoints; and allow for incremental development and management of cost, schedule, and quality.

To facilitate the discussion concerning the extent of owner participation throughout the project's lifecycle, six main phases have been selected to describe the project development process. These phases include:

1. Project Configuration
2. Procurement
3. Design Development and Engineering
4. Construction Execution
5. Start-up
6. Operations and Maintenance

Although the six groups of activities inherently contain a basic chronological order, there is generally a significant degree of overlap with the extent dependent on the project delivery strategy selected. For example it is obvious that the project configuration phase must begin before the remaining phases, although a standard level of project development during this phase before proceeding to the following phases has not been established. Based on the degree of overlap desired or permitted, alternative contracting and organizational relationships are available to achieve the owner's objectives concerning time, cost, and/or quality.

Project Configuration

The first phase of the project lifecycle, project configuration, establishes the key concepts for the phases to follow. It is important for an owner to recognize that the success of the project is essentially determined by the proper execution of the planning activities that are part of this phase.

Long before an owner considers issues regarding procurement, detailed design, or construction the conceptual analyses, technical and economic constraints, and the social and environmental impacts must be determined and evaluated. Estimates that attempt to demonstrate the current and future demand for the infrastructure project must be completed during this initial phase. The analyses attempt to address the social, environmental, and economic impact of constructing or not constructing the piece of infrastructure under consideration. Once the project need and feasibility requirements have been satisfied project planning and management should become the owner's focus. The major project configuration activities typically include the identification of project objectives, project scope, and project drivers; obtaining environmental/permit approval;

the selection of a contracting strategy; and the initiation of a project management strategy.

Depending on the owner's degree of knowledge and expertise the owner either completes the activities during this phase alone or with the assistance of consultants who are knowledgeable in the required fields. The owner can take advantage of the experience provided by architect/engineer consultants, design-constructors, professional construction managers, or program managers to complete these initial activities.

Procurement

Procurement is divided into two main activities, contract procurement and purchasing. Contract procurement, typically performed by the owner and/or construction manager, requires obtaining contracts for labor and services. Contractors and occasionally the owner will purchase the equipment, materials, and supplies required for construction and operations.

There are multiple project delivery options available to an owner. These strategies combine design, construction, and operation services with either direct or indirect financing in different ways. Most owners have the opportunity to select the project delivery strategy that has the greatest potential to meet their objectives and deliver a successful project. However, Federal, state and local governments have chosen to rely on the design-bid-build method of project delivery over the past few decades.

The procurement of materials and equipment is typically the responsibility of the contractor and is executed throughout the construction phase. In combined delivery strategies where construction and design overlap the procurement of major equipment and materials can proceed incrementally as the design develops. If it is known in advance that certain materials or equipment will require a long lead time an owner may want to purchase these items before a contractor is selected to reduce the overall project duration.

Design Development and Engineering

Architects and design engineers have typically completed the engineering and design phase. Owners are now trying to incorporate the expertise of contractors and operations personnel into the preliminary and detailed design processes. A pre-defined project configuration and management process will help achieve consistent and effective participation of contractors and operators in the design process as each party will understand their role up-front. The designers will also understand the nature and timing associated with contractor and operator participation.

Preliminary design results in a preliminary set of plans and specifications that are subject to review and serve as the starting point for the detailed engineering and design process. The complexity of the project will determine the need for specialty consultants. The detailed review process can vary depending on the project. Regulatory bodies are increasingly being included in the review process to determine compliance with zoning regulations, building codes, licensing procedures, safety standards, environmental impact, etc. Constructibility is an issue that must be considered throughout the design and construction phases. The decisions made during this phase establish the physical arrangement of the project, therefore constructibility must serve as a test against which each design decision is evaluated.

The process of detailed engineering and design results in a set of explicit drawings and specifications that indicate how to perform the construction activities. These drawings and specifications are developed by breaking down the preliminary designs in a manner that is consistent with the scope of work statement through a work breakdown structure that meets known design, engineering, and safety standards.

Construction

During the construction phase the contractor executes the construction activities guided by the schedule and workplan to convert the designer's plans and specifications into physical structures. The owner's efforts during this phase are generally focused on monitoring progress, managing change, and updating schedules. In order to perform the construction activities in an efficient manner, contractors typically use construction management practices to control resources, cost, and time. The construction management workplan involves the organization and coordination of labor, materials, equipment, money, and time to complete the project on schedule, within budget, and according to the quality standards established by the owner and designer. The sequencing of construction will be initially planned to reflect the most logical and cost-effective approach that satisfies the project start-up and completion dates.

The value of having a pre-defined and stable project management system will reduce the amount of uncertainty in contractors bids or proposals and will allow them to better understand and fulfill the owner's needs.

Start-up

From the owner's viewpoint, start-up is the process of verifying the project is in complete and correct operation, and verifying that it is in compliance with the contract documents. As a project nears completion installed systems are tested to confirm their proper operation. It is essential that electrical, mechanical, and structural systems meet or exceed their performance standards and are properly integrated. The intention of the start-up phase is not limited solely to the testing of systems but includes the adjusting and correcting of these systems so that they perform at their optimum level. The tests should evaluate the performance of these systems under extreme as well as normal operating conditions.

Operations and Maintenance

The project's value and the majority of the cost are realized during this phase. Most large infrastructure projects will have an estimated operational life of 50 years or more. Although annual operations and maintenance costs may only represent a fraction of design and construction costs, over time the O & M costs become more significant.

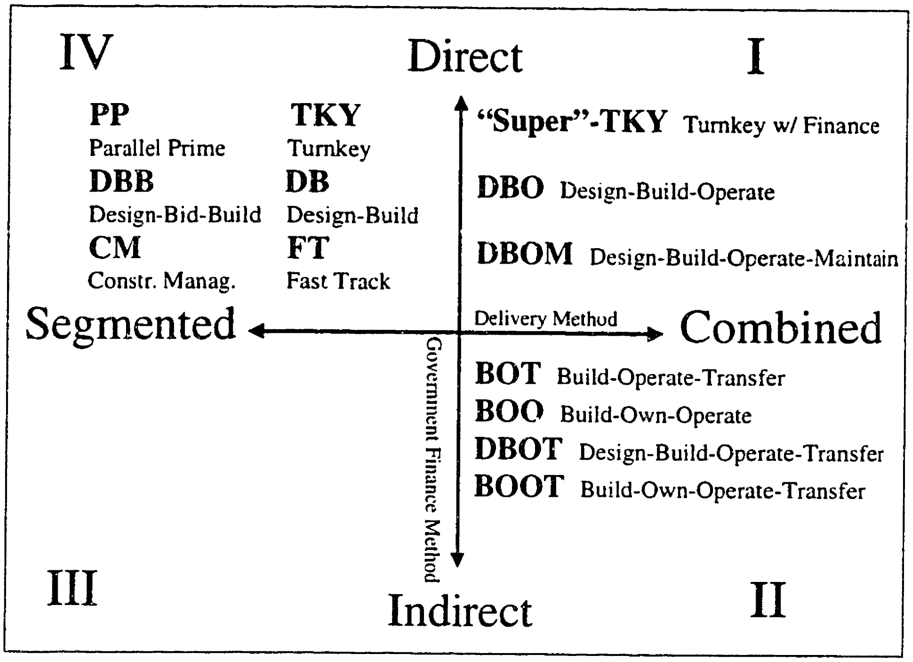
The functional or utilization value of a facility is essentially determined by decisions made during the project configuration and the design development and engineering phases. Today many owners are trying to incorporate the experience and expertise of contractors and operations personnel into the design process to achieve more efficient facilities over lifecycle time periods.

2.5 Open Project Delivery System

The public project delivery system, recommended by Professor John Miller at MIT, seeks a new role for government in the pursuit of a sustainable strategy. The government needs to be actively involved in the identification of public infrastructure needs and provide for long-term development. How each individual project will be delivered is considered separate and distinct from the government's support for each project.

Any new strategy must allow project delivery to be a variable that can be appropriately chosen to satisfy the current need in the most efficient manner possible. Treatment of project delivery as variable will increase the options available to the owner and will enhance the owner's control over project development throughout the remaining phases. The combined use of design-bid-build, design-build, design-build-operate, build-operate-transfer, and other variations will provide public owners the best potential value in terms of infrastructure quality, level of service, and development of technology. The framework shown in Figure 2-2, developed by Professor John Miller at MIT, compares the various procurement strategies in a quadrant framework. The quadrants provide a quick analysis of each strategy relative to the level of phase segmentation and source of financing. The project delivery method could range from an entirely segmented process, where each service is provided by a separate entity, to a completely integrated approach, where all services are provided by a single entity. The financing mechanism ranges from direct, where the project is completely financed through public sources, to indirect, where the project is financed by external sources.

Figure 2-2 Quadrant Framework Analysis



Public owners will need to shift their approach to infrastructure delivery to a portfolio view, which includes all viable projects and allows for the use of any project delivery method. "Principled, transparent management of this portfolio – in ways which encourage competitive private sector participation across all delivery methods, treats participants fairly, and commands widespread public support – is the single most important problem facing legislators and regulators interested in establishing sustainable procurement strategies for constantly improving the configuration and performance of the public infrastructure portfolio" (Miller, 1997a). The intent is to welcome innovation, attract both public support and private sector capital investment, and provide high quality infrastructure services at reasonable initial and long-term costs (Miller, 1997a.)

Although private sector participation is essential to a sustainable strategy, it is important to recognize that the government is well suited to perform many of the functions associated with infrastructure development. The government is in the unique position to ensure the protection of the environment, establish permitting requirements, and provide services that cannot financially support themselves. Government effort in identifying public need, clearly defining project scope, and conducting a fair competitive delivery process will ensure the government obtains the greatest value from public funds.

2.6 New Project Planning Strategy

Current industry practices, statutes and regulations, legal precedents, and industry structure support the use of the segmented design-bid-build project delivery strategy. Requirements for the implementation of design-bid-build are standardized through the Model Procurement Code, which most states have adopted. Recent government "experiments" or "demonstrations" attempting to implement alternative project delivery strategies have shown anything but standard requirements or procedures, executed by the government, prior to a project's release into the private sector. These applications of alternative delivery methods have confused the role of government in infrastructure planning. Many of the ineffective or unsuccessful projects have been proposed and developed by private interest groups. Therefore, the delivery of public infrastructure in America; with Federal, state, and local governments as the owner, can be improved by the development of a project configuration process that can be consistently and efficiently applied for any delivery strategy.

The intent of the new project configuration process is shown by the strategic goals in Figure 2-3.

Figure 2-3 Project Configuration Goals

- Fulfill Government Mission
- Determine project drivers
- Check financial viability
- Enhance level of project quality
- Improve cost predictability
- Improve schedule predictability
- Improve definition and allocation of risk
- Align and prioritize objectives - Owner, Designer, Contractor, Operator
- Establish functional performance requirements
- Identify users
- Manage and reduce scope changes
- Maintain team atmosphere and relationships - Partnering/Team Building
- Provide adequate and appropriate staffing
- Provide adequate project control
- Identify socio-economic and environmental impacts

The general objective of any strategy is to meet the public infrastructure need in areas such as water and wastewater; air, land and water transportation; power generation; technology; and quality of the environment. The strategy must allow the government to adequately identify and define the public need, allow for options to meet these needs, clearly indicate government support of selected projects and delivery processes, allow for fair private sector involvement, and encourage the dedication of private sector resources to generate innovation in technology and design, as well as, construction and operation processes. The strategy must allow both the public and the private sectors to contribute in ways that are amenable to their inherent strengths. The public sector can best:

- Identify public need and viable projects
- Align economic and infrastructure strategies
- Establish government commitment to viable projects and delivery processes

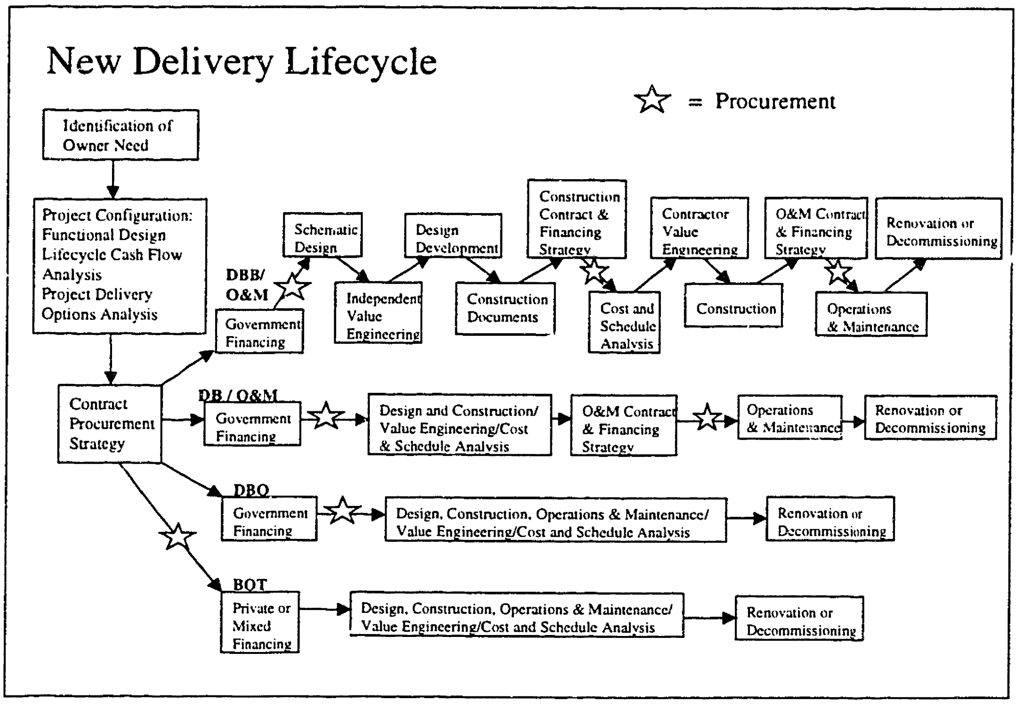
- Provide a fair, competitive environment for private sector participation
- Establish reliable commitments for infrastructure financing

The private sector can best:

- Provide an independent competitive check on the technical and economic viability of projects
- Provide an alternative source of financing
- Develop and introduce innovations in technology, design, construction, and operation processes

These concepts lead to the creation of a new generic project lifecycle, Figure 2-4, that depicts the multiple possibilities for a project's development.

Figure 2-4 New Project Lifecycle



After the government has sufficiently defined, organized, and analyzed the project the private sector becomes involved, and the direction of project development depends on the project delivery strategy that is selected. The open system will create a new market that encourages private sector investment in infrastructure as it allows the private sector to innovate and implement the use of new technology and methods that would allow private firms to effectively compete in this market. Variations of integrated finance, design, construction, and operations will allow the public sector to obtain better service quality for lower costs by introducing competition across project lifecycle time periods.

2.7 Process Development

As stated earlier, the objective of this research is to create a project configuration process based on common strategic planning principles and practices that can be consistently applied by owners. The goal or intention of the process is to provide an owner with strategic methods to obtain information, address risk, and commit resources to maximize the probability of a successful project. Therefore, it is critical that owners personally define what is meant to complete a successful project and then identify project variables that affect the outcome of the project. There are specific project variables that are determined during this initial phase that will affect the outcome of a project. An owner needs to consider how each of these variables will provide the best means to achieve the owner's cost, time, and quality objectives. A few common project variables are shown in Figure 2-5.

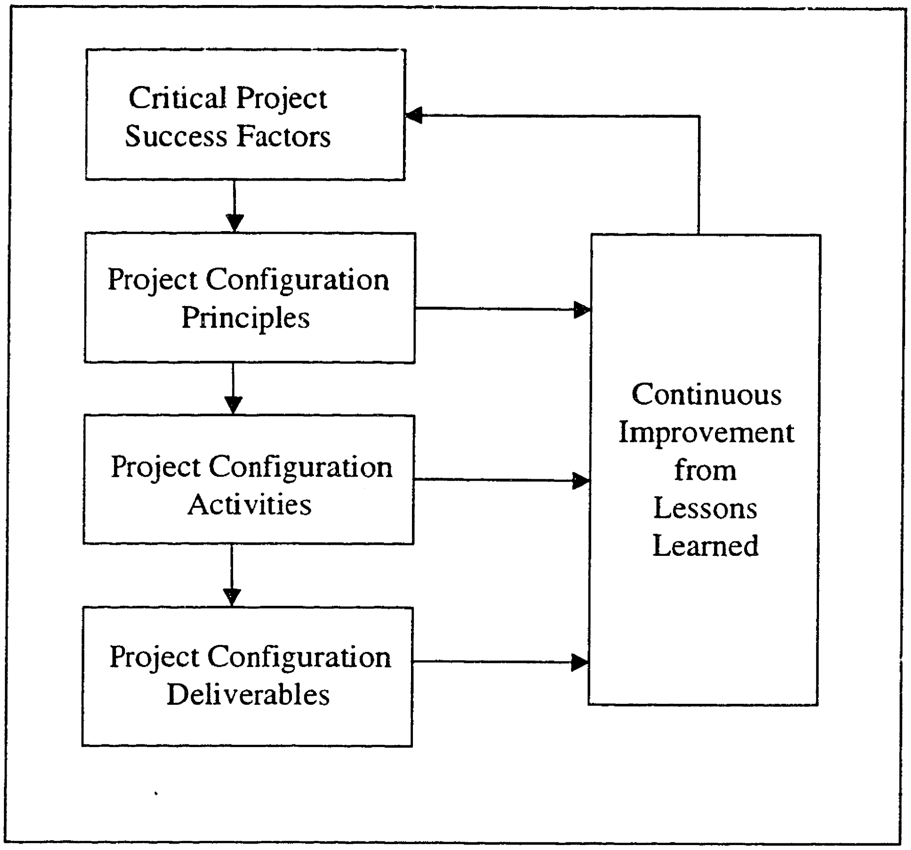
Figure 2-5 Project Variables and CPSFs

Project Variables	Critical Project Success Factors
• How to determine the level of project development and internal alignment, i.e. configuration, to facilitate the various project tasks to follow	• Achieve a level of project development and internal alignment, i.e. configuration, to facilitate the various project tasks to follow
• How to organize an experienced team for the management, planning, design, construction, and operation of the facility	• Organize an experienced team for the management, planning, design, construction, and operation of the facility
• When to introduce project management practices in the project lifecycle to support project configuration	• Introduce project management practices early in the project lifecycle to support project configuration
• How to develop a contract, or series of contracts, that allows and encourages the project participants to work as an integrated team with aligned objectives	• Develop a contract, or series of contracts, that allows and encourages the project participants to work as an integrated team with aligned objectives

These variables are directly associated with Critical Project Success Factors (CPSF) which are considered the starting point for the development of the project configuration process. The direct translation of project variables into CPSFs demonstrates their importance to all projects, but they are still variables because each project is unique and therefore an owner must configure each variable to maximize the probability of a successful project.

The main purpose of process development is to identify and define good project planning and management principles and practices. The development of planning and management resources begins with the CPSFs and ends with project configuration deliverables that are tools used by an owner and project manager to guide the initial development of the project. A secondary effect of the project configuration process is that it attempts to standardize the methods and tools used by project managers to select the staff, organizational structure, contracting strategy; monitor construction execution; and anticipate problems.The development of project configuration deliverables follows the process shown in Figure 2-6.

Figure 2-6 Deliverable Process Diagram



The process is used to clearly indicate the connection between the implementation of project configuration deliverables and project success through the CPSFs. The direct connection between CPSFs and project variables demonstrates how an owner can set the tone for a successful project during the project configuration phase. Although typical project success factors and project configuration principles are identified in this paper, it is important that an owner understand the deliverable process diagram in order to improve upon the system developed here and to properly configure the planning effort for individual projects. An owner, therefore, must understand the intention of each step.

Critical Project Success Factors – Are elements that an owner has identified as critical to the success of the project and that can be influenced by the owner's response to configure the associated project variables.

Project Configuration Principles – Good project management principles or concepts that lead an owner to define project needs and that can be associated with CPSFs.

Project Configuration Activities – Useful owner activities that stem from project configuration principles and lead to the development of project resources, referred to as project configuration deliverables, that promote the delivery of a successful project.

Project Configuration Deliverables – Resources or tools that an owner and project manager can implement to promote the delivery of a successful project.

Continuous Improvement from Lessons Learned – Continuous improvement and refinement of each stage allows the project configuration process to evolve with the changing needs of the owner.

The last stage is essential to the development of a project configuration process that is useful to an owner. It is very important that owners evaluate the effectiveness of project configuration activities and the use of project configuration deliverables to incorporate the lessons learned into the planning efforts of future projects. Only through continuous refinement and improvement can an owner obtain the greatest benefit from the project configuration process and consistently produce successful projects.

2.8 Process Application

The project configuration process developed here is intended to provide owners with consistent project planning practices that will serve any of the available project delivery strategies. The consistent application of the project configuration deliverable process by an owner will help identify useful project configuration methods and activities that address problems identified through the owner's experience and the continuous improvement process element.

2.9 Process Evaluation

The evaluation of the project configuration process, once a project is complete, is an essential element behind the intention to obtain the greatest benefit from an owner's project planning activities. The evaluation must address both the ideology behind project planning expectations and the owner's implementation of project configuration deliverables. The ideology behind project planning refers to the determination of project configuration activities that can be best fulfilled through an owner's efforts. The evaluation of the appropriateness of an owner's project configuration scope is restricted to qualitative criteria. The main criteria are whether the project configuration efforts can be associated with the successful outcome of the project and whether the efforts are appropriately allocated within the owner's scope. The research presented in this paper provides a description of multiple project configuration deliverables and suggests how these deliverables can be useful to an owner. An owner's implementation of project configuration deliverables can be evaluated by their contribution to developing positive relationships between project team members and/or to the completion of a successful project.

2.10 Process Improvement

It is very important that owners evaluate the effectiveness of project configuration activities and incorporate the lessons learned into the planning efforts of future projects. Time, financial, and personnel resources are always limited, therefore, it is essential that an owner determine how planning efforts relate to the outcome of the project. Project configuration methods and principles that prove to enhance the outcome of the project must be incorporated into a long-term strategic project configuration process. Only through continuous refinement and improvement can an owner obtain the greatest benefit from the project configuration process.

3 Project Configuration Process

3.1 Scope and Intended Use

Construction is particularly management intensive because of the large number of decisions resulting from factors such as the advanced determination of contract prices, the coordination of multiple stakeholders, the need for complex communication systems, the constant need to reassess risk and the uniqueness of individual projects.

The intent of the research is to identify common strategic planning principles and practices in order to develop a project configuration process that assists owners in making decisions regarding objectives, scope, delivery strategy, management methods, risk allocation, and resource availability. The project configuration process and recommendations provided are intended to improve the planning process and begin to establish uniform standards which can be used by public owners for the mutual benefit of owners and the design and construction community.

The increasing complexity and protracted time-scale of modern systems design and development have made working to a standardized project management (configuration) system both essential and mandatory. The primary mission of the project management (configuration) process is to establish well-planned, well-administered, and well-disciplined approach to the specification, design, development, manufacture, support, and maintenance of large and complex technical projects (Rigby, 1998).

As a whole the project configuration process developed here is geared toward large infrastructure projects. Typically, the size and complexity of these projects require some form of a planning process because of the number of project participants and the coordination and integration issues involved. The difficulties inherent in public approval processes coupled with the fact the impact of project decisions will be realized for many years increase the need for successful planning. The project configuration process developed in this chapter can serve as a checklist to assist an owner in performing effective project configuration. Although the process was developed for large public projects, the recommendations for each project configuration deliverable are based on the construction industry's "best practices" and can be useful as needed for smaller projects.

3.2 Owner Involvement

This section addresses the development of a project configuration and management process and suggests how owner organizations should become involved in its design, implementation and utilization throughout the life of the project.

Graham, Crandall, Warren, and Mazzini all agree that there must be one central leadership point from which mega-projects are directed and controlled and that this leadership must be established before any project can succeed (Cox, 1983).

Although the level of owner participation throughout the design and construction phases ultimately depends on the capabilities of the owner organization, there are certain activities that should not be delegated. Owners must identify the project need, determine project objectives and scope, secure necessary financing, and select a contracting strategy. Owners should address constructibility and participate in the development of the project management workplan which includes the constructibility, risk management, project control, change management, quality management, safety, dispute prevention and resolution, and data management programs; as well as the development of the design and the monitoring of construction.

Recent evaluations of large-scale projects indicate that they often exceed the existing management capabilities of owner organizations, their consultants and the construction industry in general (Crandall, 1983). One contributing factor is the extent of preplanning required to establish a viable control environment. Owners must be willing to invest the necessary funding and wait until the control environment is established before initiating these mega-projects (Crandall, 1983).

In order to maximize the benefit of treating project delivery as a variable an owner must:

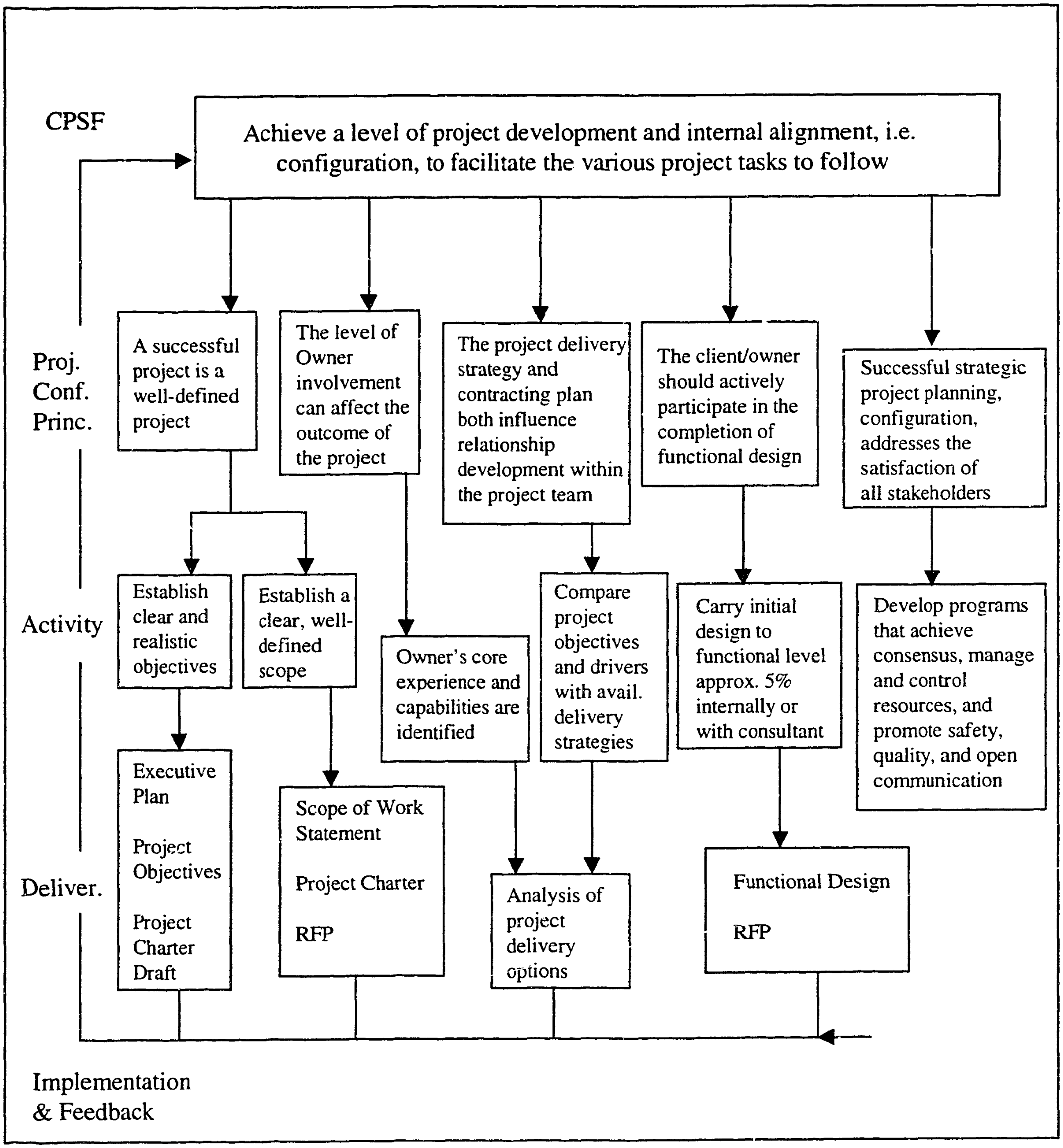
- Understand the advantages and disadvantages of the available delivery strategies
- Be able to estimate the value of the project – budget, lifecycle cost, franchise value
- Understand the competitive market
- Clearly define project objectives
- Clearly define the project drivers
- Create a team atmosphere
- Encourage communication within the project team
- Clearly indicate and delegate responsibility
- Clearly define documentation and performance expectations
- Initiate the development of essential control programs

3.3 Process Development

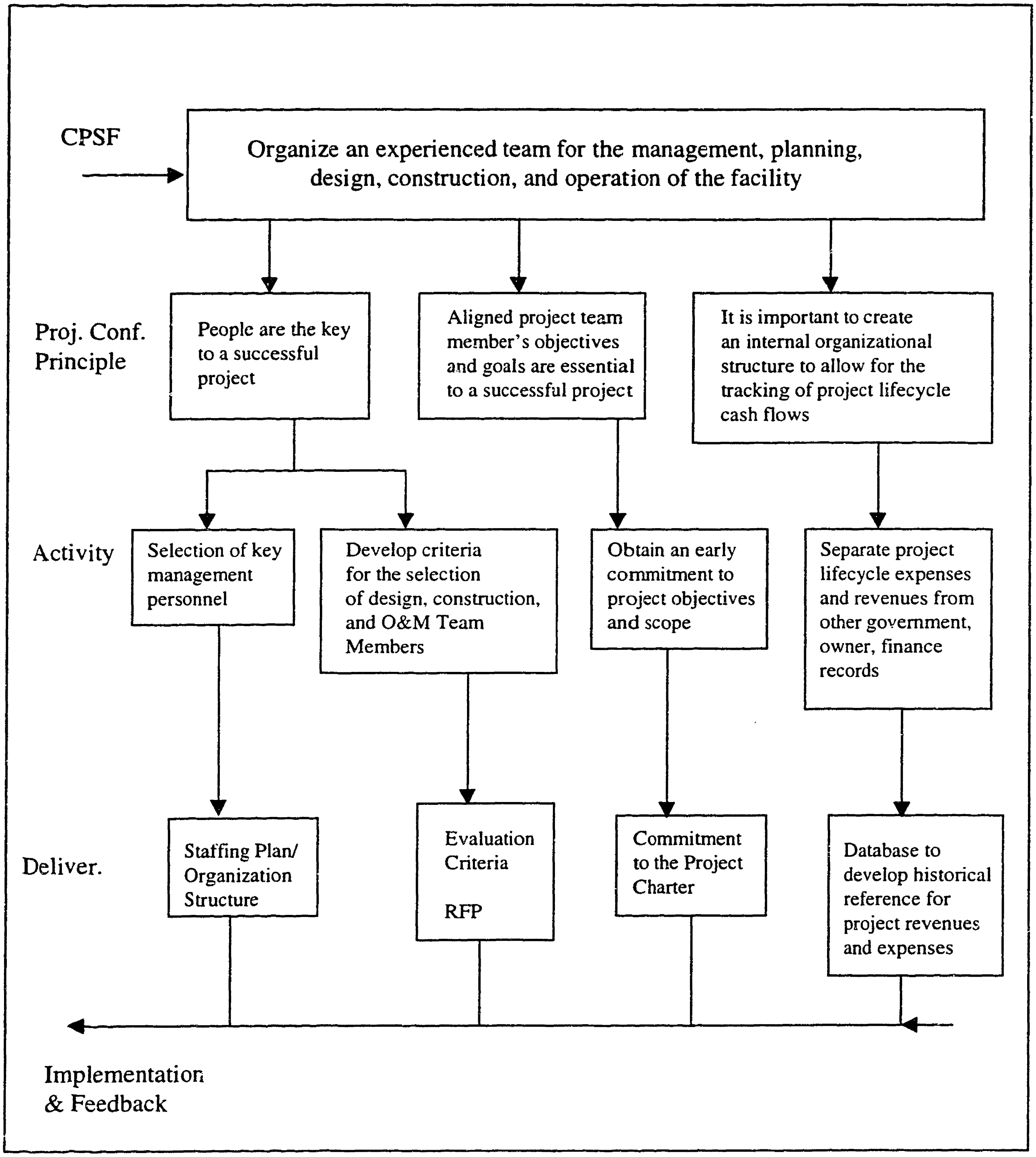
As stated earlier, the development of planning and management resources begins with the CPSFs and ends with project configuration deliverables that can be used by an owner to guide the initial development of the project.

The following process diagrams 3-1, 3-2, 3-3 and 3-4 demonstrate the connection between project configuration deliverables and CPSFs.

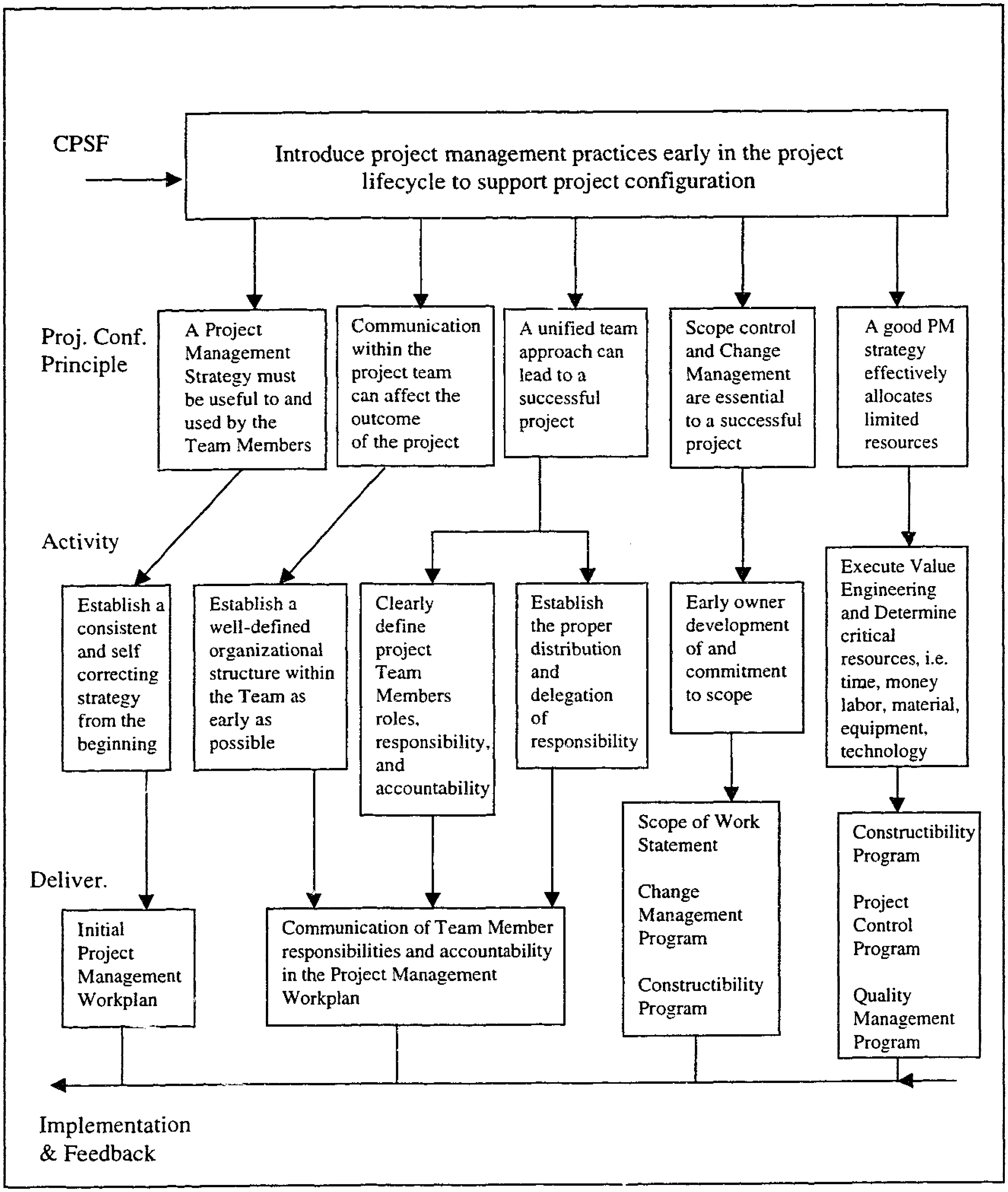
Process Diagram 3-1 CPSF - 1



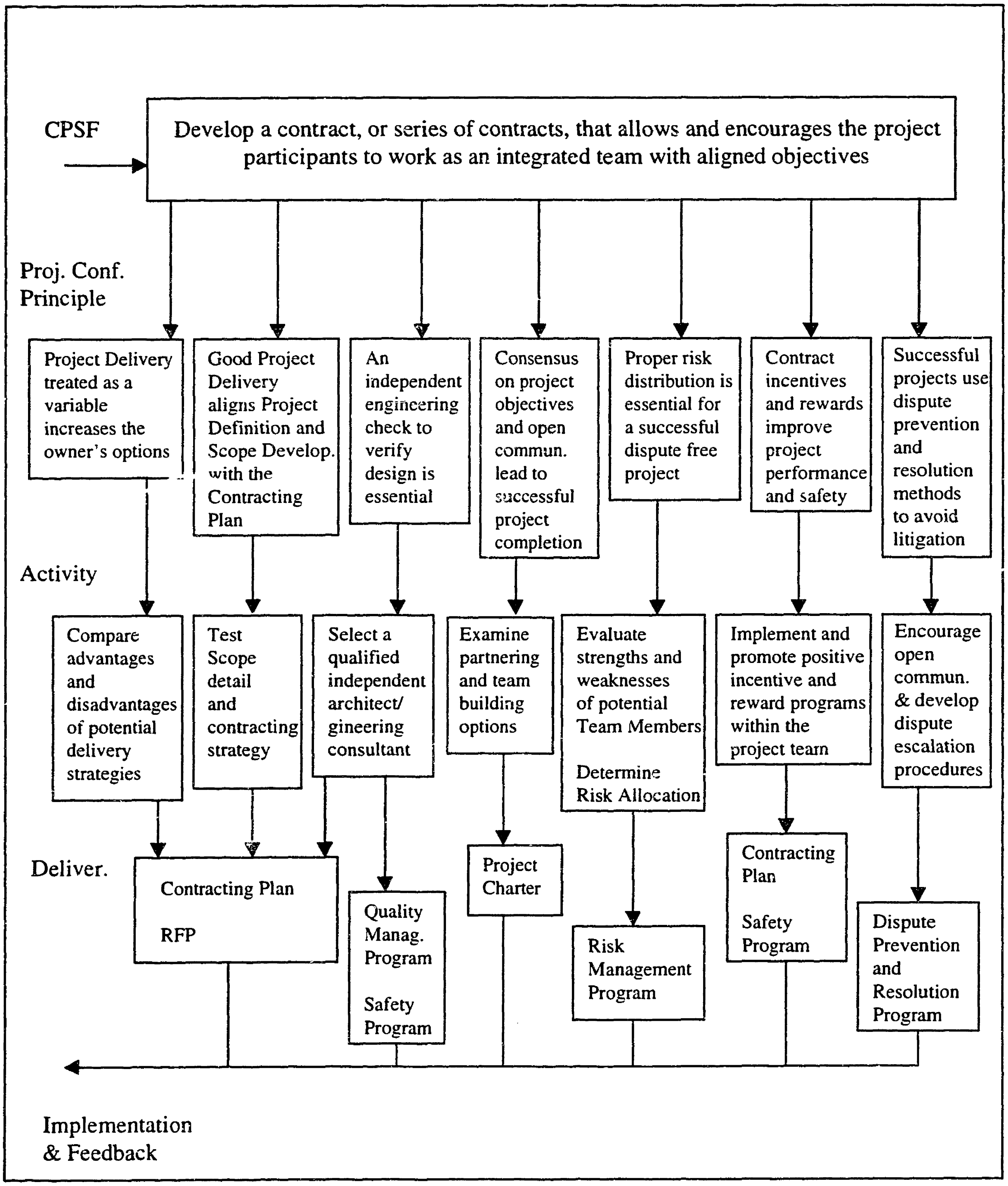
Process Diagram 3-2 CPSF - 2



Process Diagram 3-3 CPSF - 3

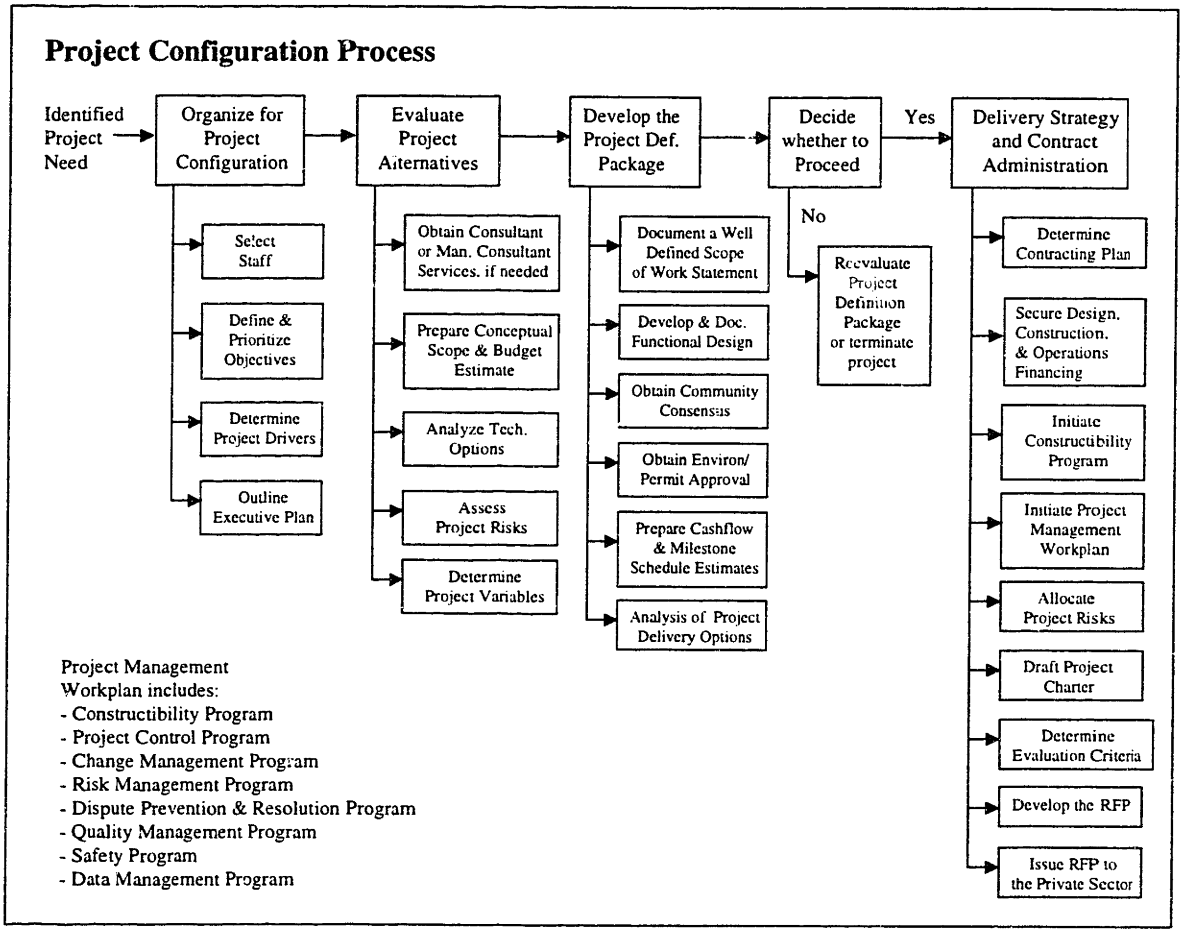


Process Diagram 3-4 CPSF - 4



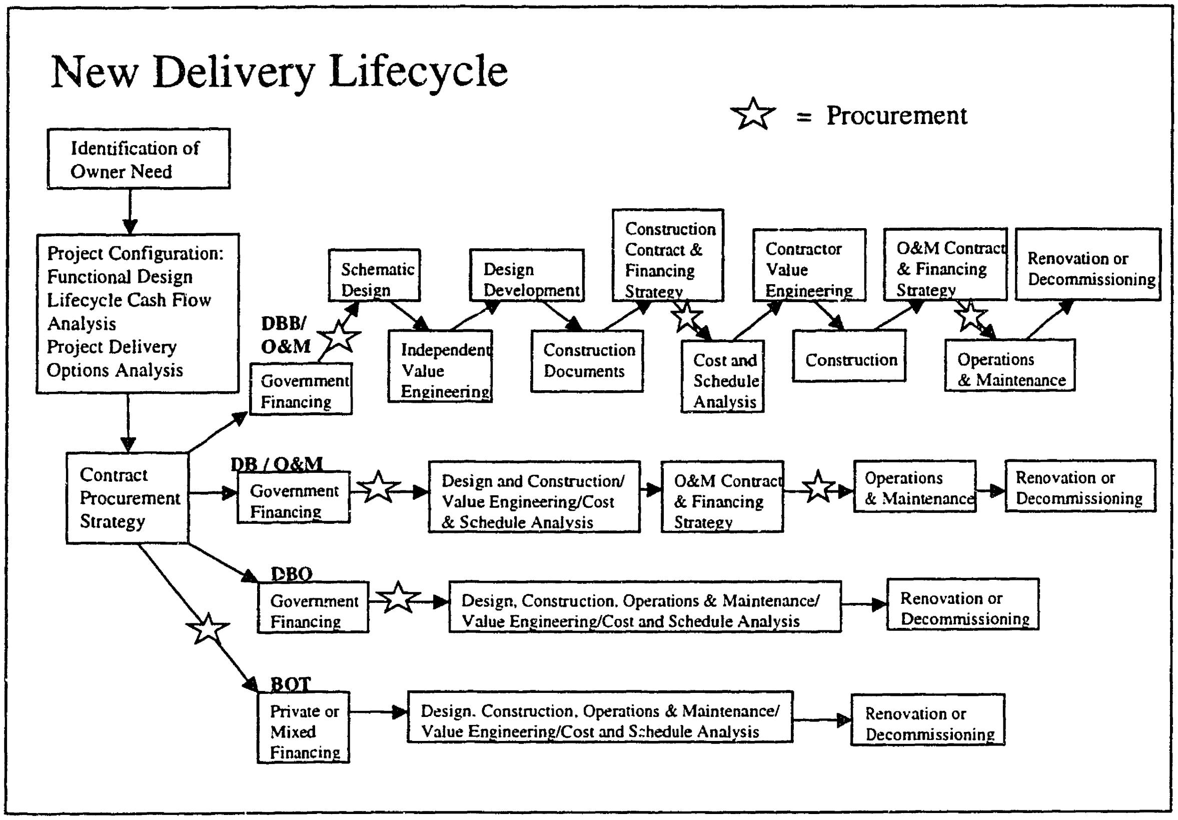
The process diagrams support the development and application of project configuration deliverables by illustrating the relationships between project management principles, activities, and deliverables. Just as important as the identification of planning tools, is the order which an owner should utilize these tools. The project configuration process generated from the deliverable process diagrams is shown in Process Diagram 3-5.

Process Diagram 3-5 Project Configuration Process



The Project Configuration Process supports the new project lifecycle, Figure 3-1, that depicts the multiple possibilities for a project's development. An owner must consider the project's objectives, advance the design to the functional (5-10%) level in order to complete a conceptual budget and lifecycle cash flow analysis, obtain the required environmental and permit approvals, and analyze the characteristics of the project against the advantages and disadvantages of each delivery method in order to select the most appropriate strategy. These activities are ongoing until the project has achieved satisfactory scope development, environmental and permit approval, public consensus, and a viable delivery strategy. Once the public owner has advanced the project to this stage, project development will follow the path of the chosen delivery strategy.

Figure 3-1 New Project Lifecycle



The project configuration process suggests the use of specific project configuration deliverables that can enhance the potential for an owner to deliver a successful project. Many of these project configuration deliverables are already completed by owners, such as the determination of project objectives and the selection of a project delivery strategy. However project configuration deliverables such as a project charter, functional design, and financing/cashflow analysis require project planning actions by an owner that are not always performed by owners. Therefore, it may be argued that either the project configuration expectations for owners are too high or that the project configuration process suggested here may improperly allocate configuration activities to the owner, for others may perform these tasks better and more efficiently. However, the project configuration process presented here suggests that the owner will be responsible for completing some of the activities and will only be responsible for expressing the intent behind others. Certain project configuration deliverables are a work in progress as the project team is solidified. Table 3-1 shows which project configuration deliverables are completed by the owner prior to private sector participation as well as those that require the involvement of designers, contractors, and operators.

Table 3-1 Project Configuration Deliverables

	Owner
Executive Plan	I
Project Objectives	C
Staffing Plan/Organizational Structure	C
Project Charter	I
Scope of Work Statement	C
Functional Design	C
Financing/Cashflow Analysis	C
Analysis of Project Delivery Options	C
Evaluation Criteria	C
Project Management Workplan	I
Constructbility Program	I
Project Control Program	I
Change Management Program	I
Risk Management Program	I
Dispute Prevention & Resolution Program	C
Quality Management Program	I
Safety Program	I
Data Management Program	I
Contracting Plan	C
RFP	C

C = Complete Development
I = Initial Development

The intent of the project configuration deliverables will be expressed in a separate monograph dedicated to each deliverable in Chapter 4. Each monograph will describe common concepts regarding the deliverable and will provide suggestions for its development.

4 Project Configuration Deliverables

4.1 Monographs

The intent of the project configuration deliverables, shown in Table 3-1, are expressed in a monograph dedicated to each deliverable. The monograph is a short text on a single topic that describes why the topic is important and what it contributes to successful project delivery. Each monograph will describe common concepts regarding the project control programs and will provide suggestions for their development.

The project configuration deliverables are organized into three groups, Organizing for Project Configuration, the Project Definition Package, and the Project Delivery Package.

4.2 Organizing for Project Configuration

4.2.1 Executive Plan

In may be useful for an owner to express the project objectives, scope, contracting plan, and organizational structure in a summary document. An executive plan should allow those unfamiliar with the project to obtain a general understanding of the objectives and the project participants.

The executive plan is intended to standardize the initiation of each project and shall be maintained throughout the duration of a project to provide an executive view of the entire project. The plan shall identify the owner's objectives and shall outline the staffing plan and organizational structure for the project.

The executive plan will allow an individual unfamiliar with the project to understand the purpose and objectives of the project, the primary business parties and individuals involved, and where to locate any appropriate reference documents for additional information.

Project Configuration Recommendations and Conclusions

- An outline of an example Executive Plan, modified from an example Program Plan developed by Rigby is provided in Appendix A.

4.2.2 Project Objectives

The owner must solely determine the project objectives. The project objectives will be used to help select a contracting strategy, organizational structure, and determine the need for management programs.

A basic element of project configuration and planning is the determination of project objectives. The objectives must be measurable, define a definite end to the project, and address any assumptions about and constraints on the project. To prevent problems during design and construction it is important that everyone understands and agrees to the definition of the project objectives.

The project objectives will help guide the multitude of decisions required for the completion of a project. These decisions will involve tradeoffs between time, cost, quality, and other technical, aesthetic, and operational performance characteristics. Project objectives generally originate from within the owner's internal organization, which often includes engineering, operating, marketing, and financing personnel.

Typical owner objectives often include minimizing total project cost, meeting schedule dates, avoiding accidents and injuries, and meeting quality requirements. Contractors on the other hand generally focus on obtaining a satisfactory profit margin. However, the contractors profit motive can be used to improve productivity, quality and safety through contract incentives.

Project Configuration Recommendations and Conclusions

The identification of project drivers help an owner formulate the objectives for the project. Christopher Gordon suggests an owner consider the following potential project drivers (Gordon, 1994).

- Time Constraints – Owners must determine whether it is beneficial to complete the project in a normal, sequential fashion, or if a fast-track schedule is needed.
- Flexibility Needs – Owners must recognize the potential for changes and determine the flexibility required to manage change during the construction process. Some owners are unable to make construction documents final because of indecisiveness, permit requirements, market fluctuations, time constraints, or unknown site conditions.
- Pre-construction Service Needs – The owner must decide the value of pre-construction services performed by a contractor or construction manager, such as cost estimates, constructibility advice, or value engineering.
- Design Process Interaction – The Owner must determine their desired or needed level of involvement with the design professional throughout the design process.
- Financial Constraints – The owner must determine the most efficient way to finance the project, short-term and long-term by either the owner or contractor.
- Construction Sophistication – The owner must realistically assess the level of construction knowledge and expertise within the owner organization and determine what external advice will be needed.
- Current Capabilities – The owner must compare the required administrative, monitoring, and/or management staff with the personnel that are available for the project.
- Risk Aversion – The owner must assess the organization's tolerance for financial and project risk.

It is important to remember the owner is responsible for determining project objectives regardless of how many outside parties are contracted with for the planning, design, construction, and operation of the project. The process through which these objectives are formulated, communicated, and integrated is essential to effective project planning.

4.2.3 Staffing Plan/Organizational Structure

The owner must select the appropriate in-house staff to manage the project. The owner either solely or with the assistance of consultants or a construction manager must develop the organizational structure for the entire project.

Organizational Structure

An organizational structure for a company or project often takes one of four forms – a functional organization, project task force organization, line and staff organization, or a matrix organization. The purpose of an organizational structure is to define and promote an orderly communication network. In construction, matrix organizations are often used successfully as they provide project or task specific management with the support of general administrative or functional personnel.

Matrix organizations can be either strong or weak. A weak matrix gives the functional departments more authority than the project manager, while a strong matrix gives the most authority to project management, as they are responsible for delivering a technically sound project that meets cost and schedule restrictions. In construction, a strong matrix generally builds a stronger team approach, keeps projects objectives focused, and facilitates timely and efficient communication channels by placing team members in the same locale.

Project Executive

The project executive is the owner's principal in charge for the project's support, development, and execution. The majority of the project executive's participation is during the project configuration process. The individual must define and support the project objectives, develop the scope and functional design, secure the needed financing, select a delivery strategy, and select the project team. Once project configuration is complete the project executive's participation shifts from direct involvement to ensuring the project's financial and functional status.

Project Manager

The importance of the project manager position is well recognized within the construction industry. Project success is closely correlated to the technical and managerial abilities of the project manager. This is not a direct relationship, however, as it is tied to the implementation of sound management practices. In addition to the necessary technical skills a project manager must possess leadership skills, interpersonal skills, and administrative experience. Effective leadership will ensure the proper application of project management principles. Interpersonal skills will help develop the project team into an effective decision making body that is capable of directing the progress of the project. Administrative experience incorporates both planning and organizational skills required to coordinate the efforts of the project team.

The project manager is a leader and manger. The project manger must lead the project team and manage resources. Leadership of the project team involves preserving, protecting, and improving the productive capability of people, the most valuable resource available to the project manager. The position requires interpersonal, management, and business skills. Management skills provide the basis for overseeing the technical and administrative details of the project and its performance. A project manager's work demands coordination and integration of activities on the part of many individuals, therefore interpersonal skills are essential for effective project management.

The project manager must be trained in the implementation of the project delivery process and be capable to lead and manage the project. The project manager's primary responsibility is to ensure that the project meets the established technical and financial objectives.

Project Team

The project team can include owner, designer, contractor, and operator personnel. As a rule, the development of a good project team, informing team members, and clearly defining responsibilities are more important than direct day-to-day oversight of individual tasks. The project team should be comprised of skilled and experienced members who can respond to the overall financial and project objectives. The project team provides critical input from business, project management, technical services, and operations. The project team needs to define and prioritize its objectives, project scope, role, and responsibilities that give the team clarity of purpose. Useful questions to ask are:

- Is there open and honest communication?
- Is there mutual respect and trust?
- Is there a shared vision for the project?
- Are the project objectives clear and understood?
- Are roles, responsibility, and accountability well defined?
- Are the benefits as well as risks properly shared?
- Is there a commitment to improving relationships within the team?
- Is there an effective conflict resolution process?

Good relationships between the owner's project manger, the contractor's project manager, and the design professional are the result of all parties understanding and agreeing to the project objectives and the project team structure. It is generally useful to formalize this structure through a contractual agreement such a project charter. The responsibilities within the project team must be clear and each party must act with integrity, strive for open communication, and treat one another with respect and common courtesy.

Project Configuration Recommendations and Conclusions

- The owner's project manager and team members have a critical influence on the success of the project (Jaselskis and Ashley, 1991) (Radtke and Russell, 1993).

- Choice of the management organizational structure will depend on factors such as size, content, complexity, and distribution of the project. It is important to remember that the success of any organization is a function of the capabilities of the individuals rather than the way in which they are organized. Talented personnel will perform well in most organizational structures and even better in a good organization. However, poor talent will always do an inferior job irrespective of how the organization is structured (Rigby, 1998).

- Organizations perform best when information flows freely and rapidly therefore strong communication, clear management lines, and standard, timely reporting methods are essential.

- Identify the owner's capabilities and the available company personnel to execute the project. After the owner's capabilities and needs are determined services from consultants, designers, engineers, project managers, and/or contractors can be obtained.

- According to a 1996 study by Michael Magnano, CSI, in which he conducted interviews with 54 project leaders, project team communication was identified as the single most important factor in the success of projects, followed by the commitment of the owner's and contractor's project manager (Magnano, 1998).

- The owner's project manager must be able to lead the project team in the following four areas: 1) Establish a supportive project environment; 2) develop a commitment to increased cost-effectiveness; 3) use constructibility to facilitate achieving project objectives; and 4) involve construction personnel (Radtke and Russell, 1993).

- Typical criteria for the selection of the owner's key team members may include: 1) Project experience; 2) Construction knowledge; 3) Communication skills; 4) Teamwork skills; 5) Skill to objectively evaluate design and construction trade-offs; and 6) Receptiveness to new ideas (Radtke and Russell, 1993).

4.3 Project Definition Package

4.3.1 Scope of Work Statement

The owner either solely or with the assistance of consultants or an A/E develops the scope of work statement for a project. The scope of work statement is a description of the owner's intentions designed to help direct and control design development.

The scope of work statement includes both the project objectives and a description of the scope. The objectives describe the results to be achieved once the project is complete. The objectives must be realistic, attainable, specific, and measurable. The scope is a description of the work that will need to be done to achieve the objectives. It clearly defines the tasks associated with the project and the deliverables that will result from their completion. Improved scope definition typically leads to better budget estimates as the understanding of the project tasks is increased.

The preliminary scope of work statement is intended to communicate objectives and guide future design development. The scale, technical, and operational intent of the project are typically identified. The preliminary scope of work statement is typically broad enough to allow significant latitude of interpretation. As a stand-alone document it is not intended to provide a level of detail necessary to control the work. In conjunction with the owner furnished functional design, the preliminary scope of work statement provides the private sector the knowledge of the owner's objectives and expectations.

The scope of work statement defines the breadth and limitations of the work but does not include specification requirements, descriptions of products, or directions to the contractor on how to perform tasks. Once the construction documents are approved and available, comprehensive scope definition for the control level is available and will define the requirements for project deliverables and services to be performed.

In a study on scope definition and control, conducted by CII, it was found that poor scope definition at the estimate stage and loss of control of the project scope rank as the most frequent contributing factors to cost overruns (Neil, 1986). "The relationship between poor scope definition and the propensity for creeping scope and changes within scope is quite clear – a poorly defined scope does not provide a clear baseline against which changes can be evaluated as being either changes within or outside of the scope" (Neil, 1986).

Although inadequate scope definition is typically due to insufficient planning and management, it is important to acknowledge the fact that each project is unique and the fulfillment of project drivers and objectives may preclude full scope development before proceeding with design and construction. The study by CII identified some common explanations for why an owner may proceed in spite of inadequate scope definition (Neil, 1986).

- An owner does not have the engineering expertise to provide a complete conceptual definition
- If the initial order-of-magnitude (feasibility) estimate looks favorable, there is no reason to spend additional funds on scope definition
- If time is a project driver then owners want to spend less time on project planning
- If cost is a project driver then owners want to spend less money on project planning
- Market pressures make project durations critical and many owners contend that further scope definition would add up to 25 percent to the project duration

In many cases the potential profits from operation of the completed facility may outweigh changes in design and construction costs. Therefore reducing the time to obtaining an operable facility dominates the owner's priorities. "Regardless of the reasons, when there is poor scope definition, final project costs can be expected to be higher because of the inevitable changes which disrupt project rhythm, cause rework, increase project time, and lower the productivity and morale of the work force" (Neil, 1986).

Alaska Pipeline Example

Inadequate scope definition, along with regulatory and environmental difficulties, in the development of the Alaska Pipeline project resulted in a rise of total project costs from an estimated $900 million to more than $7 billion. However, in spite of this dramatic increase in design and construction cost the project is considered a success as profits from operations have overshadowed all the cost overruns.

Project Configuration Recommendations and Conclusions

- The only way to reduce the problems associated with poor scope definition is to adopt an organized, efficient philosophy for planning and controlling projects (Neil, 1986).

- According to Rigby a well-written scope of work statement shall (Rigby, 1998):
  - Specify requirements clearly to permit the owner and contractors to estimate probable costs and the contractors to determine the levels of expertise, manpower, and other resources that are needed to accomplish the task
  - State specific duties of the contractors in such a way that each contractor knows what is required and completes all tasks to the satisfaction of the contract
  - Be written so specifically that there is no question of whether the contractor is obligated to perform specific tasks
  - Reference only the minimal specifications and standards pertinent to the task

- According to the AIA and AGC scope of work documents shall include (Widom, 1995):
  - Program statements for the facility that describe space needs, design goals, and objectives
  - Equipment requirements
  - Other pertinent criteria, such as energy use or accommodation for future expansion or adaptation
  - Site information, including a site survey and soil boring report describing subsurface conditions
  - Any minority business enterprise (MBE), women business enterprise (WBE), or disadvantaged business enterprise (DBE) requirements
  - An outline of specifications
  - Budget parameters
  - Project schedule

- The scope of work should be as flexible as possible to elicit creative responses from competitors that may reduce the cost of the project in the short-term and improve life cycle costs in the long-term. A generally stated set of project requirements will allow competing teams to suggest imaginative ways to meet the requirements by combining or reorganizing functional areas or by applying innovative design ideas, construction methods, materials, or systems (Widom, 1995).

4.3.2 Functional Design

The functional design identifies the major elements of the project based on the owner's operational objectives. Owners that participate in the establishment of the functional design increase their control over further design development, total project cost and schedule, and operational performance.

Owner control during the project configuration phase is primarily concerned with the identification of the minimum essential components that will satisfy the required functions. Ideally the project design is brought to a stage of completion necessary to fix the intent of the owner and minimize the risks associated with design, construction, and operation of the facility.

An owner rarely approaches a designer and contractor without providing some information regarding existing conditions, preliminary designs, or design restrictions. This information can take the form of design or performance specifications. Design specifications precisely describe the work the contractor is to accomplish. Performance specifications do not instruct the contractor how to perform the work, but dictate the required performance results.

It is important to consider that there is risk associated with providing design information. Typically an RFP provides 100% "complete" design information, as in design-bid-build, or provides the minimum requirements for the project that are needed to form the basis of a price proposal.

Project Configuration Recommendations and Conclusions

- An owner must be careful about what information is provided and how the risk associated with the accuracy of such information is allocated.
- In terms of liability, contractors are generally required to take all steps reasonably necessary to ascertain the nature and location of the work, and to satisfy themselves as to the general and local conditions affecting the work, however they are not required to conduct costly or time consuming technical investigations.
- Note that when problems result from the contractor's inability to meet the performance criteria when using the design data provided, liability for the design defect is unclear and may ultimately be allocated on the basis of which party had superior knowledge (Sweeny, 1997).
- It is important to consider that a project can tolerate only a certain amount of unproven technology (Halpin, 1983).

4.3.3 Lifecycle Cashflow Analysis

The objective of lifecycle costing analysis is to optimize the total cost of ownership over the life span of an asset (Arditi and Messiha, 1996). Lifecycle cash flow analysis provides an owner with the information to make decisions concerning design and long-term financing. An owner should take advantage of the opportunity to estimate the long-term cost of design alternatives. Value engineering performed by designer(s), contractor(s), and the operator will utilize lifecycle cost analysis during the design and construction phases. Combined, these efforts are intended to provide the best value for the owner's financial commitment.

Financing is perhaps the most important element in the project planning process. The owner must secure specific financing mechanisms in advance to cover the cost of the project. No matter how well the project is planned, designed, constructed, or operated, if it cannot be paid for, it will not be completed (Deiterich, 1998).

Traditionally the approach to cost analysis has considered only first-costs which impact design and construction. Arditi and Messiha identified that the lack of formal guidelines and the difficulty of estimating future costs and incomes as typical reasons why municipalities do not use lifecycle costing analysis (Arditi and Messiha, 1996).

Lifecycle cost analysis requires the analyst to estimate many parameters including future costs, future revenues, the analysis period, the useful life, the discount rate, and inflation rate. Lifecycle cost estimates provide the owner with cost information for design, construction, and operation. An ideal estimate of project development costs not only indicates the total cost for design and construction but indicates the timing of the expenses as well. The knowledge gained from estimating operation costs and potential revenues are very important to ensure the project is financially viable over its entire lifecycle.

After estimating all future cash flows for all the alternatives under consideration, the values are then discounted to a present value and combined with initial present costs to facilitate a direct comparison. Although the purpose of lifecycle cost analysis is to identify a low cost solution, considerations such as delivery time, pollution effects, aesthetic considerations, maintainability, and owner preference, together with other indirect non-economic influences, will temper the hard fast rule of always choosing the system with the lowest LCC (Arditi and Messiha, 1996) (Ahuja and Walsh, 1981).

If the estimates for lifecycle costs are too high, value engineering processes performed by the designer, contractor, and operator have the potential to reduce project costs. Value engineering is an organized effort by the project team to obtain optimum value by providing the necessary function at the lowest life cycle cost. Typical value engineering practices are discussed under the constructibility program.

Functional Estimate

Lifecycle cashflow analysis provides the overall picture using summary information concerning debt, equity, and potential revenues. It is also useful for an owner to identify major cost drivers by completing a functional estimate. The functional estimate allocates costs to the major systems and building components identified in the functional design. During the project configuration phase improved scope definition typically leads to better budget estimates as the understanding of the project tasks is increased. The owner can obtain a functional estimate, accuracy level plus or minus 30 percent, during the project configuration phase. The functional estimate should be constructed by identifying major project systems that divide the project into distinct areas to develop a work breakdown structure. Major activities are identified so that the major equipment and material requirements can be determined. It is assumed that cost, quantity, and dimensional relationships exist between this equipment and other project cost components. The functional estimate will not be adequate for control purposes but will provide a useful estimate of the total project cost. The variability of 30 percent relates only to the total cost and not the individual systems within the project.

Project Configuration Recommendations and Conclusions

- The greatest savings potential for a lifecycle cost analysis occurs in the earliest stages of the project. Not only are the potential savings more significant, but the costs of making changes in the plans and specifications are much less (Arditi and Messiha, 1996) (Dell'Isola and Kirk 1981).

- To operate an LCC program in procurement, specifications should put more emphasis on performance, thus allowing specialist suppliers to submit alternative suggestions to meet the required performance at the lowest total cost (Arditi and Messiha, 1996).

- When performing LCC analysis it is important to consider the effect of using multiple material and equipment suppliers as it may increase maintenance costs.

- Once a contractor has been selected, contract clauses stating the benefits that will accrue to the contractor if further LCC improvements are offered by the contractor during construction will further encourage contractor participation (Arditi and Messiha, 1996).

- For some cost elements, good judgment may be more useful than precise calculations. Good judgment will apply to such elements as interest rates, useful life, and inflation rates. Precision would apply to the elements of energy consumption, operating efficiencies, and total hours of operation (Arditi and Messiha, 1996).

- It is essential to recognize the impact of incorporating new technology and innovations in the design when performing LCC analysis. In these instances, sufficient data in usable form to enable reliable estimates of lifecycle costs are usually unavailable (Arditi and Messiha, 1996) (Novick, 1991).

- It is also possible to use LCC in conjunction with value engineering, this way augmenting the value of both approaches considerably (Arditi and Messiha, 1996) (Barrie and Paulson, 1992).

4.3.4 Analysis of Delivery Options

The identification of the project delivery strategy is an important step of the project configuration process as each strategy may require different levels of project planning and owner involvement. An owner must understand both the advantages and disadvantages of each strategy to properly match the project objectives and resources with the best delivery method. This section provides an overview of the common delivery methods along with a summary of the advantages and disadvantages of each strategy.

Ever increasing owner demands for lower project costs, fewer claims, better quality and improved schedules have applied pressure to utilize innovative construction methods to achieve these objectives. The owner, particularly the public owner, should have the proper latitude and ability to select the most effective contracting method for the specific project at hand (Monti, 1997).

Gordon points out that the choice of contracting method can affect the duration of the project, provide flexibility for changes, reduce adversarial relationships, allow for contractor and/or operator participation in design, provide cost saving incentives to the contractor, or provide alternative financing methods (Gordon, 1994). Too often, an owner uses a particular contracting method simply because it is what they are used to, it appears to be the easiest, or it was suggested by the designer or contractor, when in reality some methods are more suited for certain owners and projects than others (Gordon, 1994).

Private owners have a number of different options available to them in how they procure design, construction, and operations services, which will, in turn, affect who performs the various tasks. While public owners have traditionally relied on the design-bid-build method for delivering projects, in the last decade the government has experimented with other project delivery strategies.

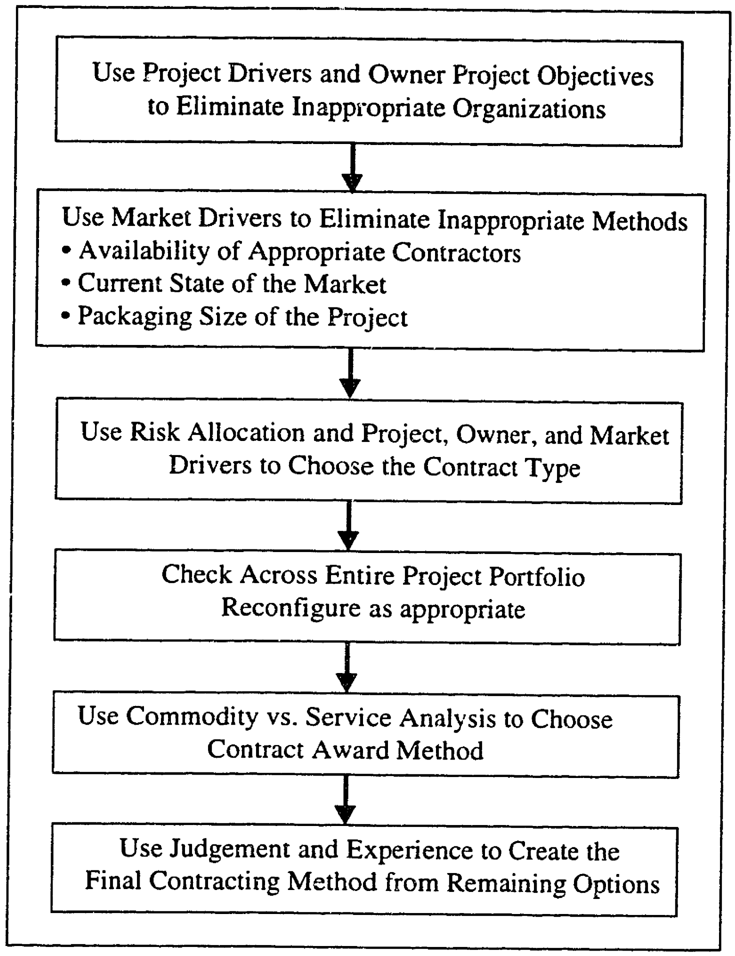
The Contracting Plan suggested here uses a strategy developed by Christopher Gordon, which correctly established that for most projects, the more important question facing owners is the elimination of inappropriate project delivery and finance strategies, not the identification of a correct one (Gordon, 1994) (Gordon, 1991).

The choice of contracting method created by Gordon is composed of four parts: scope, organization, contract, and award (Gordon, 1994).

First the scope, the portion of the work assigned to the contractor, such as separate design, construction, and operation; design-build; design-build-finance; design-build-operate; or design-build-operate-finance. The scope is basically determined by the organization, or the construction contract, selection. Organizational types include General Contractor, Construction Manager, Multiple Prime, Design-Build, Turnkey, Design-Build-Operate, and Build-Operate-Transfer. Third, the contract, or payment agreement between the owner and contractor, maybe lump sum, unit price, fixed fee, cost plus, or guaranteed maximum price, depending on the organizational selection and the owner's objectives. Finally, the award is the method used to select the contractor and/or price which can be based on competitive bid, negotiation, cap, quality-price, time-price, quality-time-price, or design-price, depending on the organizational selection and the owner's objectives.

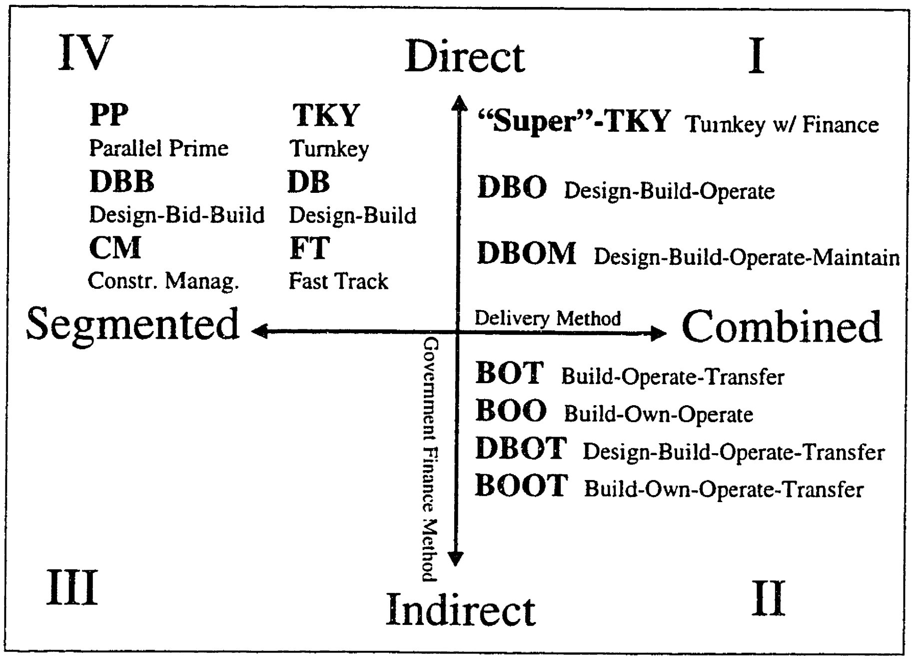
The contract method selection flowchart illustrated in Figure 4-1 is an adaptation of the method selection flowchart developed by Gordon.

Figure 4-1 Contract Method Selection Flowchart



Treatment of project delivery as variable will increase the options available to the owner during project configuration and will enhance the owner's control over project development throughout the remaining phases. The combined use of design-bid-build, design-build, design-build-operate, build-operate-transfer, and other variations will provide public owners the best potential value in terms of infrastructure quality, level of service, and development of technology. The framework shown in Figure 4-2, developed by Professor John Miller at MIT, compares the various procurement strategies in a quadrant framework. The quadrants provide a quick analysis of each strategy relative to the level of phase segmentation and source of financing. The project delivery method could range from an entirely segmented process, where each service is provided by a separate entity, to a completely integrated approach, where all services are provided by a single entity. The financing mechanism ranges from direct, where the project is completely financed through public sources, to indirect, where the project is financed by external sources.

Figure 4-2 Quadrant Framework Analysis



The multiple procurement strategies available to complete a project combine the design, construction, and operations phases in various arrangements. Each arrangement requires a change in the distribution of responsibility for the work performed as well as the project management methods needed to ensure the completion of a high quality project on schedule and within the budget.

Project Configuration Recommendations and Conclusions

- Issues regarding risk and control are of particular importance when selecting a project delivery strategy. The allocation of risk and the amount of control that the owner either desires or actually requires will have a tremendous impact on the strategy that is chosen and how potential bidders will respond to the project (Deiterich, 1998).

- A sustainable infrastructure delivery strategy recognizes that the method of delivery is a variable to be analyzed and managed. The combined use of design-bid-build, design-build, design-build-operate, build-operate-transfer, and other variations will provide the best potential value in terms of infrastructure quality, level of service, and development of technology.

- The Contracting Plan suggested here uses the strategy developed by Christopher Gordon (Gordon, 1994) (Gordon, 1991).

General Recommendations and Conclusions

- Requirements to minimize cost or time, encourage innovation, expand competition, or rely on private sector standards are viewed as implicitly requesting the use of design-build (Songer et. al., 1994).

- A well defined scope, the shared understanding of project objectives, and the owner's construction sophistication are the main criteria for evaluating whether design-build is appropriate for a project (Songer et. al., 1997).

- Owner objectives to shorten the project duration, establish costs, and reduce costs are the main reasons why owners choose design-build (Songer et. al., 1997).

- Previous research by Vesay developed a set of guidelines for when design-build should be selected (Potter, 1994). The research indicated that it is best to use design-build when:

1. the scope is well defined
2. the design is industry standard or slightly complex
3. time is of the essence
4. the owner is inexperienced
5. the team is experienced
6. quality can be industry standard or slightly higher
7. cost is critical
8. the composite project risk is low to medium

- A comprehensive study a few years ago in New York City concluded that multiple prime contracting in the long run is more expensive than all inclusive single prime general contracting (Monti, 1997).

4.3.4.1 Design-Bid-Build

General Contractor

The design-bid-build project delivery strategy segments design, construction, and operations and maintenance. The owner must enter into direct contract agreements with a designer(s), the architect/engineer in charge of design, a contractor in complete and sole charge of construction, as well as an operations and maintenance organization. This strategy relies on public funding to support the design and construction of infrastructure projects since the potential revenue generating period, if there is one, during operation is separated from design and construction.

When a need is identified the development of the project follows distinct stages. Once the feasibility of the project has been established the owner selects a designer, typically based on qualifications over price. The design professional then develops 100% complete plans and specifications for the owner. The construction contractor is selected through a low bid process based on the completed design furnished by the owner. The contractor is then responsible to complete the project as specified in the design documents by the specified date and within the contract price. Because there is no contractual relationship between the designer and the contractor all directives must come from the owner. Therefore, the owner is often responsible for oversight of the construction process as well as any disputes or changes that occur.

The process is dependent on having secured financing mechanisms in place. Although the owner, consultant, and/or design professional may be present during all phases of the project including design, bid, construction, start-up, and operation, each phase is a separate activity dependent upon the results of the prior activity. The nature of this sequential process requires that each activity be completed in full, including the assurance of available financing, prior to execution of the next activity. (Dieterich, 1998, pg 18)

In a typical design-bid-build project, or any Quadrant IV project delivery strategy, the government spends most of its planning and design budget to produce 100% complete plans and specifications for the project. However, the notion that all site conditions are known, understood, and accounted for in the complete plans and specifications is hard to accept. Therefore unforeseen site conditions and scope changes often result in disputes.

Although it may seem clear that the design-bid-build project delivery strategy cannot deliver all projects successfully, there are reasons for its frequent use. Some of the advantages and disadvantages of using the design-bid-build strategy with a general contractor are outlined in Table 4-1.

Table 4-1 Segmented Design-Bid-Build, General Contractor*

Advantages:
1. Procurement Strategy is accepted and historically supported with well established legal and contractual precedents
2. Multiple Design Professionals available to the owner
3. Independence of the Design Professional to monitor the work with the owner's interests in mind
4. Owner has the ability to make changes and evaluate alternative during the design phase
5. Construction estimates should be accurate due to the availability of complete design
6. Owner can delegate construction responsibility to one entity
7. The owner obtains a low price for construction through competition
8. The contractor takes all the construction risk in the absence of changes or unforeseen site conditions
Disadvantages:
1. Design usually does not benefit from construction or operation expertise or a value engineering process
2. Overall design-construct time is typically the longest
3. The owner is often in an adversarial position with the contractor
4. The designer is often in an adversarial position with the contractor and the owner must be a referee
5. Changes and unforeseen difficulties often end in disputes and litigation that increase costs
6. The owner has minimal control over the performance of the work
7. Contractor pressure for the lowest bid may result in the use of marginal subcontractors
8. The owner is confined to options developed by one designer

*Developed from Gordon 1997 and Barrie and Paulson 1992

Construction Manager

The two types of relationships an owner can take with a construction manager are referred to as "agency" and "at risk." If a construction manager is acting as an agent to the owner the CM is more or less the owner's advisor or consultant and the owner contracts directly with the designers and contractors. If the construction manager is "at risk" the construction manager typically contracts directly with the contractors and at times the designer as well. The CM will provide pre-construction and construction management services for a fee which is then combined with the cost for the trade contracts to establish a guaranteed maximum price.

The construction management concept is flexible and generally appropriate for projects with an undefined or an evolving scope as the construction manager can provide the needed pre-construction and construction services. Construction Management is often used where multiple prime contracts or general contractors are used. The CM is responsible for coordinating the project team's efforts and will keep track of the costs and schedule for the multiple parties involved in design and construction. Because of the multiple parties involved the CM must establish acceptable methods of resolving disputes and negotiating project agreements to avoid delays due to litigation.

Some of the advantages and disadvantages of using the design-bid-build strategy with a construction manager are outlined in Table 4-2.

Table 4-2 Segmented Design-Bid-Build, Construction Manager*

Advantages:
1. Construction Manager's Professional construction skills may be utilized at all stages of the project
2. Independent evaluation of costs, schedules, and overall construction performance
3. Full-time coordination between design and construction contractors is available
4. Minimum design-construction time can be achieved through the use of phased construction
5. Significant opportunities for CM to provide value engineering in the design, bidding, and award phases
6. Approach allows price competition for construction contracts
7. Approach allows increased flexibility for changes
8. Potential for adversarial relationship between the contractor, owner, and design professional is reduced
9. The contractor takes all the construction risk in the absence of changes or unforeseen site conditions
Disadvantages:
1. If phased construction is used, the owner begins construction before obtaining a known price
2. The owner has certain responsibilities and obligations that must be fulfilled in a timely manner
3. Success of the project depends greatly upon the planning, scheduling, estimating, and management skills of the professional construction manager
4. The professional Construction Manager generally does not guarantee either the overall price or quality of the work
5. The owner has minimal control over the performance of the work

6.	Contractor pressure for the lowest bid may result in the use of marginal subcontractors

*Developed from Gordon 1997 and Barrie and Paulson 1992

4.3.4.2 Multiple Prime

In a multiple prime project delivery strategy the owner enters into multiple direct contractual arrangements with contractors, subcontractors, and a designer(s) to complete the project. Under a traditional multiple prime framework the design is completed by one designer before construction begins and the owner accepts overall project management and coordination responsibilities, replacing the general contractor or construction manager. Ideally the contractors are to cooperate with each other and conform to the schedule to perform their piece of the work.

However, no one contractor is legally or contractually in charge of the entire project, nor has any one contractor the legally binding responsibility for successful completion. Therefore, multiple prime contractors may not coordinate and administer themselves. An experienced and well-established construction inspection and contract administration in-house staff is essential for multiple prime contracting.

The multiple prime strategy indicates that the owner has multiple direct contractual relationships but does not comment on the type of relationship. An owner may combine the use of a multiple prime strategy with any combination of the available project delivery strategies. Typically, however, the multiple prime strategy is used in conjunction with the traditional design-bid-build method. A Construction Manager can assist the owner to ensure the coordination and administration of the multiple prime contractors on the basis of a cost plus fee basis or a cost plus with a guaranteed maximum cost provision.

The advantages and disadvantages of using a multiple prime strategy are outlined in Table 4-3.

Table 4-3 Segmented Design-Bid-Build, Multiple Prime*

Advantages:	
1.	Allows for a fastrack schedule, individual contracts can be awarded as soon as the design documents are complete
2.	Allows for increased flexibility regarding changes
3.	The owner has direct access to the competitive market for construction services – can obtain low price
Disadvantages:	
1.	If phased construction is used, the owner begins construction before obtaining a known price
2.	The owner has certain responsibilities and obligations that must be fulfilled in a timely manner
3.	The owner must be heavily involved and knowledgeable about construction
4.	Coordination of multiple contracts can be difficult and costly for the owner
5.	Changes in scope and unforeseen site conditions potentially affect multiple contracts

6.	The project does not benefit from independent pre-construction services such as an engineering check, value engineering, or estimating
7.	Contractor pressure for the lowest bid may result in the use of marginal subcontractors

*Developed from Gordon 1997 and Barrie and Paulson 1992

4.3.4.3 Design-Build and Turnkey

Under a design-build framework the coordination of design and construction activities is internal within the organization of the design-builder. The owner has a single point of responsibility for both design and construction services.

The selection of a design-build team is typically a two-part process. The owner issues a Request for Qualifications (RFQ) to evaluate the ability of each team and a Request for Proposals (RFP) after which the owner selects a design-build team based on the submitted design and construction packages. The firm awarded the contract is then responsible for completing the design and construction under the contract terms. When construction is completed the project is turned over to the owner for operation.

The financing commitments are nearly identical to design-bid-build as the owner must have secured all project financing in advance. In the design-build model the government generally spends much less of the planning and design budget on design preparation, leaving more for project definition, planning, and organizing activities. The government prepares the design up to the functional level, representing approximately 5 to 10% design completion. The government finances the detailed design and engineering after contractual agreements have been made for the combined design and construction services.

A turnkey project delivery strategy adds temporary construction financing to the responsibilities of the design-builder. The process is similar to design-build except for the owner must supply the required financing upon completion of the project instead of up front. In the turnkey arrangement the owner is free to function in an advisory or review role, because the burden of day-to-day operations rests with the contractor.

In both the design-build and turnkey strategies the owner combines design and construction services into a single contract. However, both are considered Quadrant IV strategies as they do not include long term operation.

In a survey conducted by Songer and Kappers respondents sited the following as typical advantages to using design-build (Songer and Kapper, 1995): 1)Ability to schedule and control work; 2) Ability to control cost; 3) Freedom to innovate; 4) Encourage positive client relationships; and 5) Increase value of finished product to the owner.

Other advantages are recognized as greater participation by the contractor during the design process, early knowledge of firm costs, enhanced communication between designer and contractor, and a single point of responsibility for design and construction services.

The typical advantages and disadvantages of using a design-build or turnkey strategy are outlined in Table 4-4.

Table 4-4 Combined, Design-Build & Turnkey*

Advantages:
1. There is one contract for the owner, with design, construction, and process know-how furnished by a single organization
2. The total cost and schedule estimates can be known prior to contract award
3. Minimal owner coordination is needed between design and construction
4. Overall design-construct time can be reduced through phased construction
5. Teamwork between the designer and contractor during design is enhanced
6. There are opportunities for construction expertise to be incorporated during the design phase
7. Implementation of changes is simplified due to the single point of design-construction responsibility
8. The owner has no liability for change orders, unless the scope or site conditions change
Disadvantages:
1. If phased construction is used, the owner begins construction before obtaining a known price
2. Owner design changes are often expensive
3. The owner loses some flexibility in, and control over the detailed design process
4. The owner loses the direct relationship with the design professional and the independent designer relationship with the contractor
5. The owner must be knowledgeable to establish the initial parameters and monitor the process
6. As a result of the minimum involvement of the owner, the final product may not fully comply with expectations
7. There are few checks and balances and the owner is often not advised or aware of design and construction problems

*Developed from Gordon 1997 and Barrie and Paulson 1992

Incorporation of the field constructor's expertise into the design phase increases the attractiveness of the design-build delivery strategy. The contractors transfer this knowledge through direct participation in the design process as well as through the opportunity for design reviews.

One of the major disadvantages is that the owner is often less involved in the design process and may not receive exactly what is desired. When the design-build contract is awarded based on incomplete plans and specifications the owner may find difficulties in attempting to ensure the project satisfies both the design proposal and the performance specifications.

The turnkey strategy can provide an owner, who cannot obtain the financing required for construction, with a method to complete the project. Depending on the characteristics of the project owners may or may not be able to obtain construction financing due to project risk and/or project timing. However, if an owner has the ability to secure long-term financing based on revenue projections from operations, the turnkey method provides a means to meet the owner's cash flow restrictions.

4.3.4.4 Design-Build-Operate

The design-build-operate project delivery strategy combines design, construction, and operations and maintenance within a contractual arrangement to obtain a single point of responsibility for these services. Typically, the owner directly finances a design-build-operate strategy and assumes the risk or reward associated with potential revenues from operations. Similar to the segmented strategies, the owner must secure the project financing for design and construction prior to the procurement of the services.

Incorporation of the field constructor's expertise and the needs of the operator into the design phase increase the attractiveness of the design-build-operate delivery strategy. The contractors and operators transfer this knowledge through direct participation in the design process as well as through the opportunity for design reviews.

Like design-build, in the design-build-operate model the government spends much less of the planning and design budget on design preparation, leaving more for project definition, planning, and organizing activities. The government prepares the design up to the functional level, representing approximately 5 to 10% design completion. The government then finances the detailed design and engineering after contractual agreements have been made for the combined design, construction, and operation services.

The advantages and disadvantages of using a design-build-operate strategy are outlined in Table 4-5.

Table 4-5 Combined, Design-Build-Operate*

Advantages:
1. The owner has one contract and a single point of responsibility for design, construction, and operations
2. Total design, construction, and operation costs and schedule can be known prior to contract award
3. Minimal owner coordination is needed between design and construction
4. Overall design-construct time can be reduced through phased construction
5. Teamwork between the designer, contractor, and operator during design is enhanced
6. There are opportunities to incorporate construction and operation expertise in the design phase
7. Implementation of changes is simplified due to the single point of design-construction responsibility
8. The owner has no liability for change orders, unless the scope or site conditions change
Disadvantages:
1. If phased construction is used, the owner begins construction before obtaining a known price
2. Owner design changes are often expensive
3. The owner loses some flexibility in, and control over the detailed design process

4. The owner loses the direct relationship with the design professional and the independent designer relationship with the contractor
5. The owner must be knowledgeable to establish the initial parameters and monitor the process
6. As a result of the minimum involvement of the owner, the final product may not fully comply with expectations
7. There are few checks and balances and the owner is often not advised or aware of design and construction problems

*Developed from Gordon 1997 and Barrie and Paulson 1992

4.3.4.5 Build-Operate-Transfer

The build-operate-transfer project delivery strategy combines design, construction, and operations and maintenance within a contractual arrangement to obtain a single point of responsibility for these services. These projects are either indirectly financed by private sources or they are financed by a mix of public and private funds. Typically, the private developer or consortium assumes the risk or reward associated with potential revenues from operations.

Similar to design-build and design-build-operate, the build-operate-transfer model allows the government to focus efforts on project definition, planning, and organization during the project configuration phase. The government prepares the design up to the functional level, representing approximately 5 to 10% design completion. However, in the BOT model the private sector finances the detailed design and engineering.

The advantages and disadvantages of using a build-operate-transfer strategy are outlined in Table 4-6.

Table 4-6 Combined, Build-Operate-Transfer*

Advantages:
1. Independent private sector assessment of the technical and economic viability of a project
2. The financial arrangement and schedule can be known prior to contract award
3. Teamwork between the designer, contractor, and operator during design is enhanced
4. There are opportunities to incorporate construction and operation expertise in the design phase
5. The owner has no liability for change orders
6. The owner has one entity to deal with for site responsibility and operations
7. The owner is able to delegate financial responsibility
8. Overall design-construct time can be reduced through phased construction
9. The strategy encourages the use of new technology and innovation
Disadvantages:
1. Only supports financially viable projects
2. Process may support sole source procurements

3. Owner design changes are often difficult
4. The owner loses control over the detailed design process
5. The owner loses the direct relationship with the design professional and the independent designer relationship with the contractor
6. The owner must be knowledgeable to establish the initial parameters and monitor the process
7. There are few checks and balances and the owner is often not advised or aware of design and construction problems
8. The owner is entirely dependent on one entity

*Developed from Gordon 1997 and Barrie and Paulson 1992

4.3.4.6 Allocation of Responsibility

Table 4-7 illustrates an example of the distribution of responsibility for each of the project configuration deliverables when using the design-bid-build, design-build, design-build-operate, and the build-operate-transfer delivery strategies.

Table 4-7 Responsibility for Deliverables

	Design-Bid-Build				Design-Build			Design-Build-Operate		Build-Operate-Transfer	
	Owner	Designer	Contr.	Operator	Owner	D-Builder	Operator	Owner	DBOper	Owner	BOT Cons
Executive Plan	D	D	D	D	D	D	D	D	D	D	D
Project Objectives	D	I	I	I	D	I	I	D	I	D	I
Staffing Plan/Organ. Structure	D	I	I	I	D	I	I	D	I	R	D
Project Charter	D	A	A	A	D	A	A	D	A	-	-
Scope of Work Statement	D	E	E	E	D	E	E	D	E	D	E
Functional Design	D	I	I	I	D	I	I	D	I	R/A	D
Financing/Cashflow Analysis	D	-	-	-	D	-	-	D	-	D	D
Analysis of Proj. Del. Options	D	-	-	-	D	-	-	D	-	D	-
Evaluation Criteria	D	I	I	I	D	I	I	D	I	D	I
Project Management Workplan	In/E	D/E	D/E	D/E	In/E	D/E	D/E	In/E	D/E	In/R	D/E
Constructibility Program	In/E	D/E	D/E	D/E	In/E	D/E	D/E	In/E	D/E	In/R	D/E
Project Control Program	In/E	D/E	D/E	D/E	In/E	D/E	D/E	In/E	D/E	In/R	D/E
Change Management Program	In/E	D/E	D/E	D/E	In/E	D/E	D/E	In/E	D/E	In/R	D/E
Risk Management Program	In/E	D/E	D/E	D/E	In/E	D/E	D/E	In/E	D/E	In/R	D/E
Dispute Prev. & Res. Program	D	A	A	A	D	A	A	D	A	In/R	D/E
Quality Management Program	In/E	D/E	D/E	D/E	In/E	D/E	D/E	In/E	D/E	In/R	D/E
Safety Program	In/E	D/E	D/E	D/E	In/E	D/E	D/E	In/E	D/E	In/R	D/E
Data Management Program	In/E	E	E	E	In/E	E	E	In/E	E	In/R	D/E
Contracting Plan	D	I	I	I	D	I	I	D	I	D	I
RFP	D	E	E	E	D	E	E	D	E	D	E
Project Financing	E	-	-	-	E	-	-	E	-	A	E
Preliminary Design	A	D	-	-	A	D	-	A	D	A	D
Detail Design/Engineering	A	D	-	-	A	D	-	A	D	A	D
Design Review	E	E	-	-	E	E	-	E	E	E	E
Value Engineering	E	E	-	-	E	E	-	E	E	E	E
Construction Activities	A	M	E	-	A	M	-	A	E	A	E
Start-up, Testing	A	M	E	E	A	E	E	A	E	A	E
Operations & Maintenance	M	-	-	E	M	-	E	M	E	M	E

D=Develop M=Monitor I=Inform A=Approve
E=Execute R=Review In=Initiate -Not Applicable

4.4 Project Delivery Package

4.4.1 Contracting Plan

The owner either solely or with the assistance of a construction/project manager determines the contracting plan for a project. An owner has the opportunity to select a delivery strategy that maximizes available resources and offers the greatest potential to deliver a successful project.

There are five main activities that are typically described in the contracting plan:

1. Identifying the Project Delivery Strategy
2. Developing the RFP
3. Performing proposal evaluations
4. Conducting contract administration
5. Performing project coordination

4.4.1.1 Project Delivery Strategy

The identification of the project delivery strategy is an important step of the project configuration process as each strategy may require different levels of project planning and owner involvement. An owner must understand both the advantages and disadvantages of each strategy to properly match the project objectives and resources with the best delivery method. An overview of the common delivery methods along with a summary of their advantages and disadvantages is provided in the Analysis of Options monograph to aid the owner in performing the analysis of delivery options.

4.4.1.2 RFP/Evaluation Criteria

The owner either solely or with the assistance of consultants or an A/E develops the RFP for a project. If evaluation criteria are needed, which depends on the project delivery strategy, an owner must establish the evaluation criteria to reflect the objectives for the project.

The RFP is the primary communication tool for conveying the owner's objectives to the designer and contractor. The RFP typically includes detailed instructions for preparing and submitting proposals, the owner's definition of requirements and project specifications, project conditions and site data, design guidance, and a description of the evaluation criteria.

The RFP should explain how the method of procurement meets the criteria in law or regulation for use of the delivery method. It should describe the selection process, including detailed submission requirements and selection procedures, the composition of the selection panel, and a timetable for the entire procurement process. Finally, it should provide credible assurance that the project is fully funded (Widom, 1995).

When developing evaluation criteria the owner should consider the following suggestions (Songer et. al., 1994):

1. There cannot be an evaluation factor on anything that is not included in the technical requirements of the RFP.
2. Any special objectives such as time, cost, and quality must be represented in the evaluation criteria.
3. Consistency must be maintained between the evaluation criteria, technical specifications, and submittal requirements.
4. Evaluation factors should be limited to the important factors for the specific facility.
5. The RFP should not be secretive about the evaluation criteria and where the emphasis will be placed.

Project Configuration Recommendations and Conclusions

- An owner may consider employing a consultant or an A/E to aid in the development of the RFP.

- Typical criteria used for selecting a consultant or an A/E includes experience with the contracting strategy, and familiarity with industry standards, performance oriented specifications, and the local construction community's capabilities (Songer et. al., 1994).

- The RFP must clearly indicate the proposal selection procedure and identify objective evaluation criteria to attract quality bidders and minimize potential challenges by unsuccessful proposers and the public.

- It is important that the RFP developer remain as open as reasonably possible toward design so as not to preclude creativity and innovation by the designer and contractor. Performance specifications generally enhance flexibility.

- The weight assigned to the evaluation criteria should assist the proposer in understanding the owner's priorities.

- The final selection must be defensible, objective, and convey a sense of propriety to the owner, the proposers, and the public.

- Government procurement regulations require that the evaluation process be executed objectively and consistently. This is to ensure fairness to all proposers and to be justifiable with regard to the procurement regulations (Songer et. al., 1994).

- The AIA and AGC advocate the use of a two-phased process for the procurement of design-build services (Widom, 1995).

- A two-phased procurement process (Widom, 1995) is recommended for the design-build, design-build-operate, and build-operate-transfer delivery strategies. In the first phase a short list of pre-qualified finalists is compiled. A number of three to five teams is enough to ensure competition, but is also a manageable number for the selection panel. Selection of a short list should be accomplished by reviewing applications packages, supplemented by brief interviews if possible, and should be based on a comparison of qualifications. The qualifications often include: 1) the ability of the competitor to satisfactorily carry out the design and construction requirements; 2) past performance of individual members of the competitor; 3) relevant experience or potential performance of the competitor as a team; and 4) financial capacity to perform. In the second phase, the final selection, each competitor on the short list must be aware of the final selection criteria and the weight assigned to each criterion. Criteria typically include excellence of the proposed design and construction approach to the project, demonstrated satisfaction of the project requirements, management plan for the project, and estimated cost and schedule of the project. The same panel should make the first and second phase selections, in order to provide continuity and consistency in the selection process.

- It is extremely important to provide candid feedback to unsuccessful teams after the selection process has been completed. Teams want and need to know why they were unsuccessful and how they can improve themselves for future competitions (Widom, 1995).

4.4.1.3 Contract Administration and Coordination

The owner either solely or with the assistance of consultants or a construction manager conducts contract administration and coordination for a project. It is important to recognize that the type of contracts used may affect the relationships among the members of the project team.

Contract Types

The two main types of contracts, or pricing methods, that are used to procure design and construction services are fixed price/lump sum and negotiated price/cost reimbursable.

A lump sum or firm fixed price contract requires a well-defined scope and nearly "complete" design specifications and drawings at the time of the contract agreement. The ideal is to have no changes during construction execution and the project is completed for the agreed upon price. In this scenario the owner retains the risk associated with complete design and scope while the contractor bears the performance risks. This type of contract requires less owner oversight and administrative monitoring during construction.

Variations of a straight fixed price contract may include incentives based on contractor performance. Unit price contracts may be used when the type of work is known but the quantities have not been established.

Typically negotiated or cost reimbursable contracts are used when the scope is not clearly defined. An owner may want to negotiate a contract price on the basis of a cost-plus a fee and/or a guaranteed maximum price. The fee on a cost plus contract can either be fixed or include incentives based on agreed upon performance metrics. These types of contracts require greater owner involvement and oversight in the management and monitoring of the design and construction phases.

Contract Clauses

The contract documents are composed of multiple contract clauses, or terms. The parties entering into the contract agree that these clauses will structure and guide the actions of each party. Contract clauses are often used to allocate risk. One party may wish to allocate risk to another reducing their own level of risk. Attempts to use contract clauses in this manner often results in conflicts and disputes between the members of the project team. A study conducted by CII, identified that the nine statistically most problematic clauses can be grouped into three main categories: Work Scope Definition, Change, and Project Control ("Impact...", 1986).

Work scope clauses are used to define the boundaries of the project and the boundaries of each party's responsibility. They typically describe the work to be completed, the minimum standards of acceptability, procedural guidelines, and the drawings and specifications. Problems often arise when these clauses contain errors, omissions, or inconsistencies.

Change clauses are used to describe the procedures that are to be followed when there is a definite or potential change to the contract scope. These clauses provide a way to modify the original or base contract between the parties of the project team. Disputes resulting from project changes, particularly concerning categorization and compensation are very typical.

Project control clauses are used to describe the procedures that are to be used to monitor work progress and confirm acceptability. These clauses provide standard methods of documentation and reporting.

Owners often attempt to use indemnity, consequential damages, differing site conditions, and delay clauses to improperly shift risk to the contractor. A study conducted by CII indicated that improper risk allocation between the owner and contractor for these four clauses is not cost effective and generally has a negative impact on the owner-contractor working relationship. The study showed that both owners and contractors supported clauses that on average left risk with the owner ("Contract...", 1988).

If a contact did not address these issues the common law would govern. The common law indicates that for indemnity owners and contractors would be liable for their own acts of negligence and joint liability would be prorated by degree of fault, for consequential damages the contractor would be liable for all consequential damages within it contemplation, for differing site conditions the contractor would generally be liable for the cost of any differing site conditions, and for delay the owner and contractor would be liable for the delays they cause.

Incentives

Incentives are tools used by an owner or project manager in an attempt to align the objectives of other project participants with those of the owner. Contract incentives typically reward or punish a member of the project team based on agreed upon performance expectations. Incentives can be either positive or negative. Positive incentives or rewards typically provide the party with some sort of financial benefit. Negative incentives generally result in a financial loss such as a reduction in the party's fee.

Psychology indicates that positive reinforcement, or the potential for improved relations and financial gain, is more persuasive than the threat of punishment. Observation has shown that positive reinforcement or potential financial gain through positive incentives has greater potential to improve performance, quality and safety, while reducing the overall cost and schedule of a project.

Responsibility and Coordination

Although each project is unique they all share the same need for design and construction services. If an owner is to consider using new delivery strategies that combine these services, that owner must also consider the potential effects that decision may have on the allocation of responsibility and the coordination of the various contracts.

A general comparison of responsibility or participation in the various management activities was provided in section 4.3.4.6. The standards for general liability and performance expectations have been developed over time and are based on the design-bid-build method of project delivery. The combined strategies are more complex as design and construction services, which are treated differently when considering general performance liability, are completed by one entity.

Regarding the design professional's standard of care, most courts to consider the issue have held that a design-build contractor is more nearly akin to a contractor than to a design professional, therefore design-builders are usually held to the same warranty standards as contractors, which covers the design services they offer. (Friedlander, 1997) However, this general liability can be changed through provisions in the contractual agreement.

The use of any variant of the design-build or turnkey delivery strategy includes the advantage of transferring the risk for the design, construction, and delivery of a complete project to the contractor. The combination of services under one contract should decrease the coordination efforts required by the owner. Another advantage from implementing these delivery strategies is that the project can be awarded and the process set in motion before the design is complete. This can be a key factor when time is of utmost importance to the owner.

Project Configuration Recommendations and Conclusions

- Thoughtful and meticulous contract preparation, tailored to the circumstances of the project and reflecting both the owner and contractor objectives, does achieve improved project performance ("Impac…", 1986).

- Prime attributes of a good contract are 1) maximizing areas of common agreement, and 2) dealing with matters of potential conflict in a way that both parties regard as fair ("Impact…", 1986).

- The contractual relationship between the owner and design professionals must be structured with care and contain adequate safeguards to the owner providing protection from errors and omissions by the design professionals. It is essential that a member of the owner's organization monitor the output of the design professional and that this member carry sufficient authority to accomplish all conflict resolution within the design effort (Graham, 1983).

- The contractual relationship between the owner and the construction manager must be structured with care and contain adequate safeguards to the owner providing protection from errors and omissions by the construction manager. It is essential that a member of the owner's organization monitor the efforts of the construction manager and that this member carry sufficient authority to rectify any and all construction management deficiencies (Graham, 1983).

- In a study conducted by CII response analyses indicated that contract clauses concerning work scope, changes, and project control are those that are most frequently involved in problems and disputes ("Impact...", 1986).

- Well-defined scope of work and change clauses are the best mechanisms to prevent conflicts and disputes regarding work responsibility and compensation.

- During contract negotiations it is important to obtain mutual understanding and agreement concerning project control responsibility and procedures.

- Careful and thoughtful selection of indemnity, consequential damage, differing conditions, and delay clauses that do not grossly and inequitably allocate all risk to the contractor benefit overall project performance and the owner-contractor working relationship ("Contract...", 1988).

- Incentive clauses provide a way of fine-tuning the contract to bring the contractor's goals closer in line with those of the owner, while rewarding the contractor for superior performance ("Impact...", 1986).

- Owners should routinely use positive incentives to reward contractors for cost-effective project management and consider the use of innovative bonus provisions ("Impact...", 1986).

4.4.2 Project Charter

The owner should be involved in drafting a project charter designed to establish communication within the project team. Through this process an owner has the opportunity to establish the general environment in which the owner, designer(s), contractor(s), and operator interact.

The intention of a project charter is to obtain consensus within the project team concerning project objectives and scope, commitment to the project team, and the commitment to completing a successful project. The charter's purpose is to build a well-aligned, focused, high-performance project team. Essential elements of any project charter are:

- Project goals and objectives
- Project team purpose and mission
- Project scope
- Measures of project success
- Project team member commitment

First, the project goals and objectives are a statement of the owner's intent through clearly defined objectives and project drivers. Second, the project team purpose and mission define the existence of the team and the relationships necessary to attain the project objectives. Third, the project scope clearly defines the boundaries of the project. A good Scope of Work Statement matches functional characteristics with the owner's physical needs. Fourth, project success must be clearly defined in measurable terms such as quantities, quality, cost or time, as well as the less quantitative measure of team member satisfaction. It is important to remember the greater the clarity of the measurable criteria the greater the probability project team members will achieve them. Finally, project team member commitment to, or endorsement of, the project charter is essential. All project participants with a direct contractual relationship with the owner are asked to sign this document to verify their commitment to the success of the project.

The project charter is a useful tool to obtain consensus within the project team during the planning/pre-construction phases. The owner's business managers are generally concerned with the overall financial viability of the project. Designers and A/E's typically focus on the operational performance as well as the physical and aesthetic characteristics of the facility. The owner and contractor's project managers are typically concerned with the project execution phase, which focuses on project control and ease of engineering, procurement, and construction. Operations managers are mostly concerned with operating characteristics and performance of the facility. The project charter can be a useful tool in aligning these various objectives into a collective agreement to guide future decisions.

If the project delivery process has multiple phases, and hence the introduction of new parties, endorsement of the project charter must be obtained as each new phase is defined and executed. The project charter is therefore a work in progress and subject to continuous improvement, as new team members are added, and as projects are rarely fully endorseable by all parties the first time.

Partnering & Team Building

Partnering and team building are both forms of collaboration and are terms often used synonymously. Although partnering and team building are similar they are not identical. The differences between partnering and team building are worth noting.

CII defines partnering as a long-term commitment between two or more organizations for the purpose of achieving specific business objectives by maximizing the effectiveness of each participant's resources ("Team Building…", 1993). The relationship requires trust, dedication to common goals, and an understanding of each party's expectations. The partnering process generally strengthens both projects and partners, tightens schedules, safeguards quality, and enhances each partner's competitive edge ("Model...", 1996).

In a study on partnering, CII identified key characteristics for managing successful partnering relationships ("Model...", 1996):

- Establishing Trust
- Getting Top Management Support
- Establishing Win-Win Objectives
- Addressing Internal Barriers
- Getting Champion to Direct the Process
- Developing Measures, Linked to Objectives

Team building is an informal process designed to promote harmony, cooperation, and communication within the project team. Team building brings together all of the key project participants at the beginning of the project to establish unified goals and to build relationships based on trust and open communication.

CII defines the team building process as a project-focused process that brings together key stakeholders in the project outcome to resolve differences, to remove roadblocks, and to build and develop trust and commitment, a common mission, shared goals, accountability among team members and problem solving skills ("Team Building...", 1993). In contrast to partnering, after completion of the project the project team typically ceases to exist and the team building process stops.

In a study on team building, CII identified key characteristics for effective team building ("Team Building...", 1993):

- Trust
- Shared Project Goals
- Interdependence
- Shared Sense of Accountability
- Pride in Team Members
- Open Communication
- Feedback

The core contribution of the team building process is that it facilitates the development of a group into an aligned, focused and motivated work team striving for a common project mission and for shared goals, objectives and priorities ("Team Building...", 1993). The major costs of implementing a team building process include the opportunity cost of the team members' time, costs of various training sessions, costs of an external consultant, as well as the costs of recognition and reward items and events. Typical benefits include reduced adversarial relationships, lower project costs, improved project quality, shorter project schedules and a commitment to the future use of team building methods.

With proper structuring of incentives, all participants will put themselves in the owner's shoes and complete the project with the owner's interests in mind. Team building methods are being employed to clarify communication between the participants, improve relationships, prevent schedule delays, and assist team members to focus on common goals. The process is beneficial for all those involved as more problems can be identified and resolved in the planning stage, rather than the more costly construction stage.

Project Configuration Recommendations and Conclusions

- Information flow is vital for problem solving. Problems should be solved using an open discussion but when a solution is decided the project manager shall either champion or detail another to get-it-done (Rigby, 1998).

- The partnering process can become a mechanism for obtaining a commitment from all team members to assess project status and jointly allocate responsibility for project delays during construction (Schumacher, 1997).

- Without established benchmarks to show measurable benefits, partnering will reach only a fraction of its potential ("Model...", 1996).

- Activities that increase face-to-face contact (workshops, common offices, teambuilding sessions) encourage people to try to solve problems at the lowest possible level ("Model...", 1996).

- Adversarial relationships among a project owner, designer and/or contractor are common but not inevitable ("Team Building...", 1993).

- The most important causes of adversarial relationships are: poorly defined scope, excessive change orders, changes not properly managed, lack of communication of objectives, unrealistic project schedule and unrealistic project budget ("Team Building...", 1993).

- The team building process forms a group into an aligned, focused and motivated work team that strives for a common project mission and helps team members feel ownership of the project ("Team Building...", 1993).

- The costs associated with using team building methods are miniscule when compared to the benefits received ("Team Building...", 1993).

- It is the effective use of the team building process, and not simply the use of teams that facilitates improvement in project results. Without an effective team building process, the potential benefits of teams may not be realized ("Team Building...", 1993).

- The successful use of project team building is independent of the specific type of commercial relationship that is used by the parties to the project ("Team Building...", 1993).

- There is no "one best way" to facilitate the team building process. Different facilitating styles can lead to effective project teams ("Team Building...", 1993).

- CII recommends the following for team building ("Team Building...", 1993):
  - Use the team building process

- Use a consultant to facilitate the process
- Begin the process early in the life of the project
- Seek broad participation in the process
- Make the process an integral part of project management

- Any control program can only be successful if the project team openly communicates. Formal team-building exercises, such as a retreat or sessions with team-building consultants, can facilitate the team-building process (Radtke and Russell, 1993).

4.4.3 Project Management Workplan

The management and control of all project operations falls into two main categories. First, the project team must manage the design and construction expertise to promote a well-programmed, well-designed, quality-built, schedule reactive and economical project. Second, the project team must address fiscal, schedule, and risk control for the duration of the design and construction processes.

The public owner is typically involved in managing the project. An owner has the opportunity to establish the baseline for a project management program that will guide the development of management procedures used by the designer(s), contractor(s), and operator(s). This baseline should encourage a team approach and work toward standard documentation and information distribution.

The Project Management Workplan is a tool used to establish effective communication within the project team. An effective workplan communicates essential project information to the team members and allows them to commit themselves to the success of the project. Although the focus of the workplan is content, it should also be simple, concise, legible, and logically organized.

During the project configuration phase the owner must be actively involved in developing the intent behind the workplan document. It is important for the owner to determine the needed management and control programs as well as the guidelines for their development. There is a significant difference between preliminary workplan development and the final detailed document. The project management workplan is still a work in progress at the end of the project configuration phase. Many elements of the workplan are developed by the project team once the contracting plan has been implemented.

Under the current segmented system, project management workplan development is left to the contractor's project managers, which are often not shared with the owner. This practice constitutes poor project management by the owner considering the benefits that are derived from shared communication. If the owner pre-empts the traditional process by acknowledging the necessity for and outlining the components of the project management workplan, before releasing the project to the private sector, the owner can establish a desired level of involvement in the progressive development of project.

A typical detailed project management workplan will address:

- What needs to be done? – Scope of Work Statement
- When is the work going to be done? – Project Schedule, Project Control Program
- How much is the work going to cost? – Project Budget, Project Control Program
- Who is going to be doing the work? – Contracting Plan
- How will performance/quality be ensured? – Functional Design, Quality Management Program
- How will performance be measured? – Project Control Program
- How will project risk be distributed? – Risk Management Program
- How will change be managed? – Change Management Program
- How will system operation and integration be ensured? – Constructibility Program
- How will safety be ensured? – Safety Program
- How will disputes be resolved? – Dispute Prevention and Resolution Program

A major part of construction planning is to break the project down into logical management areas, referred to as work packages, utilizing a work breakdown structure (WBS). The WBS is the basis for detailing the scope of work statement, establishing project schedules, assigning resources to tasks, assessing progress, and developing management reports.

Controlling the project through work packages improves the information that is processed by the project control system. Work packaging produces units of work, which are meaningful to both the design and construction forces (Diekmann et. al., 1987). Within the work packages costs can be estimated, activities scheduled, and responsibilities assigned.

Anthony defines three levels of planning and control (Paulson and Sanvido, 1992) (Anthony, 1965):

1. Strategic planning, typically performed by the owner and project manager, is the process of deciding on objectives of the organization, on changes in these objectives, on resources used to attain these objectives, and on policies that are to govern the acquisition, use, and disposition of these resources.
2. Management control, typically performed by the construction manager and construction superintendent, is the process by which managers assure that resources are obtained and used effectively and efficiently in the accomplishment of the organization's objectives. Information required for management control concerns the entire site or area, includes financial data, includes approximations, is summary in nature, and is historical or projected.
3. Field operational control, typically performed by the construction superintendent/general foreman, is the process of assuring that specific tasks are carried out effectively and efficiently. Information required to support operational control must concentrate on the single subject under decision, be precise and detailed, focus on real time, and measure the desired property.

Project Configuration Recommendations and Conclusions

The following are recommendations from lessons learned on projects completed by the Department of State (Retherford, 1997):

- Detailed project planning is required in advance of contractor selection.
- Engage design and construction specialists early in the project planning to provide a more realistic method of validating the total delivery process (cost, scope and schedule).
- Evaluate the appropriateness of materials, project design, assembly processes and construction labor skills early in the project cycle.
- Maintain a disciplined approach during project delivery to ensure that the project team makes scheduled and timely decisions reducing the opportunities for change.
- Management support of the team process and decisions is critical to encourage expedited decision-making.
- Project decision-making authority should be vested at the lowest level so that delays from indecision can be avoided.
- Decide early in the project planning what quality level is desired in the facility to limit the exposure to compromise and misunderstanding of the project requirements.
- Allow for contractor input during, not after, completion of the design process to ensure full impact of constructibility evaluations.

4.4.3.1 Constructibility Program

The owner should be involved in establishing the requirements regarding constructibility for a project. An owner has the opportunity to establish the baseline for a constructibility program that will guide the development of design, value engineering, and systems integration by the designer(s) and contractor(s). This baseline should establish a team attitude towards managing constructibility efforts and work toward standard documentation and information distribution.

Constructibility has been defined as the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives ("Constructibility," 1986) (Radtke and Russell, 1993).

A constructibility program generally involves value engineering as well as the management and integration of the major system components during the design and construction phases. Other typical constructibility concepts include estimating the cost-effectiveness of early involvement of construction personnel; generating, storing, and receiving constructibility lessons learned; and creating a team environment for design engineers and constructors.

The constructibility concept arose from the realization that designers and contractors frequently view the same project from different perspectives, and that optimizing the project variables requires that the knowledge and experience of both parties be applied to the project planning and design processes. Ideally, construction expertise would be incorporated from the moment of project inception during the pre-project planning (project configuration) phase of a project (Gibson et. al., 1996).

Potential benefits that may accrue from the application of a constructibility program are as follows (Gibson et. al., 1996):

- Reduced costs
- Shorter schedules
- Improved quality
- Enhanced safety
- Better control of risk
- Fewer change orders
- Fewer claims

Constructibility can be considered a service provided along with pre-construction services. A formal constructibility program obtains constructibility input during conceptual planning and preliminary design, establishes a construction-oriented philosophy for projects, outlines constructibility procedures, and tracks progress of constructibility efforts (Radtke and Russell, 1993).

Value Engineering

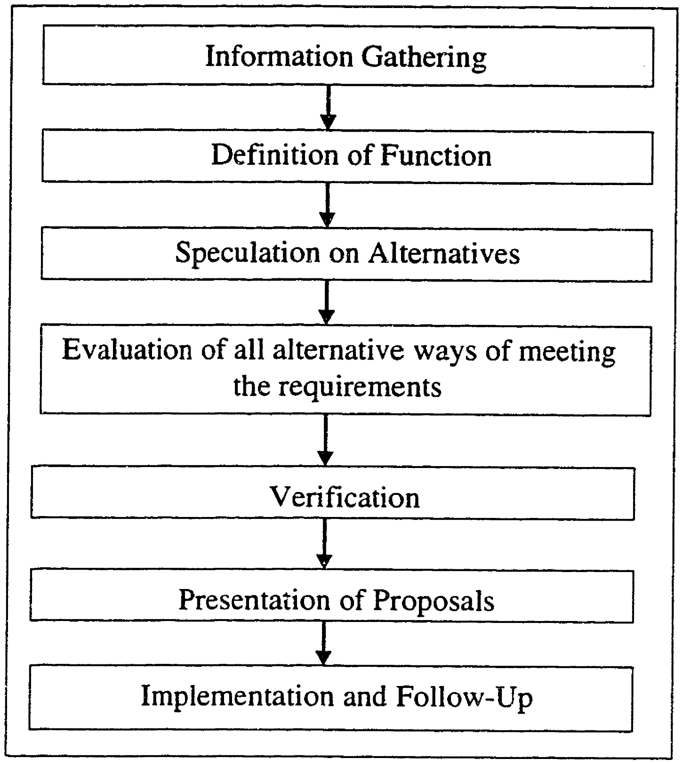
Value engineering is a proactive rather than reactive approach to design and construction. Designers, contractors, and even operators work together to determine the most cost-effective, highest quality, and safest solution to deliver the project.

Lifecycle costing and value engineering can assist in the appraisal of long-term implications involved between alternative system designs, and in the evaluation of the cost differentials between material or component selection (Ahuja and Walsh, 1983).

The terms value engineering, cost benefit analysis, and cost engineering are used interchangeably in construction vernacular. The important common thread, however, is value. They are all attempts to optimize the value the owner receives for each dollar spent. Value engineering or analysis implies the balancing of many objectives, one of which may be cost, leading to the most short and long-term satisfaction of project requirements, a key in tying back to the capital plan (Dean, 1983).

A value engineering process developed by Rigby is shown in Figure 4-3.

Figure 4-3 Value Engineering Process



Systems Engineering Management

The purpose of systems engineering management is to identify and describe the overall principles, objectives, and tasks required to manage the installation, integration, and operation of the project's system components. Typical system categories often include electrical supply, electrical distribution, mechanical, and communications.

Rigby states that systems engineering management is intended to define the system performance parameters and preferred system configuration to satisfy the technical requirements, the planning and control of technical program tasks, integration of the engineering specialties, and the management of a totally integrated effort of design engineering, computer software engineering, specialty engineering, test engineering, logistics engineering, quality evaluation, and production engineering to meet cost, technical performance, quality, and schedule objectives for a specific project or program.

The prime functions of a systems engineering program, as identified by Rigby, are as follows (Rigby, 1998):

1. Outline the system engineering program required for performing systems engineering management

- Organization, activities, and objectives
- Contract work breakdown structure
- System test planning
- Technical reviews

- Design approval and certification
- System integration

2. Describe in detail the systems engineering processes to be used and any specific tailoring of the processes to the requirements of the project
- Functional analysis
- Logistics engineering
- Life cycle cost analysis
- Generation of specifications

3. Describe the integration and co-ordination of the program efforts for the engineering specialty areas
- Details of control, monitoring, reporting, interfacing and coordination considerations between the various systems

The intended benefits of implementing a system engineering management program is to reduce risk and time to design, develop, manufacture, and install large and complex technical systems.

Integration

The term integration implies that separate entities or systems are interconnected and work together in pursuit of a common goal or function. There can be many forms of integration on a large technically complex project such as organizational/personnel integration, informational integration, contract service integration, or project wide system integration.

Nam and Tatum have identified three specific forms of integration (Nam and Tatum, 1992):

1. Organizational Integration – places design and construction functions under one organization or common leadership.
2. Contractual Integration – integrates different organizations contractually in a project team. Example – Construction Manager who has construction expertise and serves as the owner's agent from the initial planning stages through the end of the project.
3. Information Integration – integrates information within an organization or across organizations to increase coordination and efficiency.

The expansion of the public owner's project delivery options will allow the owner to combine or integrate services into a single contract. Experience has shown that integration of design and construction appears to provide a major opportunity for advancing technology on construction projects.

Although contractual improvements can effectively achieve project integration, some non-contractual means appear to offer even greater potential for integration (Nam and Tatum, 1992). These means include:

1. Owner's Leadership – A common feature of owner involvement is the role as a link between the various organizations in the project.
2. Long-term Relationships between Organizations – Maintaining long-term business relationships between different organizations, often without clear legal binding, appears vital in fostering an integrated environment.
3. Employing Integration Champions – In the construction industry there is an extreme specialization of functions therefore integration requires organized and deliberate efforts to achieve coordination among the various professions.
4. Professionalism among Project Participants – Genuine professionalism promotes mutual respect and trust on which people cooperate.

Project wide system integration is essential to ensure that the major electrical, mechanical and communication systems operate correctly. System integration requires proven methods of design review, installation, testing, and approval. On large projects where more than one contractor may be designing or installing a particular system the promptness and accuracy of information distribution becomes essential. The electrical, mechanical and communication systems must operate as one complete system and be able to operate in conjunction with one another. If one system fails the facility does not operate as designed or intended.

Although the various forms of project integration can enhance project performance, there are barriers that currently prevent integration. These barriers include the owner's resistance due to perceived extra costs; the traditional roles of construction people; reluctance of architects and engineers to accept input from construction personnel; lack of qualified personnel, training programs, and incentives; and unawareness of potential benefits ("Integrating Construction," 1982) (Nam and Tatum, 1992).

Project Configuration Recommendations and Conclusions

- Owners need a formal constructibility process. Without a formal process, organizations may have difficulty consistently applying constructibility concepts on projects (Radtke and Russell, 1993).

- Only with the owner's team committed to, planning for, and implementing a constructibility program can maximum benefit be achieved (Radtke and Russell, 1993).

- It is suggested that the owner begin planning for the implementation of a constructibility program prior to major project participants entering into a contract with the owner (Radtke and Russell, 1993).

- A constructibility program should ideally begin early in the conceptual design phase of a project (Gibson et. al., 1996).

- The owner leads the implementation effort for a constructibility program by setting project objectives, selecting a contract strategy, selecting constructibility-team participants, and funding constructibility resources during planning and design (Radtke and Russell, 1993).

- The benefits of a constructibility program are a result of an expansion of front-end planning and the investment of additional effort to anticipate and prevent potential problems. Such efforts must be owner driven ("Constructibility," 1987) (Gibson et. al., 1996).

- To function effectively, the project team must have mutually supportive constructibility interests and minimize adversarial relationships (Radtke and Russell, 1993).

- The owner's project team must be aware of and use pre-existing in-house constructibility resources to effectively determine what resources are needed from external sources (Radtke and Russell, 1993).

- To support a constructibility program the owner may incorporate constructibility considerations in the pre-qualification process and the RFP documents as well as contract incentives (Radtke and Russell, 1993).

- To keep the project team informed about the philosophy toward constructibility the owner can initiate an informal orientation concerning constructibility that may include: 1) Definition of constructibility; 2) Constructibility policy for the project; 3) Importance of teamwork and communication; 4) Discussion of project objectives; 5) Discussion of the project critical success factors; 6) Roles and responsibilities of constructibility team members; and 7) General constructibility procedures for the project (Radtke and Russell, 1993).

- Inadequate integration of constructibility input can lead to construction activities occurring out of sequence, inefficient crew concentrations, incomplete bid packages, material shortages, and accelerated design leading to rework (Radtke and Russell, 1993).

- It is suggested that at the end of the project the constructibility team objectively assess and evaluate the functional design as a basis for developing additional lessons learned (Radtke and Russell, 1993).

- The system engineering management plan for each major system of the project shall identify the organizations, facilities, methods, and procedures necessary to manage and control system design, installation, and integration.

- When and where possible identify system interfaces with general civil work and other systems in an Interface Control Document

- Rigby suggests the following recommendations for systems engineering management (Rigby, 1998):
- Identify system design baselines to protect them from uncoordinated and unauthorized change
- Define the policies and methods used to establish and control the baselines
- Outline and define the organizational structure (key positions) for performing systems engineering management and their relationship to project management
- Define the proposed methods for control and monitoring of contractors and vendors
- Define integration and coordination activities for systems engineering management with other project management activities

4.4.3.2 Project Control Program

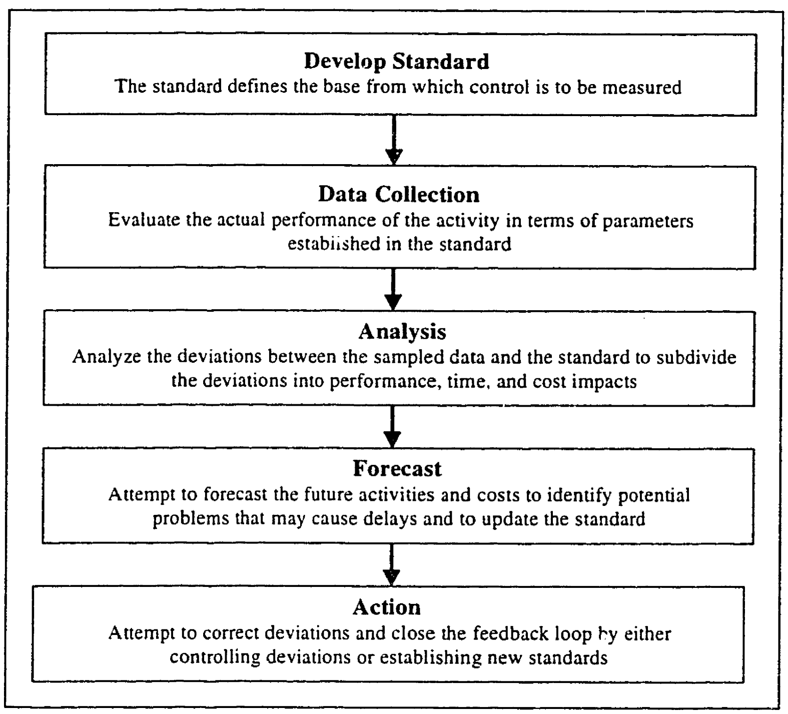
The owner should be involved in determining the requirements regarding project control. An owner has the opportunity to establish the baseline for a project control program that will guide the development of control procedures used by the designer(s) and contractor(s). This baseline should establish a team attitude towards project control, identify who will have authority and responsibility, and work toward standard documentation and information distribution.

The ideal purpose of the project control program is not solely to keep track of the schedule and budget. The ideal project control program helps predict project delays, provides possible causes for the delays, and provides suggestions for corrective action. It is also intended to define the procedures for progress monitoring, testing, reviews, and final acceptance.

Most project control programs are based on a feedback mechanism with which the activity under control is monitored against a standard and observed deviations from the standard are analyzed and, if possible, utilized to initiate action to bring the process back within the limits set by the standard (Crandall, 1983).

The project control program, shown in Figure 4-4, follows a five-step process.

Figure 4-4 Project Control Process



Typical scheduling and control systems currently available generate planning and historical information, but they are not capable of formalizing hypotheses on why variances occur, nor can they present alternative strategies for influencing project performance. Project control systems highlight schedule variance, analyze performance, capture data, facilitate planning and information sharing, and help diagnose problems, but they are not proficient at identifying potential delays, analyzing causes of delays, nor in suggesting corrective measures (Yates and Audi, 1997).

Project managers and control personnel must therefore be proactive and utilize the project control tools available to forecast schedules and budgets, plan for future activities, and make informed decisions about current issues.

Integration Control

There are two main objectives for integration control. The first is to coordinate the project control efforts of the designer, contractor, and owner to efficiently and effectively complete the project on time and within budget. The second is to integrate the cost and schedule systems to attach meaningful cost data to specific activities.

A typical project control program has two related cost control systems. One system, the Work Breakdown Structure (WBS) controls the labor costs associated with specific activities. The other system, the Cost Breakdown Structure (CBS) controls all costs associated with work activities. WBS elements are therefore included in the CBS along with material, equipment, and overhead costs. The schedule can be linked to the cost system by using the same activity codes. These steps increase the effort required during the planning stage as materials, equipment, and labor must be assigned to scheduled activities rather than sum-total line items.

There are many approaches to integrate the owner's and contractor's project control effort. Warren and Mazzini determined that integration concepts concerning attitudes and personnel must grow and develop, and this cannot occur unless the proper environment is present. That environment is one of conciliation, reinforcement, participation, leadership, and impartiality. They identified four distinct approaches listed in increasing degree of integration (Warren and Mazzini, 1983).

- Functional Separation – The most common of the four approaches used today, the owner and the contractor operate virtually independent of one another. The contractor prepares the elements of project control, presents them to the owner, and typically requests approval of the content. Mutual respect by the parties, together with a dedication to common objectives, can create a healthy team effort. The approach can indeed be highly effective, but the danger of competitive attitudes should be recognized and addressed.
- Committee Approach – This approach creates a committee comprised of personnel from the owner organization and the contractor(s). The committee meets periodically to develop, update, and integrate the key project schedules. The committee approach can be valuable when a cooperative attitude and common objectives are present. The major advantage of this approach is that a single position on the issues is obtained. Management discussions can focus on problem correction, since all identified problems reflect a common perception.

- Matrix Approach – This approach employs the integration of project control personnel from both the owner organization and the contractor(s) in a matrix structure. Schedule data is produced, reviewed, and updated with a combined effort. Although each entity continues to be responsible for various parts of the schedule, the owner's project control manager is accountable for total schedule integration. The decision making process is simplified because mutual agreement is not necessarily a requirement. The matrix approach is desirable when the optimum openness, cooperation and common objectives are not completely present.
- Complete Organizational Integration – This approach is the strongest form of integration as it contractually combines personnel from both organizations. Except for the retention of a few administrative ties to the original company there should be no distinction between these groups of employees. The optimum integration situation is created when the group identifies with the project more than their home entity.

Warren and Mazzini determined that project control for mega, or large, projects over $200,000,000 would improve from integration between the owner and contractor. The level of staffing and sophistication required for large projects increases the potential benefit from integration. Integration provides the strength of a combined effort, provides the clarifying processes necessary for purity of progress and performance measurements, and creates the most direct path to the ultimate destination of project control – project success (Warren and Mazzini, 1983).

Progress Monitoring

The project control program using earned value analysis is intended to monitor the progress of the design and construction work by comparing actual work completed with budget and schedule projections. A few project control metrics that are useful in monitoring the progress of the work are listed below.

- Actual Cost of the Work Performed (ACWP)
- Budget at Completion (BAC)
- Budgeted Cost of the Work Performed (BCWP)
- Budgeted Cost of the Work Scheduled (BCWS)
- Cost Variance (CV) – difference between budgeted and actual cost of work performed
- Cost Performance Index (CPI) – the BCWP/ACWP
- Estimated Cost at Completion (EAC)
- Earned Value (EV) – the [ACWP/EAC]*BAC
- Schedule Performance Index (SPI) – the BCWP/BCWS
- Percent Complete (PC) – ACWP/EAC

These metrics can be used to evaluate and compare the project's current budget and schedule standing with specified milestones.

It is important to remember that successful project control systems are designed such that they will be used by and useful to people. Project personnel will ultimately control project cost and schedule, not the project control systems.

Cost Control

Given an owner has invested considerable time and thought in capital planning, the owner will have determined clear and concise goals. These goals then become the major objectives of cost control. Cost control as a comprehensive approach can be defined as (Dean, 1983):

- Budgeting – establishment of a clear cost plan or model by which all subsequent project costs must be measured
- Estimating – definition of project scope in context of costs, labor, materials, equipment and other resources
- Value Engineering -- The refinement and optimization of resources and their costs, short and long term, resulting in a successfully performing product
- Procurement – Effective purchasing and installation of the appropriate components, all within the budgeted and estimated costs
- Accounting – Continuous process of recording, managing, and projecting costs for pro-active decision making and completion within budget

Budgeting, rather than being an exercise in exactness, is an exercise in cost management, strategy and planning. It serves as a communications tool, an initial project pro forma, specification outline, and a basis for a project delivery plan (Dean, 1983).

Cost estimating is a mixture of art and science. The science of estimating relies on historic costs, while the art is in visualizing a project and the construction sequence, selecting comparative historic costs and adjusting them to anticipated new conditions (Carr, 1983). Without good, detailed, timely estimating, there is no sense of project scale related to cost. There is a major void in management information and control and therefore knowledgeable purchasing and project delivery becomes virtually impossible (Dean, 1983).

Project accounting allows the entire team to maintain a comprehensive view of where the project currently stands financially, and will stand at its completion (Dean, 1983).

Schedule Control

The schedule indicates the timing and sequencing of activities within a project. A schedule consists of activities, activity dependencies, durations, constraints, and time-oriented project information. The Critical Path Method (CPM) for scheduling is a project management method used to calculate the total duration of a project based on individual activities and their dependencies. The critical path is a series of dependent activities that must be completed on time for the project to finish on time. Naturally all activities are not critical activities (on the critical path). Non-critical activities have float or slack associated with them. Total slack is the amount of time an activity can be delayed without delaying the finish date of the project. Free slack is the amount of time an activity can be delayed without delaying its successor activities.

Recent trends have decreased the importance of the CPM scheduling technique. Although it is still used extensively, short-term progress monitoring and forecasting in the field typically utilize simple bar charts with associated activity information.

Contingency Control

Generally all projects include a contingency for unexpected or excess costs in the preliminary and working estimates. Although the ideal is to reduce the contingency by detailing the design and evaluating risks, some allowance for the unexpected is included in the working estimate. Changes or unexpected conditions can cause delays and increase project costs. A contingency log is useful to monitor the contingency reserve for the project. The contingency log will list the description of the event, party responsible, the date of discovery, current cost impact, current schedule impact, proposed action, status, contingency used, and the contingency balance.

Project Configuration Recommendations and Conclusions

- An owner must establish a single set of informational standards for use by all contractual parties to eliminate the confusion resulting from many separate contractor control systems (Crandall, 1983).

- The owner and its representatives must complete, early in the organizational process, an evaluation of internal and external informational needs necessary to satisfy control and documentation requirements (Crandall, 1983).

- Project Managers should be well-educated and trained in the importance and use of the project control system (Diekmann et.al., 1987).

- Crandall points out that owners must be willing to do whatever is necessary in terms of time and funding to establish a control environment prior to starting a mega-project (Cox, 1983).

- Cost control during the project configuration phase means managing costs by clearly identifying owner budget constraints, comparing, analyzing and estimating project scope alternatives, procuring project contracts and components within the budget, and documenting expenditures for historical record.

- It may be useful for the owner to conduct a CPM orientation and schedule control seminar for all contractor and selected subcontractor project control personnel.

- As a basis for progress monitoring and progress payment the owner should receive from the contractor each week, a progress report that indicates actual start and finish dates for all activities in progress, percentages of completion, and activities the contractor plans to start the following week (Dellon, 1983).

- It is good practice for the owner, contractor, and project/construction manager to review and update the schedule each month.

General Recommendations and Conclusions

- Two findings from a study on project control conducted by the Construction Industry Institute (CII) are important to consider when developing a project control program.

- First, people, not systems, are the key to a successful project. For a project control system to be effective, the people using the system must understand the importance of it as well as understand how to use it (Diekmann et. al., 1987).
- Second, while all owners perceive their role in project control to be one of giving direction and monitoring the progress of designers and contractors, their application of that role varies from one of heavy involvement to one of only summary-level involvement. Those owners who exercise close involvement seem to be the most satisfied with their project results. Designers also agree that heavy client involvement (but not micro-management) was a key factor in successful projects (Diekmann et. al., 1987).

- A general approach to integrated project control developed by Neil (Neil, 1983).
  1. Definition of the project scope
  2. Determination of tasks and methods to complete the project
  3. Work packaging of tasks – WBS codes
  4. Assignment of responsibility for work packages
  5. Determination of resource requirements within the work packages
  6. Planning and scheduling of work – Logic Network/CPM
  7. Preparation of resource budgets to parallel the schedule
  8. Measurement of work accomplishments
  9. Collection of cost and resource expenditure data
  10. Analysis of data; remedial action as necessary
  11. Forecasting
  12. Input into historical database

- Use of an integrated work breakdown structure and cost breakdown structure will help associate costs with project tasks. A general approach to cost and schedule integration, a modified version of one developed by Neil (Neil, 1991), follows:
  1. Develop control budget based on the WBS
  2. Identify all project elements on the WBS
  3. Group the project elements into work packages
  4. Make reference to work packages on the project schedule
  5. Determine control points or milestones for each package
  6. Use earned value analysis for progress measurement

- An example layout for a project control data base, modified from one developed by Neil (Neil, 1993), is as follows:
  Column 1 – the identification of each work element
  Column 2 – the work element's package number and schedule activity number
  Column 3 – the budget for the work element
  Column 4 – the cumulative-to-date expenditures for the work element
  Column 5 – the control points/milestones and their assigned value percentages
  Column 6 – the percent complete of the work element for each control point
  Column 7 – the work element's total percent complete

Column 8 – the earned value for each work element (Col 3 x Col 7)
Column 9 – the performance index for each work element (Col 3/Col 4)
Column 10 – Budget forecast to complete each work element
Column 11 – Cost variance to complete each work element (Col 3 - Col 4)

- Engineers should be given more responsibility in developing schedules. More realistic schedules will be produced and engineering will then be committed to keeping those schedules because they are their schedules (Diekmann et. al., 1987).
- If the same work breakdown structures are used for both estimates and project control, quantity takeoff estimates generated by the design engineer can serve as a method of control where costs can be adequately represented by unit costs.
- Including the design engineer in the development of control estimates will increase their commitment to support them. The design engineer's participation in estimating quantities creates a process that immediately detects the effects of design decisions on material quantities and cost.
- When construction progress has reached about 70-85% complete, the logic of remaining work activities is revised in a manner that it can be related to start-up operating systems. This allows for coordination between the two phases (Nethery, 1987).
- There is no substitute for doing it right the first time, and that requires commitment to project control by all people in the organization, especially the crew foremen who report the time and perhaps quantity data. In return for that commitment to accuracy, those data collectors should see the value of their efforts (Ibbs, 1987).
- The Successive Estimating concept developed by S. Lichtenberg focuses on identifying project elements which have a high cost uncertainty and sub-dividing them until the cost variability has been reduced to an acceptable level (Halpin, 1983).

4.4.3.3 Change Management Program

The owner is typically involved in determining the requirements regarding change management for a project. An owner has the opportunity to establish the baseline for a change management program that will guide the development of change management procedures used by the designer(s) and contractor(s). This baseline should establish a team attitude towards managing change, identify how potential changes are processed, and work toward standard documentation and information distribution.

Project change occurs when circumstances arise that result in modifications to the existing project plan. It is generally accepted that all circumstances cannot be anticipated, therefore the next best course of action is to develop a process to accommodate change before it occurs. Change management includes identifying, analyzing, planning for, communicating, and monitoring the uncertainties brought on by change. Effective change management occurs when a source of change and its effect on the project are identified ahead of time. An effective change management program will reduce project delays, enhance project teamwork, improve project quality, and maintain project financial performance. The project scope and contract documents form the baseline for the determination and measurement of change, and therefore must be clear and complete to facilitate the identification of change. The change management program must have a process for identifying issues, which are actions or circumstances that can cause changes in scope, personnel, cost or schedule.

A well-defined project, a good organizational structure, and a good project control system generally result in smooth classification and control of changes. A change can be either within the scope to complete the project as originally planned, or outside the original scope. The later, naturally, are referred to as scope changes. However, on a poorly defined project the impact of a design change can be difficult to classify, quantify, and justify.

There are many potential sources of design changes. Design professionals must balance process and structural considerations with regulatory, maintainability, serviceability, and human factors. Multiple designers and interfaces generally increase the potential for changes. The design compatibility between multiple design disciplines often becomes a source of change. Generally, the owner's management, safety, and operations and maintenance staff also have the opportunity to request design changes at scheduled design reviews.

It is important to recognize that a change in project scope can have many potential impacts. A change in scope can lead to lower productivity, additional work hours, increased cost, and/or increased project duration. When considering the effect of a design change the point in time the change is introduced is of particular importance. Changes at the beginning of a project can be accommodated much easier than towards the end. At later times certain changes may require significant rework or delays.

The effect of a change on other work activities can be determined by examining a critical path (CPM) schedule that illustrates the relationships between activities. A change in one activity will affect other activities that have a dependent relationship with the changed activity. It is important to remember, however, that there is always potential for consequential effects to activities that are not directly connected to the changed activity. The CPM schedule will also identify the total float and the free float associated with an activity. Ownership of float is typically a subject of controversy. The contractor wants to use float as a management tool to manage resources and keep the project on schedule. The owner usually desires to retain ownership of the float to reduce the impact of owner initiated delays.

The incorporation and management of change to a project can be facilitated through procedures outlined in a change management program. An example of a change management system developed by Professor William Ibbs is shown in Appendix B. The change management program promotes the early identification, evaluation, and incorporation of necessary changes to the project.

Change Control Log

The change management program should also provide a framework for project team members to make decisions when change occurs. Managing change requires planning, discipline, and communication between the project team members to develop a response to identified change issues. The response will address what needs to be done, who is going to do it, when it is going to be done, an estimate of how much it will cost and how much time it will take, how quality will be ensured, and how it affects other project activities. This analysis is a great challenge as the scope of the change and the related impacts to other activities may be difficult to determine.

The change control log includes a description of the potential change, the party responsible, discovery date, potential cost impact, potential schedule impact, current action, status, final cost impact and final schedule impact. The change control log will facilitate the efficient recording of data and tracking of status.

Project Configuration Recommendations and Conclusions

- Owners, engineers, and contractors should establish a team approach to change management and openly communicate on the subject.
- At the outset of a project the owner and contractor should establish mechanisms and procedures for administering changes.
- The owner should identify the individuals with the authority to direct and approve changes and the contractor should identify the individuals with the authority to receive change orders.
- A well-constructed change clause defines the existence of a change, the procedures and time required for approval, the negotiation of cost and schedule, and the resolution of disputes.
- All changes should be in writing
- The project team should make a concerted effort to resolve changes in a timely manner as they occur.
- Effective, knowledgeable and cooperative construction contract management by multiple organizations is necessary to ensure timely and equitable change order resolution. Recognizing, understanding and addressing valid change order impacts on labor productivity is a critical aspect of responsive contract management (Coffman, 1997).
- A primary conclusion of a study on the Quantitative Effects of Project Change for CII was that labor productivity on original scope work is negatively affected by the amount of change work performed on a project ("Quantitative," 1995).

Whether changes are considered project development or a change in scope, there is a clear need to have a change management program to control their impact. CII suggests that the following elements be included in a change control program (Neil, 1986).

- Owner commitment to change control – If change control is not supported from the top, there is little potential for successful control. A change control committee composed of the top mangers will have the authority to approve changes.

- Team Effort – A cooperative atmosphere between the owner, design professional, and contractor will increase the effectiveness of the change control program. Clear communication between project team members will facilitate the recognition, reporting, and management of changes.

- Freezing the Design – Attempts to freeze a design are clearly the most effective in controlling scope changes. However with increased overlap between the design and construction phases, attempts to freeze the design become less realistic. Under these circumstances construction and change control will begin before the design is complete.

- Formal Change Justification – Changes must be reviewed and approved by the change review committee. It is important that all affected parties review proposed changes.

- Filtering Changes from Owner Personnel – The owner must designate which owner representative(s) has authority to introduce changes. Then all owner-generated changes are filtered through the designated individuals.

4.4.3.4 Risk Management Program

The owner should be involved in determining the requirements regarding risk management for the project. An owner has the opportunity to establish the baseline for a risk management program that will guide the general distribution of risk as well as the development of risk identification, control, and communication procedures used by the designer(s), contractor(s), and operator(s). This baseline should establish a team approach toward risk management, identify who will have authority and responsibility, and work toward standard documentation and information distribution.

The purpose of the risk management program is to identify the organization and methods necessary to provide effective management and control of the administrative, financial, management, and technical risks at the project level.

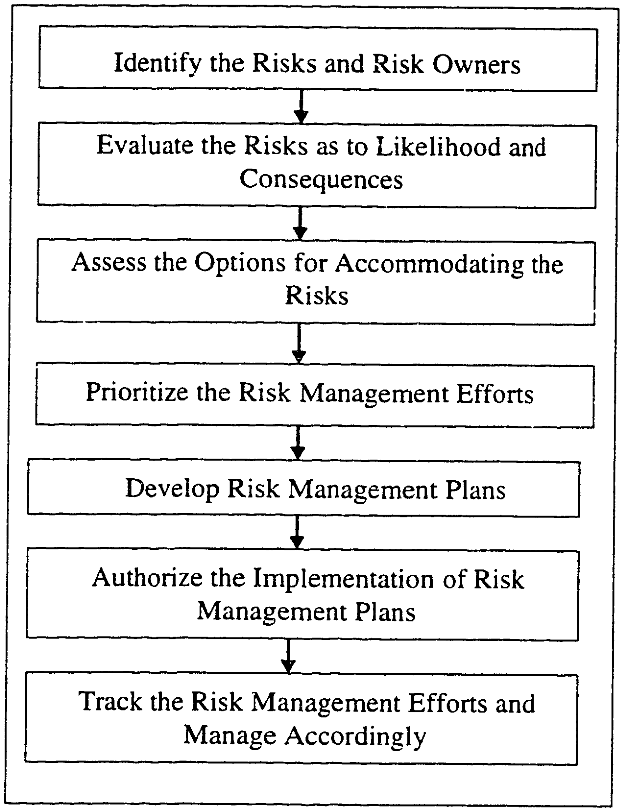
It is essential to consider a risk management program during the project configuration phase. The driving force is that for risk management to be truly effective it must be proactive. Good planning on any construction project involves careful, reasonable, realistic and equitable risk management and risk allocation and since problems cannot always be anticipated, methods of problem resolution must be created in advance (Groton and Smith, 1997).

Initially all risks reside with the owner. Owners must define their needs very precisely in terms of size, cost, quality, and location. After the initial definition, each of these elements will require extensive refinement. An owner cannot design and construct the project alone and must assemble a project team to perform essential functions. Project risks must be allocated among the members of the project team. At the most basic level all owners risk not receiving the intended end product either because of defective design and/or construction or due to overruns in cost and schedule. The project team members risk not being adequately compensated for services rendered. When allocating specific project risks it is important to remember that risk should be assigned to the team member who is most qualified to assume the risk and perform the work.

Risk Management

The traditional steps of risk management are useful here: planning, identification, analysis, management, and tracking. A Risk Management Process developed by Rigby and Simmons is shown in Figure 4-5.

Figure 4-5 Risk Management Process



Risk Identification

Risk on construction projects is a result of uncertainty. Uncertainty arises when the owner and contractor attempt to assess the cost and expected return for certain options while recognizing their risks, such as potential cost increases and schedule delays. In general, there are three types of events; those that are recognized and their effects are known, those that are recognized and their effects are unknown, and those that are not yet recognized. The challenge is to estimate the risk associated with the uncertainty of such events. It is important to emphasize that uncertainty should not be ignored, as the results would be based on assumptions that are arbitrary and often lead to disputes. Typically, owners and contractors use contingencies to protect themselves against such risk.

In general, risks can be classified as contractual or execution. Contractual risks naturally arise from the contractual relationship between the parties. Efforts to draft clearly written contract documents and to administer the contract fairly will generally minimize contractual risks. Execution risks are associated with the performance of design and construction work. Within the category of execution risks, there are performance risks – those inherent in the proposed approach; and unforeseen or external risks – those that are beyond direct control. Some risks are uncontrollable such as the weather but others can be managed and minimized through appropriate risk allocation.

The owner can use project drivers and objectives to identify and assess many of the potential risks associated with the project. A common source of risk is when an organization attempts a venture with elements that exceed their experience and capabilities. Risk management therefore involves identifying the new aspects of the venture in question, and then adopting strategies to avoid, mitigate or otherwise accommodate the identified issues (Rigby, 1998).

There are many potential risks that can affect the success of a project. A checklist of typical project risks, modified from a risk management checklist developed by CII, is provided in Appendix C. The checklist can aid an owner in the identification of potential risks and areas of uncertainty.

Risk Control

Once identified, risks must be prioritized and allocated to the project team members. The analysis of these risks should include financial, regulatory, design, construction, and operation impacts on the success of the project. Proper allocation of project risk to the party most capable of mitigating the risk is critical. If the responsible party is going to truly manage a risk, that party must be able to affect the outcome of the related circumstances by exercising control. Gordon states that a company's efficiency in handling risk is based on its power to control the risk, its possible reward for controlling the risk, and its financial position to assume the risk (Gordon, 1994).

There are different options that are available to manage risks. An owner can use:

- Risk Avoidance – Use an alternate approach that does not have the risk
- Risk Control – Attempt to reduce and track the risk
- Risk Sharing – Reduce risk through joint venture or partnering efforts
- Risk Assumption – Simply accept the risk and proceed
- Risk Transfer – Attempt to pass the risk to another project participant
- Insurance – Financially insure against the occurrence of risk events

The key elements of risk control are:

- Contingency Planning – contingencies can be used to offset the losses associated with risk events, thorough analyses and planning can reduce these loses

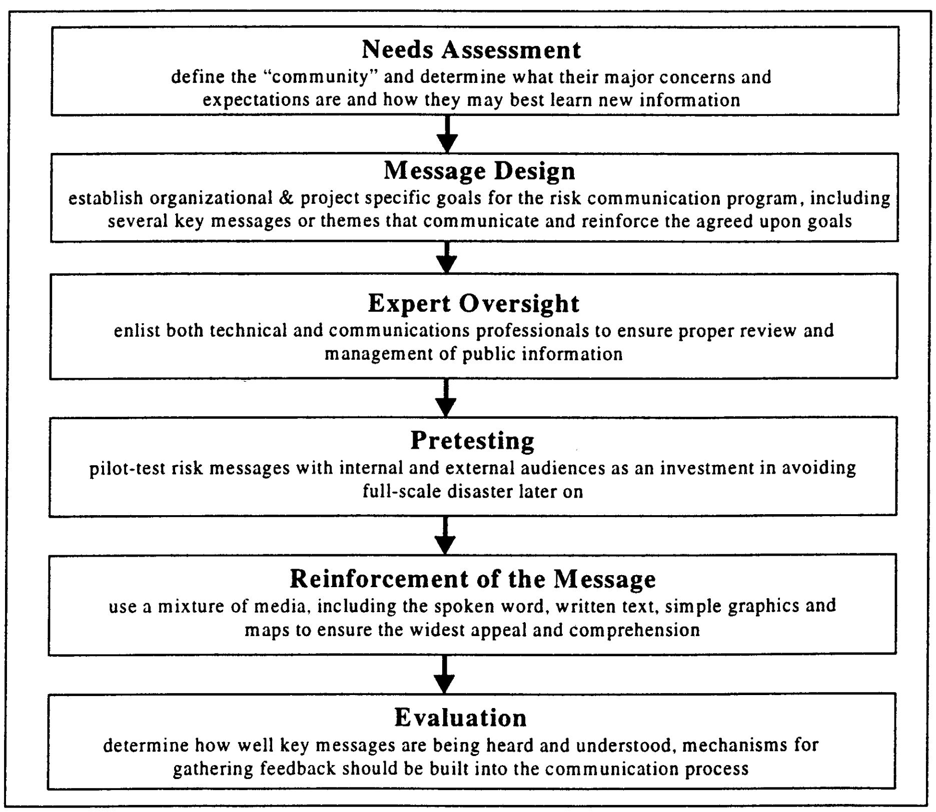
- Responsibility Allocation – risk control should be assigned to the party most capable of mitigating the risk
- Constructibility Program – constructibility analysis may help identify risks earlier
- Project Control Program – effective monitoring and forecasting may help identify risk events
- Safety Program – an effective safety program reduces the risks associated with site accidents
- Risk Re-evaluation – risk exposure should be re-evaluated as the project progresses

Risk Communication

The importance of community relations and risk communication for large infrastructure projects cannot be overstated. The relationship between the affected community and the project team has evolved from informing the public, to involving the public to maintain good relations. Taking charge of a project's community relations agenda through a proactive approach creates an opportunity to communicate project goals and risk information in the early stages of public awareness about site issues (Perry, 1996).

A sample Risk Communication Process developed by Perry is illustrated in Figure 4-6 (Perry, 1996).

Figure 4-6 Risk Communication Process



Project Configuration Recommendations and Conclusions

- Ownership of risk is the central issue in risk management (Rigby, 1998).

- Owners should establish their risk management philosophy early in the configuration phase. The philosophy may range from ultra conservative - transfer all risks to others, all the way to the highly confident – minimize the risks to others (Graham, 1983).

- Because different project delivery methods organize the project phases differently, each method allocates risks differently (Rubin and Wordes, 1997).

- The single decision that will most greatly affect relationships and risk allocation on a construction project is the choice of project delivery method (Groton and Smith, 1997).

- Graham points out that risk and costs are synonymous and that failure to manage risk increases cost (Cox, 1983).

- A balancing of the risk should be sought between the owner and his or her contractor or designer in order to utilize the incentive value of bearing risk while minimizing a contingency charged for accepting the risk (Gordon, 1994) (Levitt, 1980).

- Clear risk assignment means that both contracting parties have the same understanding of risk apportionment and risk management accountability. Contracting parties that do not have an identical understanding of risk accountability may mismanage a risk event by assuming the event or its consequences are not their responsibility (Hartman and Snelgrove, 1996).

- Mismanaged events cause project inefficiencies and make contract relationships adversarial which ultimately results in increased project costs (Hartman and Snelgrove, 1996).

- The relationship between contract documents and claims is well established and the owner who is intent on managing risk must insure that realistic and carefully prepared documents are issued (Cox, 1983).

- "Eculpatory Language" clauses in the contract documents intended to shift contract risk onto the contractor in areas beyond the contractor's control, generally do not reduce costs, but actually increase costs as a prudent contractor will price the risk into the bid (Cox, 1983).

- Because the project belongs to the owner, the owner generally bears the risk of acts of God, of subsurface conditions, or of any other unforeseen events which the designers or builders are not normally qualified or paid to assume (Groton and Smith, 1997).

- Contingency funds should be distributed across all the contingent accounts. The distribution should reflect the level of uncertainty and potential loss associated with each risk.

- A crisis management plan, that provides guidance to project personnel in the handling of situations which attract media attention, should be available and well-known to key project personnel ("Management...", 1989).

- Rigby suggests the following recommendations for risk management (Rigby, 1998).
  - Every risk identified in the program should have an organization tagged for ownership, and a position holder should be tagged as managerial lead for its resolution.

- The risk owners should also be the owners of the associated expertise, resources, and mission to do the job.
- A risk manager is recommended if a project is large enough to afford one. The role for this position will be to capture and formalize risk management activities and results and will not be to have direct responsibility for any risks. The risk manager is responsible for the definition, structure, implementation and coordination of a risk management approach and includes being a spokesperson for project risks.
- Use whatever tools are available and meaningful in a given situation, but do not get hung up on mathematical artifices that do not really have any more precision than an informed judgement.
- A matrix can be useful as the understanding of the risks evolve, producing a useful graphic for risk identification, ownership, criticality, and priority.
- The task of prioritizing risks is performed at the senior staff level to assure that all political, business, and programmatic factors are weighted in the priority assessment.

▪ Perry suggests the following recommendations for risk communication (Perry, 1996).
- Improve public understanding of site risks
- Communicate project goals, risk messages and other site information from the organization's perspective
- Listen for and respond to the community's concerns
- Build a rapport, credibility, trust and long-term good will
- Avoid project delays and associated costs caused by negative public reaction
- Select a single credible spokesperson, work to establish trust and consistently use that spokesperson to deliver all public information until project closure.
- Avoid the traditional decide-announce-defend approach to risk decision making and risk communication

4.4.3.5 Dispute Prevention and Resolution Program

The owner should be involved in determining the procedures that will be used to resolve disputes and claims on the project. An owner has the opportunity to establish the baseline for a dispute prevention and resolution program that will guide the actions of designer(s), contractor(s), and operator(s). This baseline should stress open communication through the team building process, identify procedures for dispute escalation, and work toward resolving disputes without resorting to litigation.

Conflicts are typically unavoidable. The challenge for project managers is to manage conflict and produce constructive resolutions. Every effort should be made to prevent disputes or simply resolve the dispute at the level from which it arose. If resolution is not possible, dispute escalation should follow agreed upon procedures. Good conflict resolution practice often includes the following steps:

- Clarify and define the issue
- State points of view clearly
- Establish what is agreed upon
- Prioritize the pending issues
- Propose alternative solutions
- Agree on potential solutions
- Document the agreement

- Check the results

Open and honest communication within the project team can significantly reduce the amount of potential disputes and claims. If the owner, designer(s), and contractor(s) can agree on the services to be performed, the timing and quality regarding those services, and the compensation for those services most disputes will be avoided. If each party acts responsibly and can agree on reasonable solutions it is possible to complete a successful project and for all members of the project team to be adequately satisfied.

If disputes persist the claims may result in litigation or arbitration. As a rule if a project enters into litigation all the project team members will not be satisfied. Litigation utilizes the well-known formal court proceedings. Arbitration is a formal and structured procedure. The parties must agree within the contract that in the event of a dispute, they will use arbitration to resolve the dispute. The most common forum for the arbitration of disputes in the construction industry is the American Arbitration Association (AAA), a national non-profit administrative agency. If properly executed the arbitrator(s) should have a clear understanding of the facts and the position of each party in the dispute before rendering a decision. Most states have now adopted laws to enforce the binding effect of arbitration proceedings (Treacy, 1989).

However, in addition to litigation and arbitration, there are various voluntary and non-adversarial alternative dispute resolution (ADR) procedures available such as negotiation, contract dispute review boards, and mediation. Negotiation is a voluntary dispute resolution process. A voluntary pre-hearing or pre-trial are common forms of negotiation (Muller, 1991).

A Dispute Review Board (DRB) is typically created by contractual agreement. Most DRB consist of three members, one selected by the owner, one by the contractor, and the final one by the two board members. Each member must be acceptable to all parties. The DRB meets on a regular basis to keep informed about the project and will formally convene when the parties are unable to resolve a dispute.

Mediation is a voluntary procedure that can be used to seek a negotiated solution. Mediation is an intervention between two or more disputing parties in order to effect an agreement, settlement, or compromise. The mediator is typically an impartial third party. Meetings, both joint and individual, are held with the mediator. In general the mediation process is intended to persuade the parties to understand the positions of all those involved and to reach an agreement. If this fails, mediation relies on the outside impartial discretion of the mediator. Therefore, the individual who serves as the mediator must be credible and knowledgeable in the disputed subject matter and must be acceptable to both parties. A mediator generally has limited authority and has no power to make decisions or dictate settlement terms (Muller, 1991).

Project Configuration Recommendations and Conclusions

- Open and honest communication within the project team can significantly reduce the amount of potential disputes and claims.

- As a general rule if a project enters into litigation all the project team members will not be satisfied.

- One practical disadvantage of arbitration, when arbitrators are selected by the parties involved, is the conflict of interest for the arbitrators concerning whether they are to be their party's advocate or completely impartial (Treacy, 1989).

- The main advantage of mediation is the cost effectiveness of resolving disputes at such an early juncture. Experience has shown that the success rate of mediation is over 80% (Muller, 1991).

4.4.3.6 Quality Management Program

The owner should be involved in determining the requirements regarding quality management for a project. An owner has the opportunity to establish the baseline for a quality management program that will guide the development of procedures used by the designer(s), contractor(s), and operator(s). This baseline should establish a team approach toward quality management, identify who will ensure quality, and work toward standard documentation and information distribution.

A high quality project is the result of an early commitment to the execution of quality work by the project team members. The team building and value engineering processes can help the owner obtain a unified commitment to ensuring high quality design and construction. Quality is generally enhanced when tasks are completed correctly the first time, therefore team members must be dedicated to managing quality from the outset. A quality management plan will help establish quality expectations. It is important to remember that quality work is not synonymous with perfection, but is work that meets or exceeds project standards established by the Project Team.

Typical quality assurance methods include:

- Project Team Building
- Independent Engineering/Design Check
- Project Team Design Reviews
- Progress Monitoring
- Systems and Facilities Testing
- Systems and Facilities Acceptance

CII found that the team build process facilitated the communication of quality issues, led to earlier recognition of potential problems and helped develop a quality consciousness ("Team Building...", 1993). An independent check of the project engineering/design will help ensure a high quality and safe facility. Design reviews, progress monitoring, and systems/facilities testing and acceptance conducted by quality assurance and quality control personnel will help ensure the facility is safe and satisfies operational standards.

Ensuring quality is a leadership responsibility of the project manager. This responsibility should not be delegated, however external experience and expertise can be sought to help fulfill this responsibility. When configuring the project the project manager should establish processes that make quality a continuous element throughout the delivery of the project. The quality management plan outlines the quality processes that should be followed throughout the project. Criteria included in the plan must be stated in clear and measurable terms such as time, cost, production specifications, and performance levels.

Project Configuration Recommendations and Conclusions

- A check on engineering and design by an independent architect/engineer/designer will help ensure a high quality and safe design.

- Value engineering processes offer the project team another chance to review the design and to propose alternative methods that satisfy or exceed the performance requirements.

- Quality can be enhanced if procedures are used that require contractors, then QA/QC inspectors, and then the owner's representative to sign off approving completed work, as it will require individuals to be responsible for their own work (Paulson and Sanvido, 1992).

- The quality assurance staff should be responsible for receiving all drawings, distributing them to the field, and retrieving old versions of drawings to prevent field personnel from working with outdated drawings (Paulson and Sanvido, 1992).

4.4.3.7 Safety Program

Owners are always concerned with safety regarding the project work site. Establishing safety program requirements and incentives during the configuration phase will place emphasis on the importance of site safety early in the project.

The personal safety and health of all employees associated with the project is of primary importance. The prevention of occupational injuries and illness is of such consequence that it should be given precedence over operating productivity whenever necessary. Any safety management policy must stress accident prevention and require the prompt notification of accidents and injuries. It is important to recognize that a good safety record is strong evidence of good management.

A few key components to a safety program are as follows:

- Contractor Safety Manuals
- Safety Committee
- Safety Training Sessions
- Site-specific Safety Training Sessions
- Safety Incentives

Each contractor should be required to develop a corporate safety manual that addresses all aspects of job safety and includes procedures for all personnel to maintain safety standards. Each contractor should submit a safety manual to the owner to be subject to review and approval. Naturally each employee should be knowledgeable about and exercise their respective company's approved safety procedures.

If the project is large enough and there are a large number of contractors working on site, project site safety may be improved through the empowerment of a safety committee. A safety committee may be created to:

- Establish rules and programs designed to promote safety and make known to all employees the established rules and programs
- Establish and promote safety incentive programs
- Provide all supervisors with copies of appropriate rules and regulations
- Provide necessary training for employees to perform their tasks safely
- Provide protective equipment where required
- Impress upon all the responsibility and accountability of each individual to maintain a safe work environment
- Record all instances of violations and investigate all accidents
- Discipline employees disregarding safety policies
- Conduct safety inspections, maintain records, and monitor the program's effectiveness

Accident prevention is best performed through constant monitoring, safety training sessions, site-specific safety training sessions, and safety incentives. Education and communication on safety issues is best achieved through training sessions. Each employee must have the required training to perform their given task. Site-specific safety training sessions provide opportunities to review past accidents and their causes, current activities and accident potential, hazardous substances on site, and future potential hazards. The most effective way to prevent accidents may be through the use of safety incentives. The safety program may reward individual based on the performance of their work with a clean safety record. Often company wide safety incentives are based on lost-time injury rates and total recordable injuries. It is important to recognize that incentives of this nature may discourage reporting of accidents and injuries and therefore management must also develop methods to ensure prompt notification.

Project Configuration Recommendations and Conclusions

- The owner should require each contractor to submit a safety manual for review and approval.

- Safety procedures must abide by all Federal, state, local, and OSHA codes and regulations.

- Encourage safety and accident prevention through the use of safety incentives.

- Stress prompt reporting of all accidents and injuries to management.

- Require weekly site specific safety meetings to review past accidents and their causes, current activities and accident potential, hazardous substances on site, and future potential hazards.

4.4.3.8 Data Management Program

Archiving design, construction, and particularly operation costs in a data management program is essential for an owner to know the actual costs for constructing and operating the facility. This will allow owners to fairly assess the value of the facility when it comes time to renovate, decommission, or sell the facility.

The intention of the data management program is to establish the data management requirements for an owner. The purpose of the data management program is to provide historical budget and document information regarding contractually identified data items in areas such as management, financial, administrative, and technical.

The prime functions of a data management program, as identified by Rigby, are as follows (Rigby, 1998):

- Administration of contract record keeping
- Data copying control
- Data quality control
- Acquisition/administration of supplier data
- Storage and retrieval systems
- Maintenance and control of supplier-developed information and purchaser-furnished information
- Pricing data
- Planning, scheduling, and delivery data

It is important to standardize quantity measurement methods used for estimating, statusing, and reporting. Once these are standardized the historical database will prove much more useful in preparing future estimates and evaluating bid proposals. A standard work task code structure is an efficient mechanism for inputting information into the database.

Project Configuration Recommendations and Conclusions

- It is useful for the owner to establish standard documentation requirements at the outset of the project.

- Complete and accessible historic budget and document records should reduce claims and disputes on current projects and improve estimates for future projects.

- An owner and contractor must maintain thorough estimating, planning, and controlling records as baseline documents to identify changes. When a change occurs additional records must be prepared to show all implications of that change.

5 Central Artery: Case Study 1

The two case studies are intended to illustrate how project planning, or configuration, is currently executed in a mixed delivery setting. The Central Artery/Tunnel Project in Boston facilitates the examination of a large-scale infrastructure project utilizing traditional design-bid-build procurement methods in conjunction with a management consultant assisting the DPW, the lead public agency. The case study identifies common challenges to successful project completion as well as current barriers to implementing the proposed Project Configuration Process.

5.1 Background

5.1.1 Identification of Need

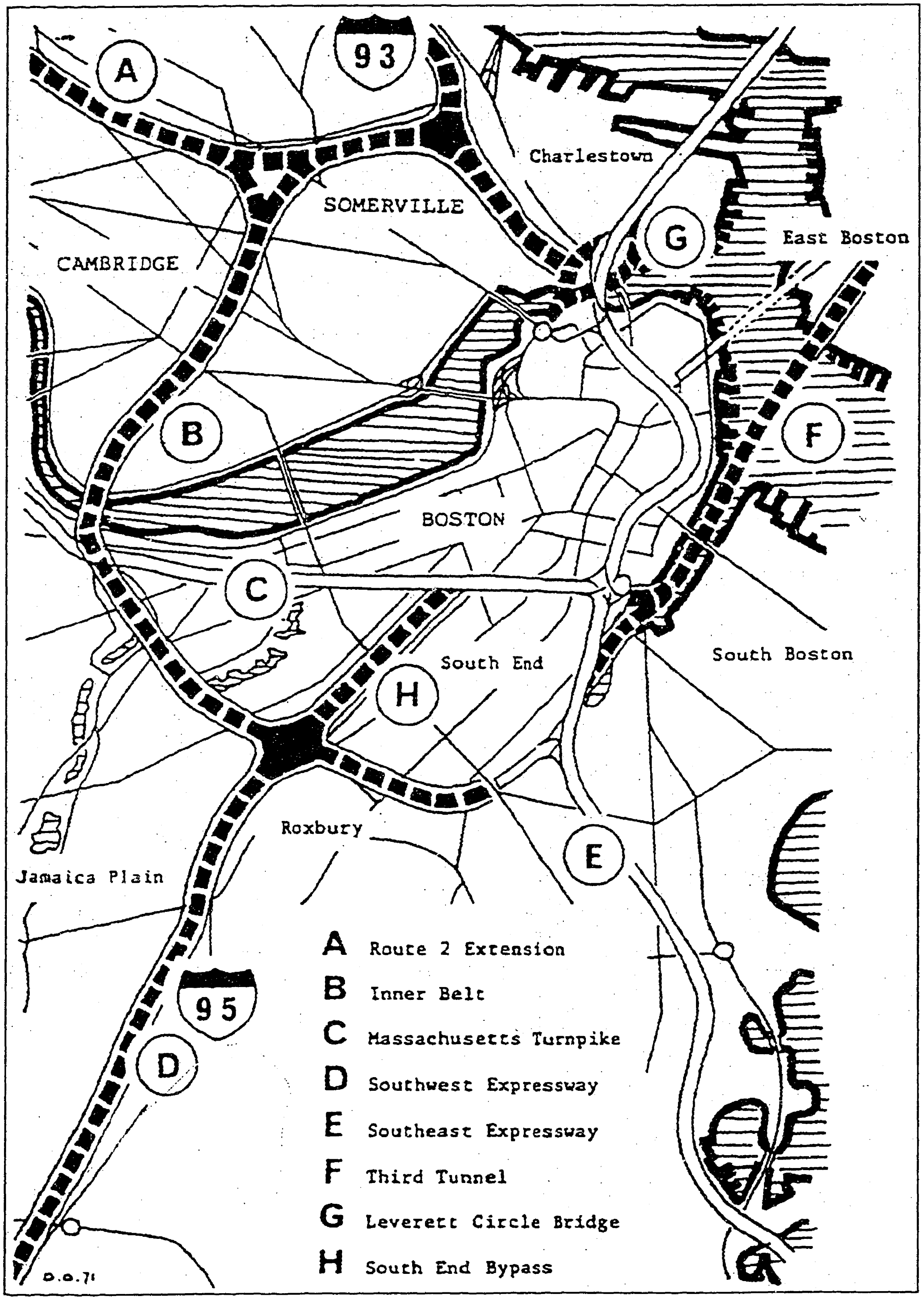
The existing elevated artery was completed in 1959 amidst the tail end of a pro-highway movement after World War II. The 1.5 mile elevated structure was designed to carry 75,000 cars per day and now carries over 200,000 per day. Due to increasing congestion, lack of traffic flow, lack of proper merge and weave lanes, and poorly located ramps the elevated artery was in need of improvement at the time it opened.

In addition to the elevated artery there are two existing tunnels under Boston Harbor. The Sumner tunnel completed in 1934 and the Callahan tunnel completed in 1961. These tunnels carry traffic from downtown Boston to East Boston and Logan Airport.

For years pro-highway and a variety of anti-highway coalitions battled over the merits of expanding Boston's transportation infrastructure within the limits of Rte 128. Proponents believed expansion was needed to increase capacity, while opponents believed new construction induced more traffic and invaded local neighborhoods. Figure 5-1 shows that the elevated artery was constructed as part of a larger transportation program for the Boston region, which had recommended construction of several controversial radial and belt expressway facilities inside of Rte 128. The major pro-highway groups included business communities, contractors, and labor unions. The major anti-highway groups included neighborhood groups that were concerned about localized housing and job displacement and well-educated activists that argued highways were destroying vital neighborhoods and contributing to sub-urban sprawl (Luberoff et. al, 1993).

Two major ideas were proposed to help improve Boston's ailing and congested transportation network. The first was the Third Harbor Tunnel (THT) crossing that would connect downtown Boston with East Boston and Logan Airport. Proposals for a THT were made to reduce congestion on the existing artery, provide easier access to Logan Airport, and accommodate the future growth of Logan and the downtown business community. Those who supported a third tunnel were also divided over the design and use of the tunnel. The main difference was over whether the tunnel should be designated a special-purpose tunnel for high occupancy vehicles and modes of transit or a general-purpose tunnel open to all forms of traffic. The second idea involved the widening and depression of the existing Central Artery. Although it was clear that Boston's

Figure 5-1 Regional Transportation Plan: Major Areas of Controversy
Source: (Luberoff et. al., 1993)



transportation network needed improvement, throughout the 60's and 70's neither idea gained sufficient support to survive the tenure of the governor who endorsed it. "The simple fact was that for over a decade, the long lead times required to bring mega-projects from concept to construction and the need for (and lack of) broad consensus on those projects had created policy gridlock in the state" (Luberoff et. al., 1993).

By 1982 congestion on the Mystic-Tobin Bridge, the Massachusetts Turnpike (I-90), the Southeast Expressway (I-93 South of Dewey Square), the Callahan and Sumner Tunnels, and the Central Artery lasted from 1 to 8 hours every day. Unless improvements were made to increase the capacity of the artery and to revise ramp connections, artery congestion was expected to continue and worsen, severely affecting the operation of Boston's regional network. In the year 2010, assuming no significant change in the user demand generating variables, congestion was expected to last from 5 to 14 hours per day (FEIS, 1985).

5.1.2 Project Description

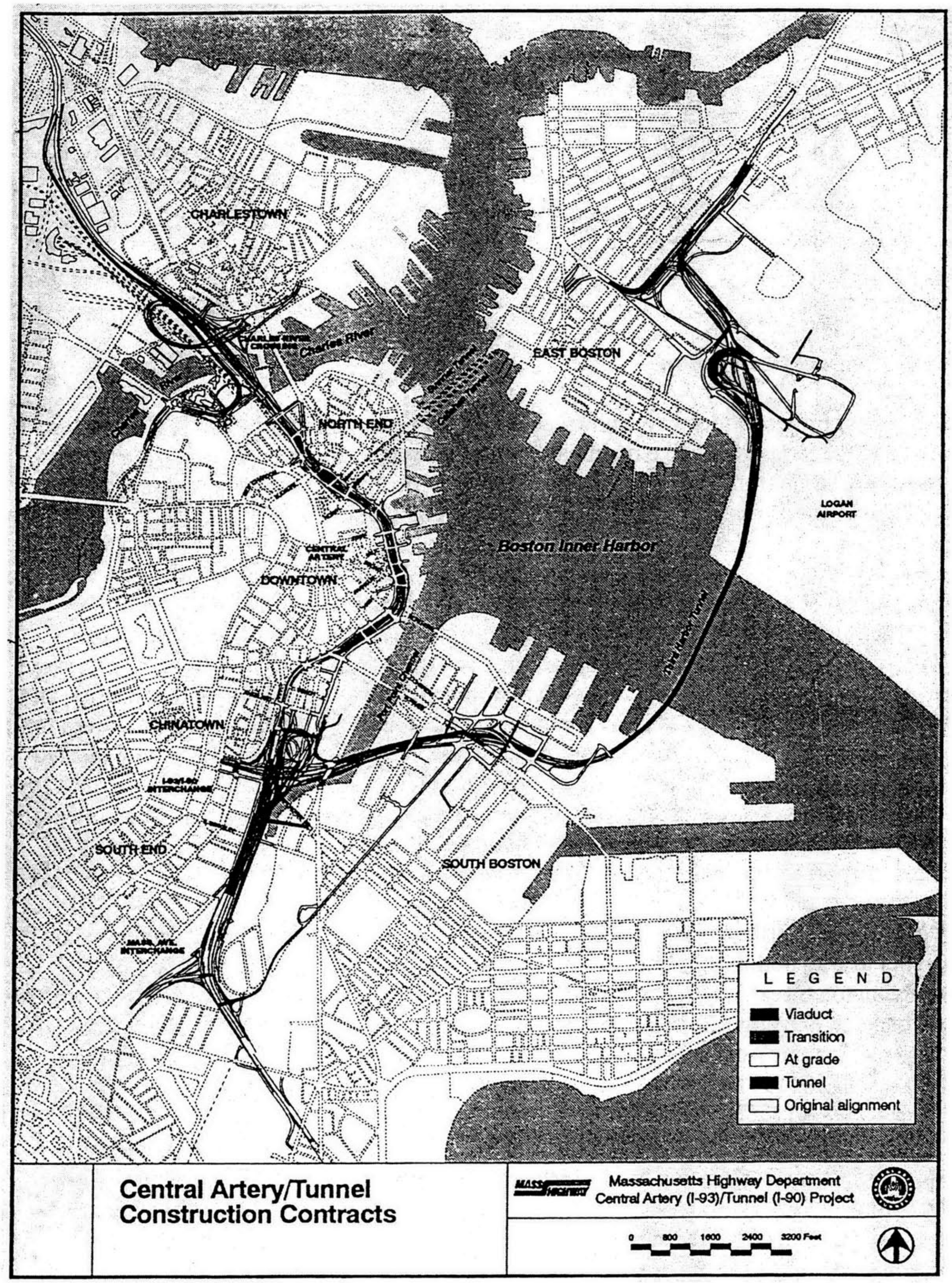
The current project underway, known as the Central Artery/Tunnel (CA/T) Project shown in Figure 5-2, consists of five main parts. The first part includes a 1.5-mile underground tunnel between North Station and South Station in Boston. The tunnel will replace the existing elevated artery and increase its width to eight lanes (FSEIS, 1991).

The second part includes an extension of I-90 via a Seaport Access Highway and a THT to Logan Airport in East Boston, with a connection to Rte 1A. The I-90 extension will begin at the present terminus of the Massachusetts Turnpike (I-90) at the Southeast Expressway (I-93) and proceed eastward in a cut and cover tunnel and an open-depressed expressway through South Boston, under Boston Harbor in an immersed tube tunnel, and into Logan Airport. The tunnel is composed of 12 double-bore tubes, each 325-foot long, which are linked in a 3,850-foot long trench in the harbor floor that is 100 feet wide and 50 feet deep (ENR, 1998, 240(20)). A much improved and expanded high-occupancy vehicle (HOV) system will also be incorporated along I-93 and I-90 to link downtown at Kneeland Street and the proposed South Station Transportation Center (SSTC) with Logan Airport and points south and west of Boston (FSEIS, 1991).

The third and fourth parts include the construction of an extended frontage road system parallel to I-93 both northbound and southbound from Causeway Street to just past Southampton Street, and the construction of a South Boston Bypass Road, most of which will be in an existing railroad right-of-way. It will connect the Southeast Expressway (I-93) to the Seaport Access Highway (I-90) and the Commonwealth Flats area in South Boston (FSEIS, 1991).

The fifth part the Charles River Crossing (CRC), a ten-lane asymmetrical cable-stayed bridge, will improve the link between the depressed CA, Storrow Drive, and the Sumner and Callahan Tunnels to I-93 North and Rte 1. The bridge will have a main span of 745 feet, a north span of 420 feet, and a south span of 293 feet. The two cast-in-place reinforced concrete towers, each extending 266 feet above the roadway, will support the

Figure 5-2 Detailed Central Artery/Tunnel Project Map
Source: Project Management Plan. Central Artery/Tunnel Project. (Bechtel/Parsons Brinckerhoff, December 1996).



spans. Of the ten lanes eight will pass through the legs of the concrete towers and two will be cantilevered on the east side of the bridge (ENR, 1998, 240(20)).

After expansion of the CA from 3 to 4 lanes in each direction, the improved ramp designs, the THT, and the CRC congestion is expected to decrease to at most 1 to 2 hours per day on all key routes except the Southeast Expressway (FEIS, 1985).

An overview of the key events surrounding the long history of the CA/T Project's development is described by the two timelines in Appendix D.

5.1.3 Project Benefits

The Central Artery/Tunnel Project is a unique project not only because of its technical complexity and size but also for the simple fact that no one had ever torn down an existing functioning elevated road to replace it with a depressed facility (Luberoff et. al, 1993). The driving factors behind depressing the artery were the widely acknowledged blighting influence of the existing elevated artery, politically it allowed anti-highway forces to support a road-building project, and it addressed the city's traffic problems without having to acquire more property from the surrounding communities.

The depression of the Central Artery and removal of the existing structure had many positive aspects, as Figure 5-3 shows it would free up approximately 27 acres in downtown Boston for public parks or real estate development. The widening of the artery from six to eight lanes and the improved merge and weave lane designs would increase capacity, improve safety and reduce congestion.

The design objectives and benefits of widening and depressing the CA are to (FEIS, 1985 and FSEIS, 1991):

- Eliminate the Charlestown High-Level Bridge bottleneck
- To increase capacity, reduce congestion, and improve traffic flow along the CA from the Charles River to the interchange with the Massachusetts Turnpike (I-93/I-90 interchange)
- Improve through traffic/local traffic mix
- Result in safer operations on the ramp system

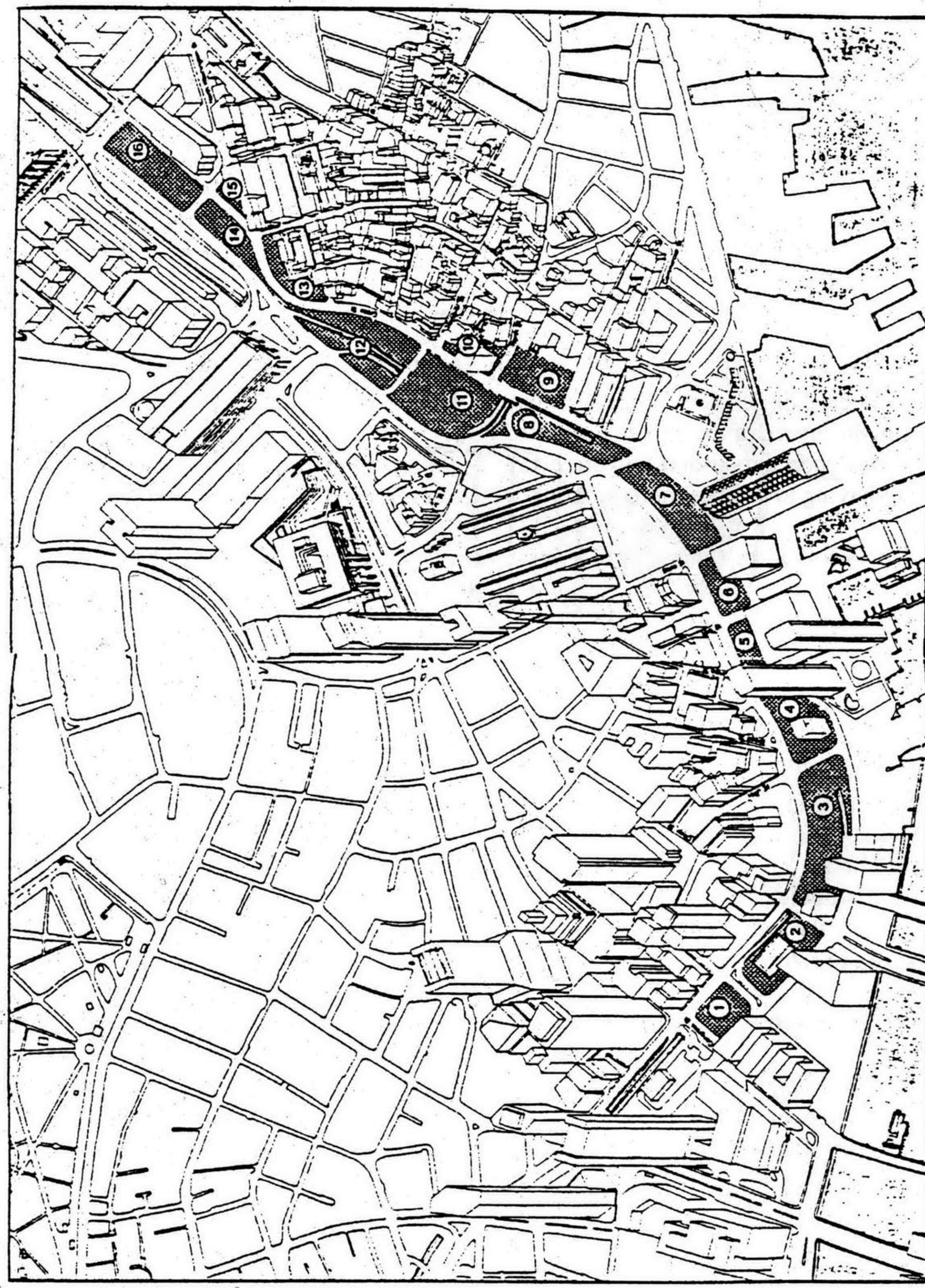
The design objectives and benefits of the THT and its chosen alignment are to (FSEIS, 1991):

- Complete I-90 in Massachusetts
- Double cross-harbor capacity/improve access to Logan Airport
- Divert traffic away from the CA
- Ensure the tunnel will surface on Logan Airport land

The design objectives and benefits of the CRC are to (FSEIS, 1993):

- Improve the link between the depressed CA, Storrow Drive, and the Sumner and Callahan Tunnels to I-93 North and Rte 1.
- Increase traffic efficiency and safety

Figure 5-3 City after Artery Depression
Source: (Hameedi, 1985)



- Eliminate the need for the existing double-crossing of the Charles River

The design objectives and benefits of the other major project elements are as follows (FSEIS, 1991):

- The Seaport Access Highway will increase accessibility to the South Boston seaport and industrial areas
- The improved HOV system will offer vehicles carrying multiple passengers head-of-queue privileges in areas where congestion occurs
- The extended frontage road system will provide increased accessibility to local and arterial streets along the Central Artery and Southeast Expressway
- Construction of the South Boston Bypass Road will create a new route for trucks and other commercial vehicles that avoids existing streets

For most neighborhoods the widening and depression of the CA is expected to improve pedestrian access and overall environmental conditions due to the elimination of the elevated structure, improvements to traffic patterns, and reduced air and noise pollution.

5.1.4 Contracting Plan

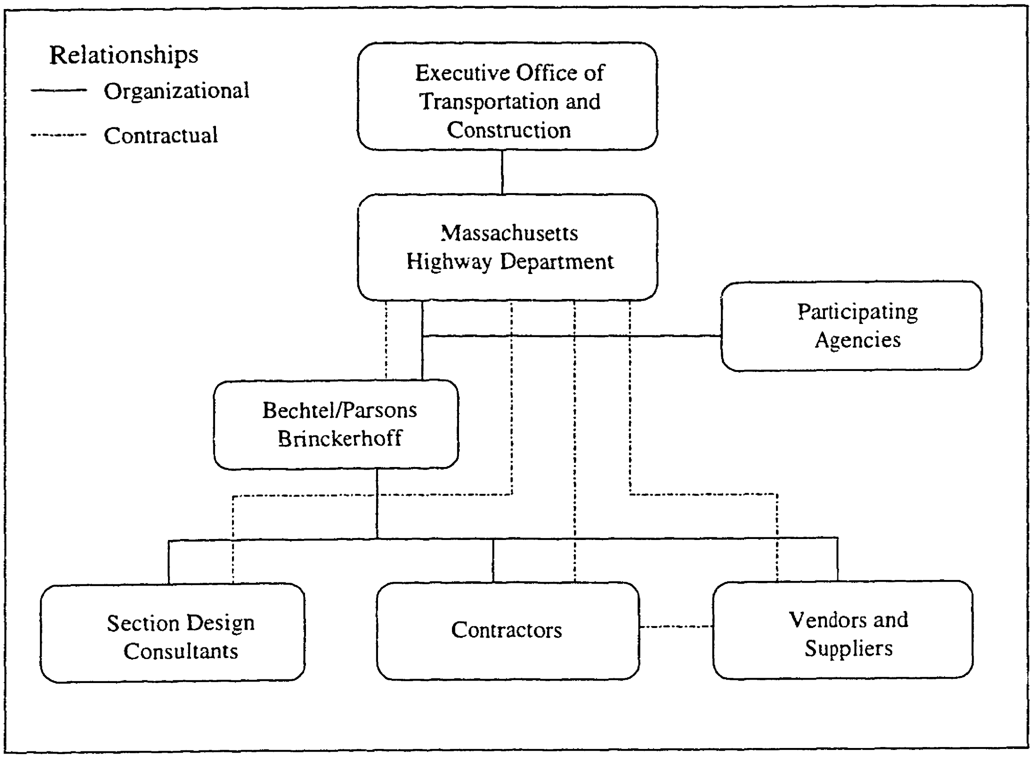
The Department of Public Works/Massachusetts Highway Department (DPW/MHD), the state's lead agency for the CA/T Project, sought the services of a management consultant to help perform the planning, management, design, and construction of the project. The consortiums that submitted proposals to provide these services were evaluated in terms of experience and proposal quality. In 1985, the state awarded the management consultant contract to a joint venture lead by Bechtel Civil Inc. and Parsons Brinckerhoff Quade and Douglas (B/PB). The management consultant contract is structured as a cost-plus a fee. The joint venture is paid by the hour and receives an additional flat fee.

The original joint venture team included B/PB and twelve smaller firms including Wallace Floyd Assoc. Inc.; Bell Assoc., Inc; Sega/DiSarcina Assoc., Inc.; J.M. Cortell and Assoc., Inc.; BCC/Cullman Assoc.; BBN Laboratories, Inc.; Cambridge Systematics, Inc.; Boston Affiliates, Inc.; Carol R. Johnson and Assoc.; Stull and Lee Assoc.; Walter Kudlick Trans. Cons. Inc.; and Mistry Assoc., Inc.

The final design and construction work is divided into geographical packages to allow work on certain sections to begin at different times and to provide numerous opportunities for local designers and contractors. This concept was used to maximize state/local involvement and to keep Federal money in the area. In total there are approximately 76 design packages and 128 construction packages. The method the DPW/MHD used to procure design and construction services followed traditional design-bid-build procedures. The designers were evaluated on reputation, expertise in the specialized area, and on their ability to work within the designated budget, while the construction contractors were compared solely on the basis of low cost.

A summary of the contractual and organizational relationships between the DPW/MHD, B/PB, and the section design consultants and contractors is shown in Figure 5-4. The contractual relationships are naturally established through contracts. The organizational relationships indicate a general hierarchy of authority within the project.

Figure 5-4 CA/T Project Contract and Organizational Structure



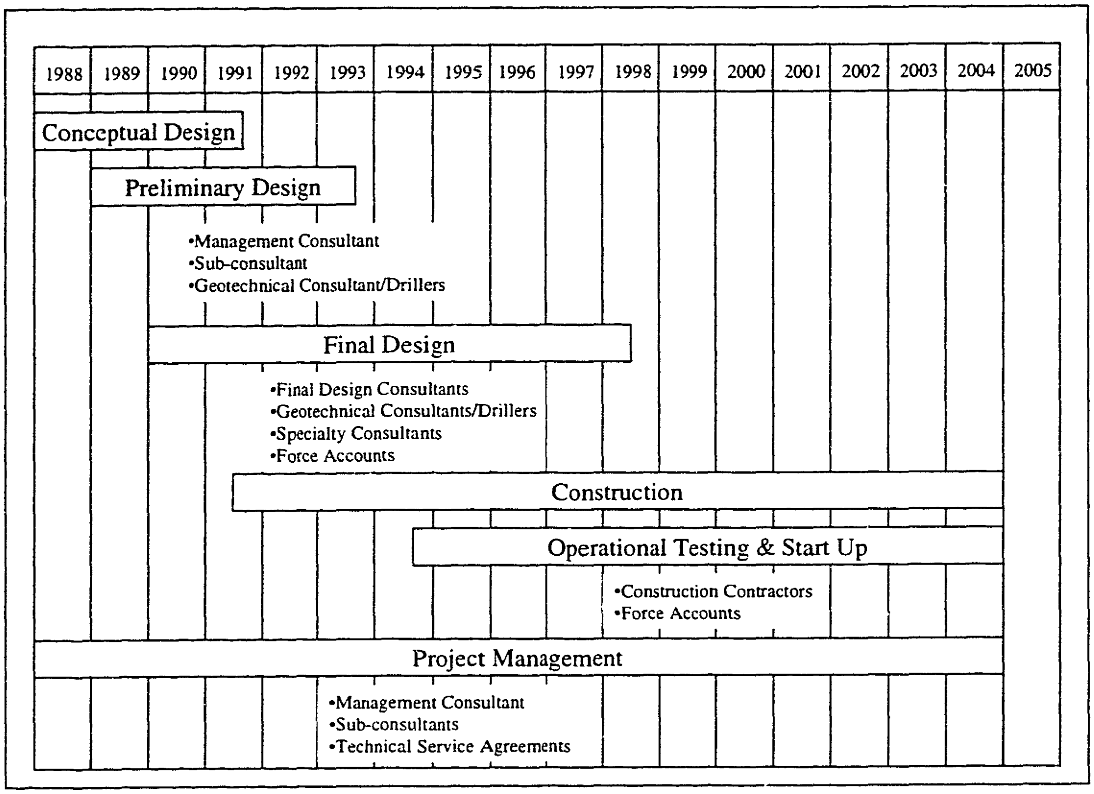
5.1.5 Project Status

Figure 5-5 displays the relationship between the project phases and the major participants as of the current schedule. As of September 1, 1998 the design of the entire project is nearly complete and the Notice to Proceed with construction has been issued for most sections.

The project passed the first major milestone when the THT opened on schedule December 15, 1995. Once open for traffic, the 1.6-mile, $1.3 billion dollar tunnel was renamed the Ted Williams Tunnel. The tunnel connection with I-90 is currently scheduled for completion in 2001.

The northbound underground highway and the cable-stayed bridge are currently scheduled to open in 2002, and the remainder of the project, including demolition of the existing elevated highway, will be complete by 2004.

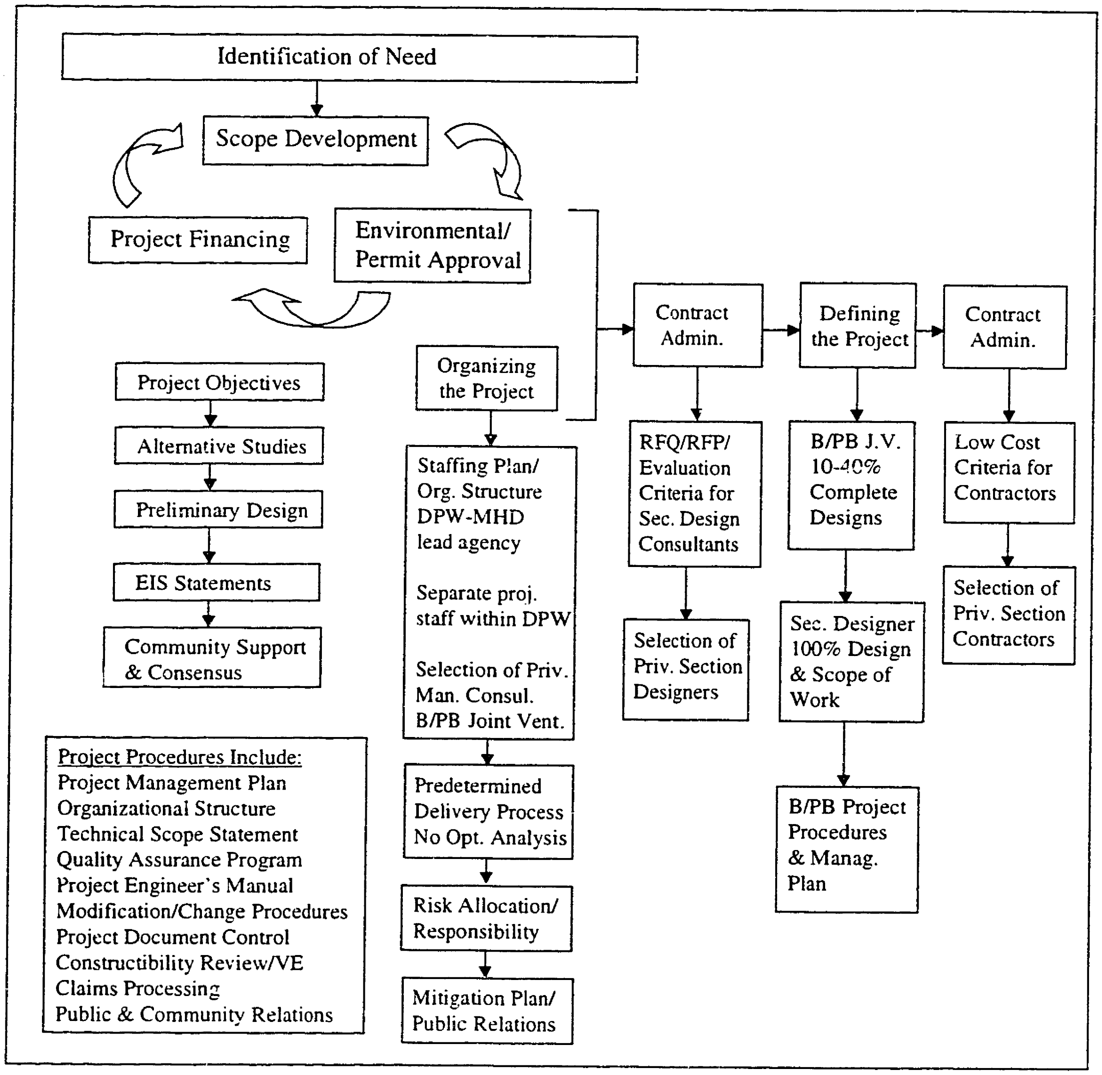
Figure 5-5 CA/T Phase-Entity Relationship
Source: (Project Control Plan, 1991)



5.2 Level of Project Configuration

The general configuration process developed here for the CA/T Project is displayed in Process Diagram 5-1. The lead agency, the DPW/MHD, was forced to utilize the traditional design-bid-build delivery method by Massachusetts State law (M.G.L. Ch. 30B Sec. 5). As a result the project spent over a decade in the political arena with local officials attempting to gather consensus for a project that was eligible for Federal funding. Although the need for an infrastructure improvement was clear, there was no one clear solution to meet that need.

Process Diagram 5-1 CA/T Project Configuration Process



The need for improvement to the transit network was identified years before the CA/T Project took shape. The need for a THT was projected by the DPW as early as 1957 and the engineering and construction feasibility of depressing the CA was confirmed in 1974 through a study funded by the DPW and conducted by the Boston Redevelopment Authority (FSEIS, 1990). Analysis of regional transportation requirements in 1983 concluded that both the THT and the depression of the CA were necessary to accommodate future traffic demand (FSEIS, 1990).

To initiate the development of a transportation solution the State began environmental studies in 1981. The first action by the DPW pursuant to what became the CA/T Project was the filing of the Environmental Notification Form (ENF) for the THT in January 1982. The ENF initiated the environmental approval and permitting process in accordance with the National Environmental Policy Act (NEPA) and the Massachusetts Environmental Policy Act (MEPA). The entire CA/T Project was under environmental review from 1983 through 1985. The FEIS for the CA/T Project was published in 1985 and approved by the FHWA and the Massachusetts Executive Office of Environmental Affairs (EOEA) in January 1986 (FSEIS, 1990). The FEIS included detailed information regarding 14 design alternatives, the no-build alternative, and 11 transit options (FSEIS, 1990). On January 2, 1986, the Massachusetts Secretary of Environmental Affairs concluded the FEIS submitted for the CA/T Project to be adequate (FSEIS, 1990). Eligibility of the CA/T Project's costs for Federal funding was clarified in April 1987 when Congress passed the Surface Transportation and Uniform Relocation Assistance Act (FSEIS, 1990).

The course of the project's development reveals that after a general solution emerged and prior to obtaining guaranteed Federal funding, the DPW/MHD hired a management consultant in 1985 to conduct alternative studies and manage the project. In the 1985 FEIS a Preferred Alternative referred to as Alternative 5A Modified was selected. The FEIS, however, also identified 14 unresolved issues that would require further study, one of which was the design for the CRC (DSEIS, 1993).

Since the approval of FEIS additional design studies have required further planning, engineering, and environmental impact reviews by the DPW. The process has required interagency cooperation and included exhaustive public scrutiny. More than 30 Federal, State and local agencies including all Federal agencies with permitting jurisdiction over the project, such as the U.S. EPA and the U.S. Army Corps of Engineers, were given the opportunity to review the DSEIS before its publication in May 1990 (FSEIS, 1991). In general, EISs are required when the project scope, which includes changes to the project scope, may have a significant impact on the surrounding environment. The SEIS serves the same purpose as the original EIS for project changes that have potential adverse affects on the environment. The SEIS describes modifications and provides an update on design, engineering, and environmental studies since the FEIS. Like the EIS the SEIS presents studies and analyses necessary for environmental permits required by local, State, and Federal agencies. Many of the modifications were in response to unresolved issues and comments received on the FEIS. Table 5-1 summarizes the DPW response in the FSEIS to resolve a few major outstanding issues from the FEIS in 1985.

Table 5-1 1985 FEIS Unresolved Issues

Issue	1990 FSEIS Status
Charles River Crossing Design	Four Alternative Design Schemes
Local, State, Federal Permit Approvals	Coordination with permitting agencies will continue, the necessary permits and approvals have been identified and applications are being prepared
Extent of Federal Funding Aid	CA/T Project Federal Funding was clarified with the passage of the 1987 Federal Highway Act

The DSEIS submitted in May 1990 represented a substantial update to the technical information and scope of the proposed project in the approved FEIS in 1986 (FSEIS, 1990). A public hearing was held in June of 1990, the 4-month review and comment period was concluded in September, and the FSEIS was submitted in November 1990 and approved in May 1991.

The NEPA and MEPA processes require that the DEIS and the DSEIS pass through a formal public review. The NEPA and MEPA processes are structured to include the public in the capital planning process to elicit public scrutiny and provide the opportunity for meaningful input into decisions of how public projects should be designed and delivered. The public hearing and public comment period occurs for both the EIS and the SEIS processes.

Perhaps the most publicly controversial aspect of the CA/T Project is the DPW's development of a preferred route for the CRC (FSEIS, 1990). The need for sensitivity in the crossing's design was first noted in the Central Artery North Area (CANA) Final Environmental Impact Review in January 1979. The Secretary's Certificate on the FEIS in January 1986 recognized that the design of the CRC was still an unresolved issue (FSEIS, 1990).

The 1985 FEIS included a preferred project-wide alternative called Scheme 5A Modified. Following the publication of the FEIS serious operational and environmental problems with Scheme 5A were identified (FSEIS, 1990). A few of the 1985 FEIS unacceptable problems for the CRC are listed below:

- Poor traffic operations
- Shadows over the Charles River Dam by the I-93 Bridge
- Impacts to Paul Revere Landing Park in Charlestown
- Impacts to the MDC Nashua St. Parkland
- Impacts to the Esplanade along Storrow Drive
- Partial taking of 2 historic structures around North Station
- Loss of service for the connection of Storrow Dr. to I-93 & Rte 1 for 2 years

To respond to these problems and develop an acceptable design the DPW identified the major design objectives for the CRC. The 1990 FSEIS CRC design objectives were as follows:

- Accommodation of traffic flow which meets appropriate highway norms on all mainlines and ramps
- Provision of a high level of travel safety
- Conformance to DPW and FHWA highway safety standards
- Minimization of environmental impacts
- Reasonable cost
- Capability to be constructed safely and with minimal impacts on traffic service during construction
- Compatibility with new and proposed construction in the area

Since 1985 the DPW studied many design alternatives for the CRC in an effort to address the issues raised through the NEPA and MEPA processes. Given the physical limitations because of existing structures, engineering teams explored design options for the areas north and south of Causeway Street. Numbered schemes 1 to 51 were developed for the area south of Causeway, while Schemes A through DD were developed for the area north of Causeway (FSEIS, 1990). The process lasted two years starting in 1987 and continuing through 1989. The main difficulty in any scheme remained the lack of adequate weave distances between the CA, Storrow Dr. and the harbor tunnels (FSEIS, 1990).

Spatial limitations led the DPW to pursue design schemes for the area north of Causeway Street. The 31 different options could be classified into three basic groups: the Viaduct/Tunnel Concept, Group "A"; the Charles River Tunnel Concept, Group "M"; and the Viaduct Concept, Group "E" (FSIES, 1990). Three schemes were selected for further study that represented the most refined design for its respective group. The other 28 design schemes were eliminated from further study due to geometric, operational, or constructibility problems or because they were superceded by the three that were selected (FSIES, 1990).

The EIS process requires that the DPW identify and provide technical information regarding the most promising design alternatives. In addition to the proposed action in the FEIS the DPW identified four alternatives for detailed assessment in the DSEIS (FSEIS, 1990). The five design concepts that were examined included the FEIS baseline 5A modified, a viaduct/tunnel concept Scheme S Modified, a Charles River tunnel concept Scheme T Modified, an all tunnel concept, and a viaduct concept Scheme Z Modified. Discussion of the all tunnel concept, projected cost $1.7 billion, was in response to community proposals (FSEIS, 1990).

After reviewing the alternatives the DPW selected Scheme Z as the preferred alternative for the DSEIS. The DPW presented a detailed case supporting the selection of Scheme Z from a transportation and an environmental point of view (FSEIS, 1990). However, this was a controversial element of the project and the public review process generated many comments on all the alternatives. As a result of the public review the DPW focused on comparing Scheme T and Scheme Z. The DPW still concluded Scheme Z provided the best overall solution in terms of constructibility, traffic operations, and environmental impact (FSEIS, 1990).

Although Scheme Z provided an acceptable operational solution, both supporters and opponents of the design continued to be concerned about its visual and environmental impacts. Comments on the FSEIS design ranged from adjustments to ramps to complete replacement with an all-tunnel alternative, previously deemed unfeasible by the DPW (FSEIS, 1991). The MEPA Certificate issued by the Secretary of Environmental Affairs urged that the CRC receive further study due to the public's reaction to Scheme Z. The FHWA ROD issued in May 1991 supported a revaluation of the CRC design (FSEIS, 1993). In response to an EOEA directive to reduce the environmental and aesthetic impacts of the CRC and to better inform the public about the crossing the DPW established the Bridge Design Review Committee (BDRC) which is composed of surrounding area community members, interested agency and association representatives, architects, and engineers. This committee is responsible for improving Scheme Z Modified to further lessen the environmental and aesthetic impact of the crossing (FSEIS, 1991). The general purpose of the committee was to receive public comment on the design and level of analysis prior to submission of the CRC DSEIS.

One of the principal concerns of the BDRC besides improving the environmental and aesthetic impacts was to investigate alternative design schemes, including partial and/or full tunnel alternatives (DSEIS, 1993). Although the BDRC sought to avoid undue delay of the Project, the committee considered 20 alternative designs (DSEIS, 1993). After two years of study and refinement of the CRC design the DPW submitted the CRC DSIES in July 1993 for State and Federal review. The new designs sought to:

- Avoid parallel bridges with inconsistent profiles
- Reduce overall bridge width
- Reduce the number of support columns in the Charles River and on land

The BDRC and local community supported a Charles River Tunnel alternative referred to as Alternative 8.1D Mod 5. The DPW filed a Notice of Project Change (NPC) with the EOEA in September 1992. The FHWA and the U.S. Army Corps of Engineers felt the tunnel alternative had greater environmental impacts and did not present a satisfactory highway design and in turn the DPW also considered a Non-River-Tunnel Alternative and a Reduced-River-Tunnel Alternative (DSEIS, 1993). The DSEIS addressed issues raised by the U.S. Army Corps of Engineers, the FHWA, public agencies, private groups, and individuals throughout the scoping process in 1992 and 1993. The new designs attempted to reduce the massive size of the crossing, the number and height of the loop ramps and their proximity to the riverbank (FSEIS, 1993). Table 5-2 displays a comparison of the four alternatives discussed in the DSEIS for the Charles River Crossing (DSEIS, 1993).

Table 5-2 1993 CRC DSEIS Comparison of Alternatives

Description	Scheme Z	8.1D Mod 5	Reduced River-Tunnel	Non-River-Tunnel
Source	91 FSEIS	92 NPC	93 DSEIS	93 DSEIS
Number of Bridge Lanes	16	10	12	14
Total Linear Feet of Tunnel	0	10,100	6,150	3,300
Number of Tunnel Lanes	0	3	2	0
Number of Ventilation Bldgs	0	1	2	1
CA to Tobin Bridge Transition	Viaduct	Tunnel	Viaduct	Viaduct
Number of Loop Ramps North of Charles River	6	1	2	2-3
HOV Lane I-93 South	No	Yes	Yes	Yes
Direct Access Ramp Downtown Boston	No	Yes	Yes	Yes
Storrow Dr. I-93 Transition	Underpass	At grade	Underpass	Underpass
Estimated Cost (M 1993 $)	489	1,282	1,131	995
Construction Duration (years)	8.5	13	9	8.5

After review of the comments received from the DSEIS the DPW issued the FSEIS for the CRC in December 1993. The DPW identified the preferred alternative to be the Non-River-Tunnel Alternative (FSEIS, 1993). The other alternatives were rejected because of lower quality of traffic operations and greater adverse environmental and aesthetic impacts (FSEIS, 1993).

5.2.1 Staffing Plan/Organizational Structure

After the DPW identified the initial project scope and initiated the environmental approval process the main question became who would plan, engineer, and build the project. A project of this scale and complexity has many management and implementation challenges regarding land acquisition, community relations, traffic engineering, environmental permitting, planning, design, and construction.

A public highway construction project in Massachusetts is generally managed by a State agency. The main agencies that were considered were the DPW, who had traditionally managed highway projects; Massport, who had a reputation for building capability; the Mass. Turnpike Authority, who had built and managed the harbor tunnels; and the MBTA, who had experience with slurry-wall construction for the Red Line.

Fred Salvucci, the Massachusetts Secretary of Transportation and Construction chose the DPW/MHD to lead the project mainly for political reasons (Luberoff et. al., 1993). Tradition held that highway construction projects were managed by the DPW/MHD. Federal law also required the flow of Federal funds for highway projects to go through the DPW/MHD. Finally, the FHWA, which would oversee the entire project, preferred to work with the DPW/MHD, a traditionally pro-highway organization. However, because of recent budget cuts the DPW/MHD staff had been reduced by 1/3. The state desired to rebuild the DPW/MHD but felt it would not be wise to hire the needed personnel only for the duration of the project. Therefore, the State saw a need to hire a private firm experienced in managing mega-projects. The Federal government supported the State's decision to hire private project managers.

In 1985, the State awarded the management consultant contract to a joint venture lead by Bechtel Civil Inc. and Parsons Brinckerhoff Quade and Douglas. Bechtel and PB pursued the joint venture for they complemented each other quite well. Bechtel brought to the table large project and construction management experience, and PB added highway design expertise. Within the JV Bechtel is generally responsible for construction management services and cost and schedule control, while PB acts as the engineering manager and is generally responsible for the completion of the preliminary design and the final design reviews. As of early 1998 the JV staff consisted of 850 people (Helmich, March 24). Over time the composition of the staff shifted from an engineering to a construction organization as the project has moved from the design to the construction phase.

Organizational management became the main focus of the DPW/MHD as a staff of around 50 people serve as an oversight group for the entire project (Helmich, March 24). In a unique arrangement a small cadre of public employees oversee a consortium of private firms that provide almost all of the functions of a typical highway department (Luberoff et. al., 1993). The organizational structure for both the DPW/MHD and B/PB are shown in Figure 5-6 and Figure 5-7 respectively. The B/PB Program Manager, ultimately responsible for all B/PB activities, is the principle interface with DPW/MHD and the Board of Control is comprised of joint venture executives who provide oversight of the B/PB effort. The DPW/MHD staff share office space with the management consultant staff, as they are to be as operationally integrated as possible.

The joint venture's project executive/program manager is responsible for upholding the consultant's contract with the State and to monitor the progress of the project to advise the State on budget and schedule issues. A project manager, four deputy project managers, and a public relations staff assist the program manager. The project manager coordinates the efforts of the four deputy project managers in charge of engineering, the environment, general services, and construction. The structure is flexible as new deputy project managers can be added if needed.

It is important to note, as is typically the case for public projects, regulatory groups, environmental agencies, architectural societies, community groups, the U.S. Army Corp of Engineers, and the FHWA all participate in the project development process.

Figure 5-6 MHD Organizational Structure
Source: (Project Management Plan, 1996)

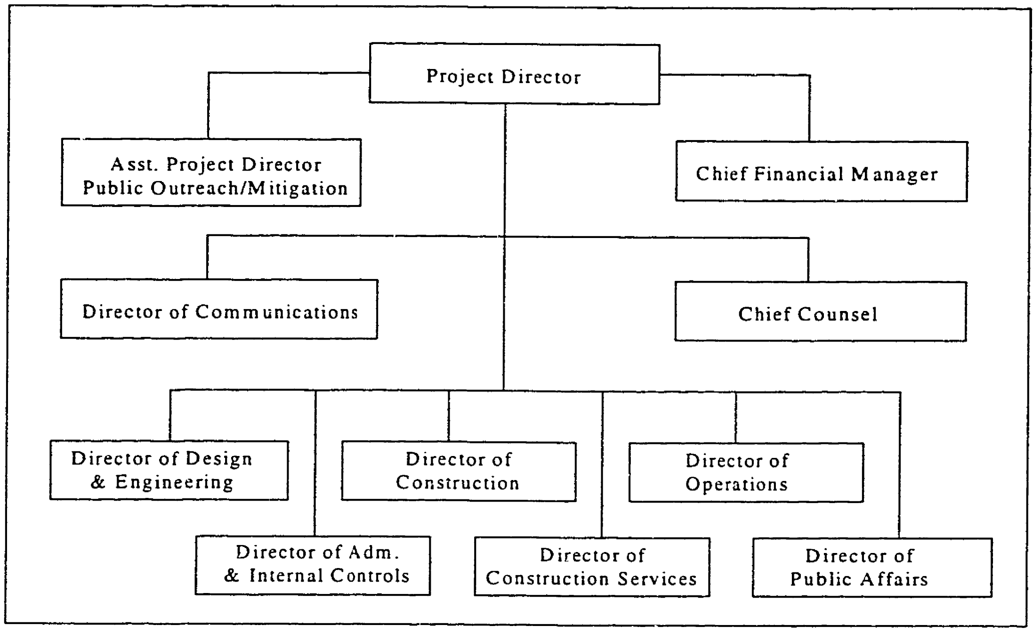
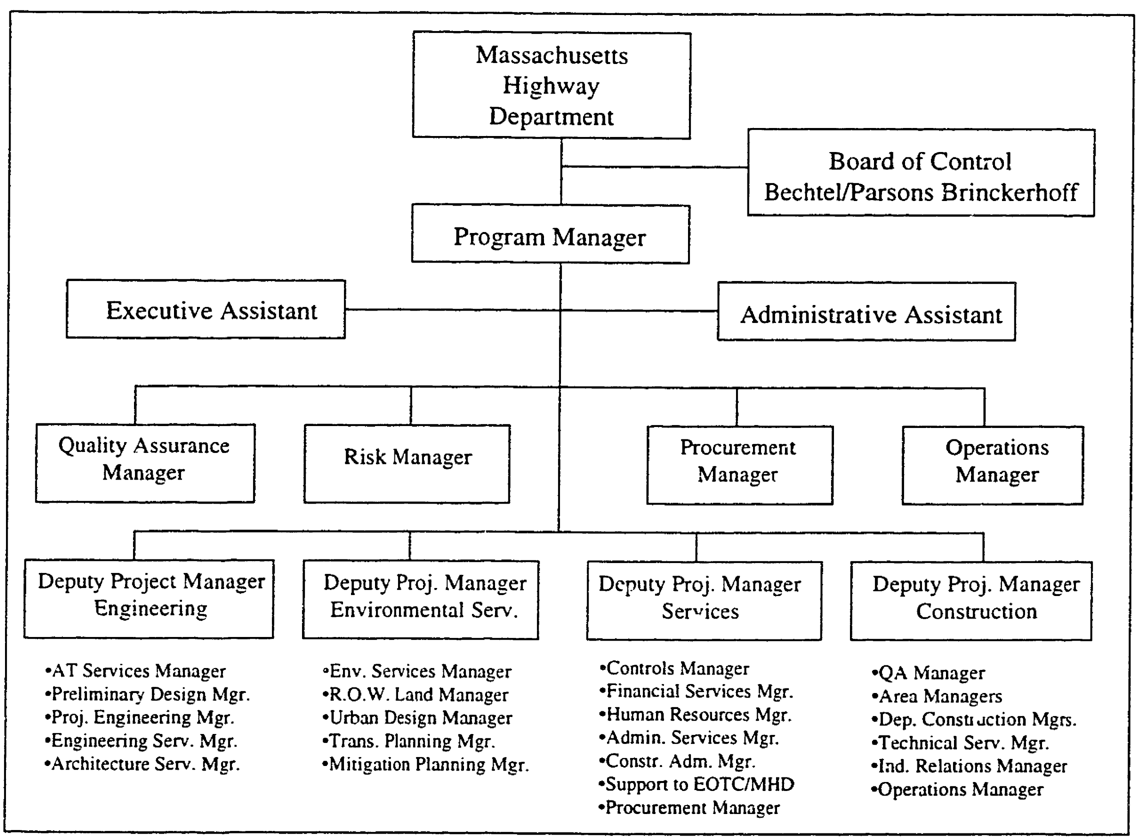


Figure 5-7 B/PB Organizational Structure
Source: (Project Management Plan, 1996)



5.2.2 Contract Administration

A public project of this size requires a well-planned contractor selection process that is beyond reproach. Matt Coogan, the undersecretary of transportation, and DPW Commissioner Robert Tierney were given the responsibility to select the management consultant. They formed a nine-member committee to rank and evaluate proposals. Formal procedures were used to rate and rank each proposal.

Even though the project required special expertise in subsurface construction 5 proposals were received. After reviewing each proposal the committee unanimously selected the joint venture led by B/PB because of their familiarity with slurry-wall construction.

As a result of uncertain project funding and unclear project organization the DPW/MHD contracted with the B/PB joint venture using short-term work programs. To date, there have been 14 work programs beginning from the start of 1986. Figure 5-8 displays the work program history between the DPW/MHD and B/PB.

All firms or joint ventures submitting letters of interest for engineering or architectural contracts received a Qualifications Package from the DPW/MHD. Each package included preparation instructions, a description of the work to be performed under the contract, a questionnaire to establish the firm's qualifications, and a description of the criteria to be used by the DPW/MHD to evaluate each firm's qualifications. Based on the DPW/MHD Consultant Evaluation Committee's (CEC) review and evaluation of each respondent's qualifications, the most qualified firms received an RFP. The RFP included preparation instructions, a scope of work statement, the list of criteria to be used by the CEC to evaluate and rank the proposals, a request for a detailed staffing and work plan, a standard contract form, a request for the firm to disclose any potential conflict of interest, and a description of the Affirmative Action goals for the project (Section..., 1988).

A summary of the selection processes used for awarding the section design contracts and the section construction contracts are shown in Figure 5-9 and Figure 5-10 respectively. The scope of services for all section contracts was developed by B/PB, then reviewed and approved by DPW and the FHWA. Qualified design consultants were ranked according to qualification evaluations and then the two highest ranked firms submitted fee proposals. The proposals were compared with estimates from B/PB to negotiate a contract value. The award of each construction contract was based solely on completeness and price. Cost proposals for the construction contracts were compared with cost estimates generated by the management consultant and the section design consultant for verification.

Figure 5-8 DPW/MHD-B/PB Work Program History

Source: (Project Management Plan, 1996)

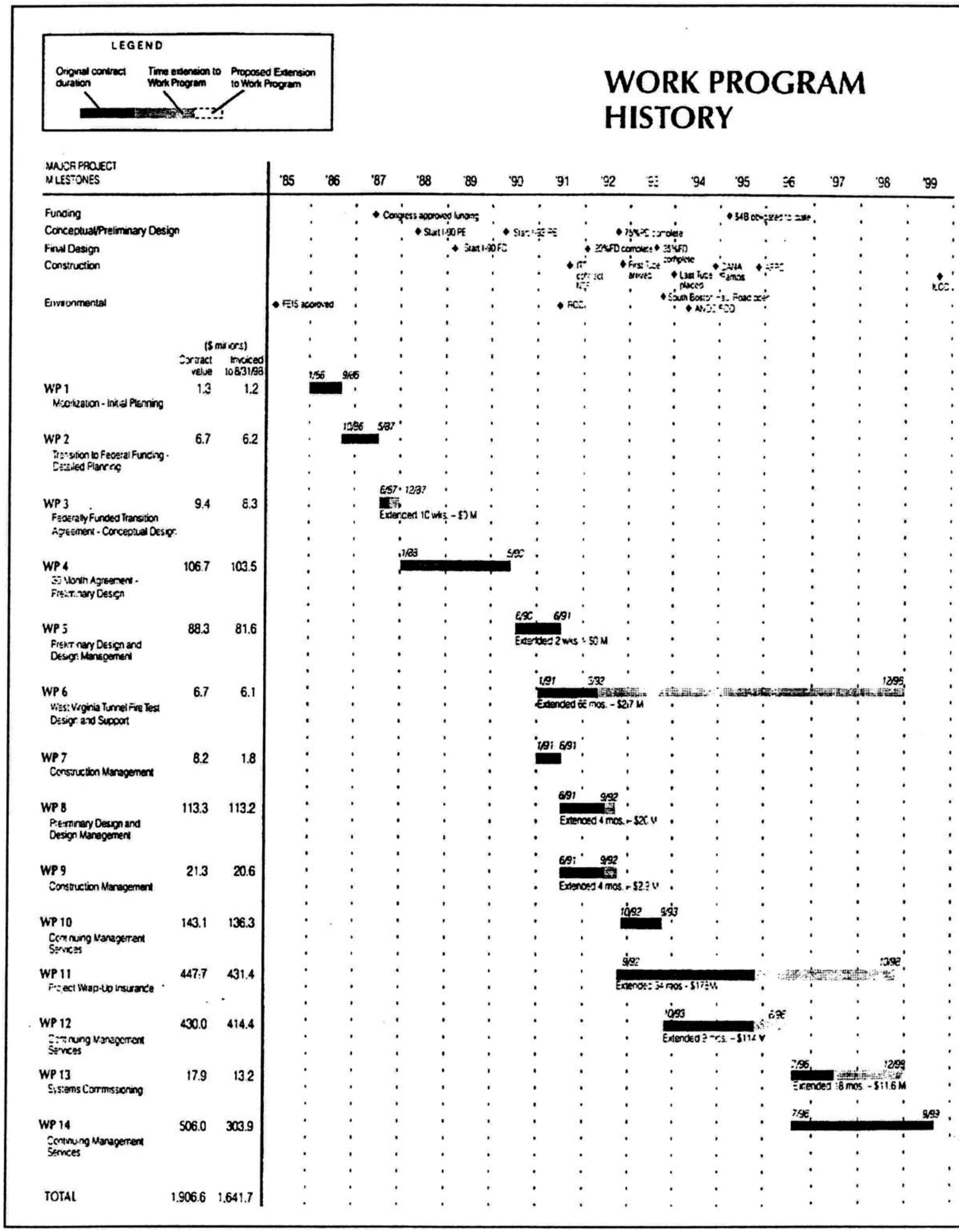


Figure 5-9 CA/T Design Consultant Selection Process
Source: (Project Control Plan, 1991)

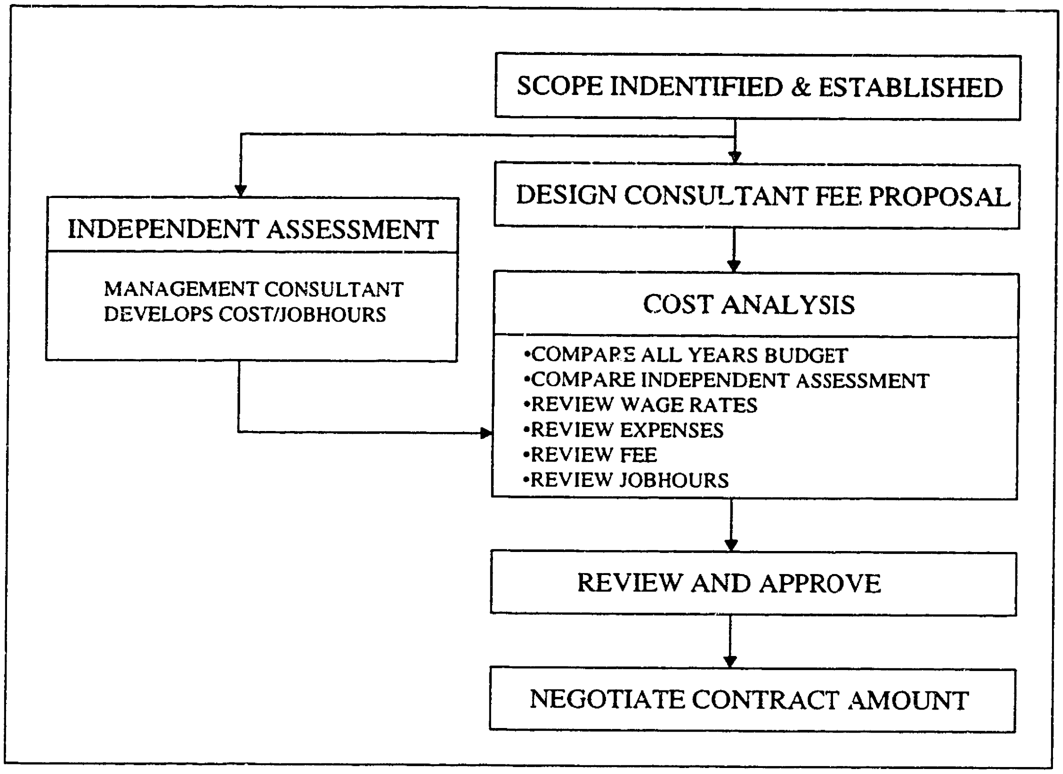
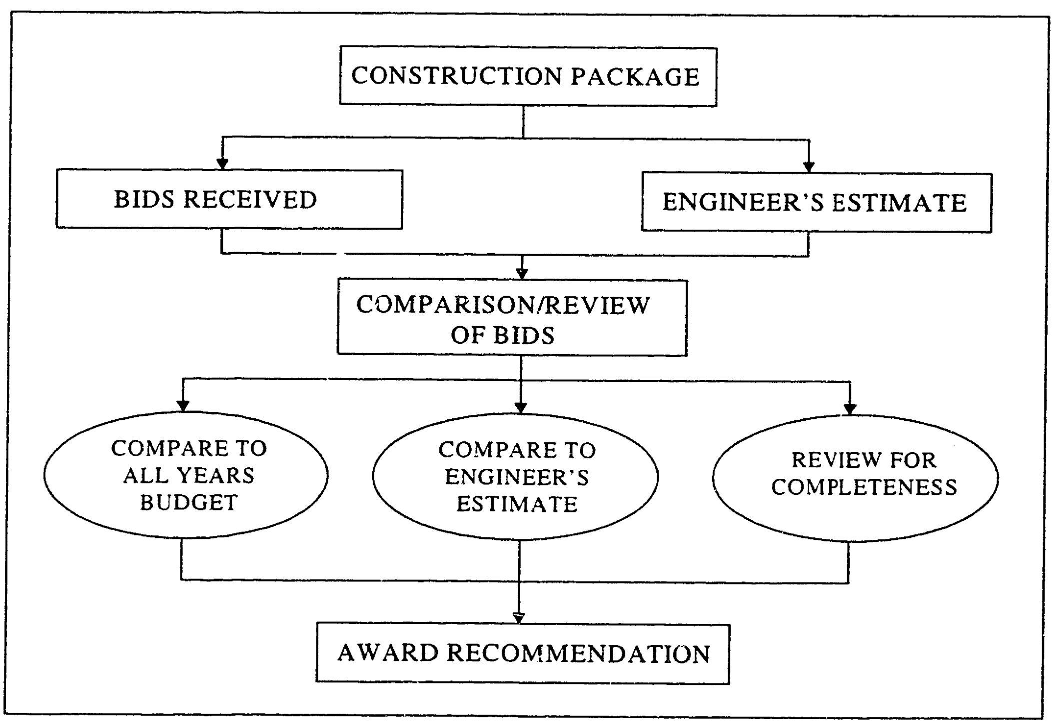


Figure 5-10 CA/T Contractor Selection Process
Source: (Project Control Plan, 1991)



5.2.3 Project Objectives

The DPW/MHD held the responsibility to establish the project objectives for management, design, and construction during the initial planning stage. The specific design objectives were reflected by the project benefits for each part in section 5.1.3. After some time the DPW distributed written objectives for the overall project. The DPW's objectives or goals are to:

- Maintain project costs through an aggressive cost containment program
- Manage interim milestones that lead to 2004 project completion
- Continue the high project standard for quality of work and workmanship
- Sustain Boston's quality of life throughout project construction
- Improve work processes, including increased use of project automation
- Establish a development program for every person on the project
- Enhance project communications
- Create a renewed spirit of partnership
- Maintain a safe work environment

These represent project-wide goals to serve as a general guide for the project team's management staff to make decisions. In order to ensure a broad awareness of these objectives written copies have been distributed to management personnel. In general, these objectives are communicated to B/PB through directives and approvals by the DPW issued in response to B/PB reports and recommendations.

In addition B/PB has created and documented both a mission statement and a set of project objectives in the Project Management Plan. The primary mission of B/PB is to design, construct and commission the CA/T Project in accordance with the current scope and within the constraints of environmental, budget, schedule, quality and safety standards (Project Management Plan, 1996). The project objectives with respect to this mission are (Project Management Plan, 1996):

- Responsiveness and Quality of Service – Establish a Team Ethic/Flexibility/Cooperation
- Timeliness – Managing the Schedule
- Cost Performance – Cost Control
- Environment, Safety, and Health – Promote a safe work environment
- Small Disadvantaged Businesses – Promote small business opportunities

5.2.4 Risk Allocation/Responsibility

The DPW/MHD organization provides financial and contract management. The intent is for government managers to focus on policy and project support issues allowing the consultant to be innovative and efficient with technical and management issues. "DPW's delegation of responsibility to the consultant was to be limited only by the DPW's legal responsibility to retain authority to select contractors, to execute contracts, and the like"

(Luberoff et. al., 1993). Matt Coogan, the Executive Office of Transportation and Construction (EOTC) undersecretary, retained responsibility to oversee the project design and maintain a project constituency.

The private management consultant serves as an advisor to the State. The consultant manages project planning, design, and related operations for construction. The DPW/MHD accepts the responsibility to supervise the work of the consultant on behalf of the State and retains the typical risks associated with construction. The management consultant is not responsible for the basic or final project design. B/PB and the 12 other private firms manage the work of the engineering firms designing the individual sections, coordinate the design of the entire project, and manage construction. The management consultant carries the section designs to 10% completion at which point the DPW/MHD selects separate firms to engineer each section. The consultant then reviews the section designs at 25%, 60%, 90%, and 100% completion.

The DPW/MHD informed section design contractors that they are responsible for the management, coordination, and review of the basic design contracts both singularly and collectively along with writing the proposed scope for their section contract. To speed up the process however, the joint venture often reached 40% design completion so that each section designer would not conduct its own alternative studies. Even though, individual designers frequently started from the beginning for they would not stamp a design based on B/PB 40% designs.

Figure 5-11 graphically displays the flow of obligations between the major project participants and Table 5-3 reflects the general distribution of responsibility and delegation of authority by the DPW/MHD to the management consultant, section designers, and section contractors. B/PB identifies the impacts that funding issues, schedule delays, and changes in the scope have on the individual packages and ultimately on the project-wide milestones. Once impacts are identified, B/PB implements appropriate remedial measures with DPW/MHD concurrence (Project Manag. Plan, 1996).

Within the management consultant structure the engineering department is responsible for providing preliminary design services, reviewing the final designs from the section designers, and providing technical support during construction. The environmental department addresses issues regarding environmental impact, right-of-way, urban design, transportation planning, and mitigation planning. The services department is responsible for project control, finance and insurance, human resources, procurement, administrative services, claims and changes, equal employment opportunity, and DPW/MHD support. Finally the construction department is divided into geographical areas that are more readily managed. Each area manager is responsible for contract administration, coordination of the work, monitoring the progress and quality of the work, and decisions regarding site conditions.

Figure 5-11 Interaction Among Participants
Source: (Project Control Plan, 1991)

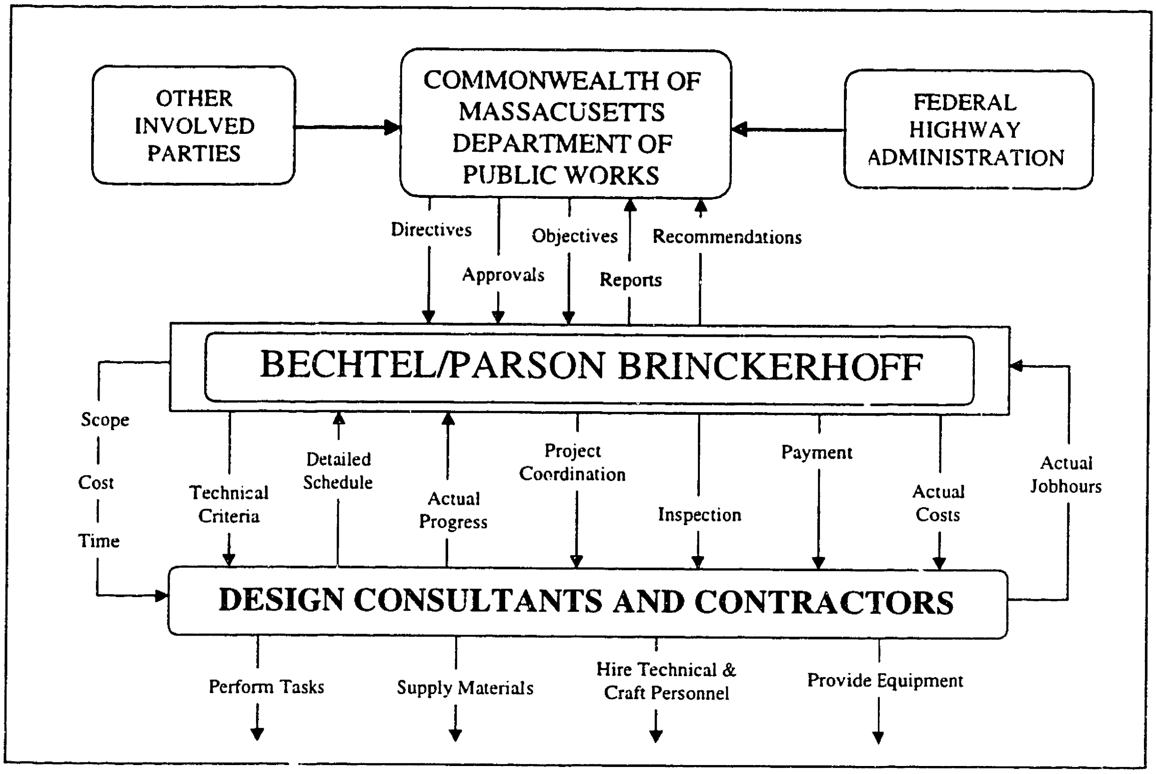


Table 5-3 General Allocation of Responsibility and Control Elements
Source: Adapted from Project Management Plan. Central Artery/Tunnel Project. (Bechtel/Parsons Brinckerhoff, December 1996)

ORGANIZATIONAL GROUP	PLANNING & DESIGN DEVELOPMENT	DESIGN	CONSTRUCTION	SCOPE	COST	TIME
MHD	Establishes Policies & Objectives Approves Implementation Plans Project Management Plan Procedures & Standards Preliminary Concepts Secures Financing Authorizes Payments Approves Quarterly Assessments of Consultant progress for conformance with the contract and schedule Monitors Progress and Implementation of MHD directives	Approves & Executes Section Design & Other Consultant Contracts Approves Plans, Budgets, Schedules Bidding Selection Process Authorizes Payments Authorizes Changes Approves Quarterly Assessments of Consultant Progress for Conformance with the Contract and Schedule Monitors Progress and Implementation of MHD Directives	Approves & Executes Construction Contracts Procurement Contracts Authorizes Construction Payments Accepts Completed Work Monitors Progress & Implementation of MHD Directives	+ Technical Scope Statement + Capital Cost Trends	+ All Years Budget + Capital Cost Trends + Cash Flow Assessments + Obligation Tracking + Budget/Forecast/Cost & Commitment	+ Project Master Schedule + Capital Cost Trends + Integrated Section Schedules
MANAGEMENT CONSULTANT	Develops Management Plans Procedures, Standards and Criteria Section Design Concepts EEO/AA, Community & Agency Coordniation Programs Controls & Schedules Base Contract Documents SDC Selection Process Performs Projectwide/Other Preliminary Design	Develops Final Design Standards Implements Control Programs Coordination/Participation Programs Performs Technical Reviews Process/Invoice Reviews Cost/Progress Trending Projectwide/Other Preliminary Design	Implements Contract Administration Construction Controls Claims/Change Orders Control Performs Quality Assurance/Control Invoice Review Technical Services Cost/Progress Reviews Construction Control Mgmt Supervise Start-up and Testing	+ Project Management Plan + Contract Services + Management Change Notice + Drawing Control Log + Quarterly Assessment	+ Contract Budget + Management Change Notice + Budget Transfer Program + Work Order System + Direct Expense Forecast + Performance/Progress	+ Section Schedules + Task Schedules + Detailed Schedules by Work Activity + Performance/Progress Reports + Quarterly Assessments
SECTION DESIGN CONSULTANT	Submit Qualifications and Proposals	Provide Final Design Technical Bid Documents Estimating and Reporting	Provide Technical Support as Requested Review Shop Drawings	+ Contract Services + Pending Change Notice + Drawing Control Log	+ Contract Budget + Pending Change Notice + Direct Expense Forecast + Performance/Progress Reports	+ Section Schedules + Task Schedules + Detailed Schedules by Work Activity + Performance/Progress Reports
CONSTRUCTION CONTRACTORS		Bid on Contracts	Perform Construction Start-up and Testing	+ Contract Services + Pending Change Notice	+ Contract Budget + Pending Change Notice + Cost Loaded CPM Schedules (CLCPM)	+ Section Summary Schedules + Detailed Schedules by Work Activity (CLCPM)

5.2.5 Management and Control Programs

Bechtel project manager Don Marshall described the project this way: "The CA/T Project is really a series of self-contained projects. Each has a focus, a set of designers and contractors who were independent of the designers and contractors on other sections. There might be dozens of prime contracts, each with sub-consultants, and on the order of 100 prime construction contracts with separate subcontractors. The management consultant has to control the interface between these sections to ensure the completion of the project as a coherently functioning whole" (Luberoff et. al., 1993).

The complexity of the CA/T Project is further compounded due to the broad level of participation of many participants including Federal, State and City agencies, utility companies, private businesses, community groups, consultants, designers, contractors and suppliers. Therefore B/PB believed clear, concise and comprehensive procedures were essential. The Project Management Plan (PMP), initiated and developed by the management consultant during the planning process, serves as a guide to successfully execute the design and construction of the CA/T Project on schedule, within budget, to the established quality and safety level (Project Manag. Plan, 1996).

The PMP contains the following sections (Project Manag. Plan, 1996):

- Section 1 – Introduction to the Project
- Section 2 – MHD-B/PB project mission and objectives
- Section 3 – Work Program planning methodology
- Section 4 – Work Program execution methodology
- Section 5 – Organization of MHD and B/PB, Allocation of Responsibility
- Section 6-11 – Responsibilities of B/PB organizational units

Figure 5-8 showed that the B/PB contract with the DPW/MHD is through a series of renewable work programs. The current Work Program (WP14) is a 39-month program from July 1, 1996 through September 30, 1999. The DPW/MHD and B/PD establish a scope of work with an associated cost and schedule at the start of each work program, which is evaluated by the DPW/MHD each month. Each work program includes an executive summary, scope of work statement, staffing plan by position, grade and organizational elements, and the latest estimated cost and schedule (Project Manag. Plan, 1996).

Table 5-4 displays the general hierarchy and relationships of the principle documents used to manage the CA/T Project. The documents establish the management processes necessary to achieve the project objectives, establish a project team, distribute responsibilities, and define internal/external relationships.

Table 5-5 displays a summary of the project control elements, who is responsible for them, when they are performed, and what they are intended to do.

Table 5-4 CA/T Documentation Hierarchy
Source: (Project Management Plan, 1996)

DESCRIPTION	DOCUMENT	INCLUDES
B/PB Project Management Plan	B/PB top-level planning document incorporating formal direction and guidance	+ CA/T Project Overview + CA/T Project Mission and Objectives + Management Plans for: - Design - Services - Procurement - Construction - Systems Commissioning + B/PB Project Policy & References
B/PB Project Procedures	Formal B/PB direction & guidance with assigned responsibilities to specific organizational individuals	+ Project Procedures requires to carry out required tasks to implement the PMP methodologies
Project Engineer's/Resident Engineer's Desk Top Procedures	Formal B/PB direction & guidance with assigned responsibilities to Resident Engineers & Project Engineers	+ Step by step approach to implement specific tasks within the Project Procedures
CA/T Technical Scope Statement	Specific outline of the project "technical" scope of work	+ Specific "technical" scope statements for each design and construction package

Table 5-5 CA/T Project Control Programs

Source: (Project Control Plan, 1991)

CONTROL PROGRAM	WHO	WHEN	WHAT
1) Project Management Plan	Management Consultant	Beginning of Work Program	Definition of scope of services to be provided by the management consultant
2) Environmental Eng./Permitting	Management Consultant	As Required	Idenitify Federal, State, & Local environmental requirements, preparing environmental compliance plans
3) Quality Assurance Program	Management Consultant	Continuous	Provide guidance to ensure the intended level of quality through training sessions, standards, and monitoring
4) Risk Management Program	Management Consultant	Continuous	Risk identification and evaluation, application of strategies
5) Technical Scope Statement	Management Consultant	Continuous	Definition of scope, limits and interfaces of all project packages
6) Contract Packages	MDPW/Man Cons/Cons/Contr	Per Project Schedule	Definition of required scope of deliverables/services
7) Change Order Control Program	MDPW/Man Cons/Cons/Contr	As Required	Formal identification and approval of changes to contract scope
8) Capital Cost Trend Program	MDPW/Man Con/Cons/Contr	Continous	Identify potential scope variances for management action
9) Annual Budget Estimate	Management Consultant	Annually	Total Project estimated costs - For fiscal year - For all years
10) Quarterly Assessments	Management Consultant	Quarterly	Review of Management Consultant Work/Program Budget/ Schedule Status
11) Perfromance Progress Reports	Man Cons/Cons/Sub-consul	Monthly	Comparison of Actuals vs. the Plan for Management Consultant/ Consultants/Subconsultants (EPPR,CPPR, and SPPR)
12) Capital Cost Trend Program	MDPW/Man Con/Cons/Contr	Continuous	Identify potential budget variances for all entities
13) Pending Change Notice/ Man. Change Notice Program	Management Consultant	Continuous	Changes to Consultant/Contractor contract scope
14) Cash Flow	Management Consultant	Semi-annually	Forecast of to-go expeditures for all entities
15) Budget/Forecast/Cost Commitment System	Management Consultant	Continuous	Registers Actual, Committed and Budget costs for all project entities
16) Budget Transfer Program	Management Consultant	As Required	Management Consultant Work Program Budget Adjustments
17) Work Order Program	Management Consultant	As Required	Off-Project Control of Management Consultant Budget
18) Obligation Tracking	Management Consultant	As Required	Control appropriation commitments
19) Cost Loaded CPM Schedules	Construction Contractor	Monthly	Construction Contractor invoiced cost vs. budget
20) 90-Day Direct Expense Forecast	Management Consultant/ Section Design Consultant	Quarterly	Direct expense costs
21) Project Master Schedule	Management Consultant	Quarterly	Summary Schedule for all Project Phases by contract package
22) Contract Package Schedule	Management Consultant	Quarterly	Integrated Schedule requirements by project phase and package
23) Area Schedules	Management Consultant	Monthly	Integrated Section Schedule for each Project Milestone
24) Section Schedules	Man Cons/Sec Design Cons/ Construction Contractor	Monthly	Integrated task oriented schedules by package
25) Detailed Schedules	Man Cons/Sec Design Cons/ Construction Contractor	Monthly	Detailed Schedule by work activity/task supporting contract package deliverables

5.2.6 Mitigation Programs

The large-scale and complexity of the CA/T Project required the project team, composed of the MHD, the FHWA, and B/PB, to develop a series of mitigation programs to address public concerns, maintain traffic flow, and minimize the project's impact on the surrounding environment. The community programs focused on residential, commercial, and business properties affected by the project. Residents and owners are generally concerned about issues such as construction noise, dust, and disruptions affecting their ability to live and conduct business.

The project team's approach to developing mitigation programs can be summarized by the following process (Rusteika and Ionata, 1995):

- Identify mitigation issues
- Develop project-wide standards and approaches
- Include the standards and approaches in construction specifications
- Develop project-wide programs to monitor and implement mitigation measures
- Improvement through the application of lessons learned

5.2.6.1 Community Outreach/Public Relations

The project team is attempting to address the concerns of each affected neighborhood. A community representative was identified for each neighborhood that serves to keep the neighborhood informed regarding the project's development and to inform the project team of neighborhood concerns. The project team instituted public information campaigns to announce information regarding detours, project progress, and future scheduled construction. Scheduled press conferences are used to keep the media up-to-date on the project, and educational materials are distributed in schools. A special program provides the community's business leaders the opportunity to receive information and discuss their concerns with the project team (Rusteika and Ionata, 1995).

5.2.6.2 Transportation Management

In an urban environment traffic flow is often a problem and construction can only add to traffic delays and confusion. The project team has developed a transportation management program in an attempt to minimize the project's impact on transportation within the city. The project-wide plan includes transportation planning for each phase of construction, detailed traffic plans by the contractor for each construction contract, and a central operations center to provide control of variable message signs, traffic radio advisories, incident response equipment, and to standardize traffic and pedestrian signage and barriers (Rusteika and Ionata, 1995).

5.2.6.3 Environmental

The environmental impacts of such a large project are examined very carefully. Over 400 permits and licenses are required for the project (Rusteika and Ionata, 1995). The project team created the environmental mitigation program to address noise and vibration control, air quality analysis, water quality analysis, pest management, right-of-way remediation, and material disposal planning.

5.3 Project Challenges/Control Issues

5.3.1 Urban Environment

The location of a construction project can often create additional challenges to complete the project. The urban setting of the CA/T Project required the project team to consider many issues that are addressed through the project design and mitigation programs. A few particular issues were how to maintain traffic flow and utility service, the disposal of waste, and access to the site.

A major challenge to completing the CA/T Project was to maintain traffic flow on the existing artery while the new tunnel was built directly underneath. Slurry-wall construction technology emerged as the best technical solution. Slurry-walls are a reinforced concrete wall, which is comprised of a combined mixture of clay, water and bentonite slurry. Milling machines simultaneously dig a trench, remove excavated material, and pump in the slurry mixture. The method allows contractors to transfer the load from the original elevated structure footings to a new support system. The reinforced concrete decking is supported on soldier pile tremie concrete (SPTC) slurry walls to carry surface traffic while the soil beneath the artery between the slurry walls can be excavated to prepare for construction of the new tunnel (Doebler and Brown, 1997). Once the walls are completed, steel beams are placed across them, and the load on each existing column is transferred to the new underpinning system. The old support piles can be removed and excavation can proceed. This method allows the existing six lanes to be kept open on the elevated CA until the depressed expressway is open to traffic.

Another challenge to below grade construction in an urban area is to maintain utility service to the affected area. Prior to excavation many miles of utility lines had to be consolidated into corridors to ensure continuous service, improve access and clear the way for construction of the depressed artery. In particular, the project's design requires the relocation of utility lines in longitudinal corridors outside the slurry wall, wherever possible, to avoid interfering with future excavations for the tunnel segments (Krawiec et. al, 1997).

Third, the disposal of materials is also a concern when the site is located in an urban area. In total, the construction of the CA and the THT is projected to generate approximately 11.9 million cubic yards of dredged and excavated material (FSEIS, 1991). Most of the dirt and clay materials have been barged to and deposited on Spectacle Island, a former dump in Boston Harbor, creating a cap to convert the island into a park.

The fourth concern in an urban environment is access to the site. A project of this scale requires heavy machinery, a large amount of materials, and a significant number of personnel. All workers, deliveries, and removals must have access without disrupting local traffic. The addition of the South Boston Bypass or Haul Road to the project scope provided an exclusive commercial vehicle route during construction connecting the Southeast Expressway and the new tunnel.

5.3.2 Contracting Plan/Risk Allocation/Responsibility

At times the state has been surprised at the relatively small number of bidders for certain sections of the project. State officials were hoping for competition between bidders and for bid prices to sink. However, the bids are often exceeding engineer's estimates (ENR, 1997, 238(5)). This may be due to fewer competitors, firms with large current workloads and reduced risk capacity, and a history of uncertain soil conditions and price increases for the project. Therefore, bidders may be increasing the contingency in their bid prices. The separate procurement of design and construction services creates a challenge for the DPW/MHD to obtain the best value for design services and the lowest price for construction services.

As a result of conflicts between the State and the management consultant over responding to community concerns and limiting design changes to control the project cost and schedule, the public began to question who is in charge (Luberoff et. al., 1993). The DPW/MHD is contractually in charge of the project team and although it has delegated technical responsibility to the consultant the DPW/MHD actually sets the policy and the consultant only carries out that policy to manage the project. Although the state officially holds the responsibility the size and complexity of the project naturally pushes more control over the project to the more capable management consultants. In reality, although there is no formal direct connection between the FHWA and the management consultant, most major design decisions have been made in key meetings between the consultant and FHWA staff (Luberoff et. al., 1993).

As a result the management consultant has been accused of attempting to extend its responsibilities (Luberoff et. al., 1993). Initially the management consultant was to complete approximately 10% of the section designs before the DPW/MHD awarded them to a specific section design consultant. The JV believed their role included a broader scope for design development with the JV completing about 25% of the design (Helmich, March 24). Because of delays, B/PB often extended initial designs to almost 40% completion. Many local architect/engineers and contractors felt the management consultant was attempting to expand its role and as a result eliminate potential work (Luberoff et. al., 1993). Any differences, in the way the DPW and B/PB perceive the role of the management consultant, are likely to be attributed to the contractual arrangement and the resulting relationships.

The public perception of a cost-plus a fee contract is also precarious. The management consultant serves as an advisor to the DPW/MHD. This type of an arrangement is financially and strategically attractive for private firms. The management consultant does not assume responsibility for construction related risks including cost overruns and delays. The public may be concerned that the consultant does not have the proper incentives to control the project cost and schedule as in reality the consultant benefits from delays and the extension of its contract. Indeed as the cost and schedule has grown over the years, the DPW and the management consultant have been accused of poor management and control of project costs (ENR, 1994, 233(24)).

5.3.3 Project Control

5.3.3.1 Cost and Schedule

B/PB's initial fast-track project schedule projected SEIS approval by 1988, construction started by 1990, the tunnel completed by 1994, and the entire project completed by 1998. In hindsight, this was a very ambitious schedule. Expansion of project scope, multiple design studies, redesigns, utility relocation, and changes during construction all added to the increased project cost and schedule.

Because of the age of the city, utility lines are randomly arranged, sometimes abandoned, and records are incomplete. Therefore, the process of utility relocation has lengthened the schedule, increased the cost and complicated the logistics of the work (Doebler and Brown, 1997).

An example of lost time and money is the initial design of the Charles River Crossing. At first, the State failed to adequately consult government agencies and local communities, and in the end the project team was forced to re-evaluate the design. Consideration of the crossing design delayed completion of the entire project by at least two years.

Because of inflation and enlarged scope, the project's cost estimate has risen since the 1980's from an early $2.6 billion to $7.8 billion as of July 1996 (Robinson, 1996). The continuing effects of inflation are expected to increase the final cost to almost $11 billion in 2004. Table 5-6 displays the progression of cost estimate changes over the years (Sloan, 1997).

Table 5-6 CA/T Cost Estimate Progression

Year	Prior Estimate (M)	Scope Changes (M)	Escalation (M)	Projected Cost (M)
1985	2,564	-	-	2,564
1987	2,564	46	565	3,175
1989	3,175	799	462	4,443
1991	4,436	299	458	5,193
1992	5,193	609	641	6,443
1993	6,443	869	428	7,740
1996/ 2004	7,740	1,087	2014	10,841

The State's effort to minimize the project's impact on the surrounding communities has greatly contributed to the cost increases. As of 1997, mitigation represented about a third of the project's $7.8 billion budget (Doebler and Brown, 1997).

5.3.3.2 Change Management

A research study on Information Technology Support for Managing Change, Cost, and Schedule for the CA/T Project, conducted by MIT Professor Feniosky Pena-Mora, found it takes an average of three to nine months to approve a modification to a contract. Claim analysts spend between 75% and 85% of the time it takes to process a pending change notice waiting for a proposal and negotiating with the Section Design Consultant or Contractor. Spending such time in waiting for and negotiating a proposal creates a bottleneck behind which pressure builds on the other activities of the process (Pena-Mora, Jan. 1995). Preliminary findings show that such a long approval process forces reactive decision making with questionable quality (Pena-Mora, March 1995).

Scope changes have significantly contributed to the large cost increases. The current CA/T Project Director, Peter Zuk, has stressed the need for more efficient oversight of the project. Table 5-7 displays some of the significant scope changes over the years.

Table 5-7 CA/T Project Scope Progression
Source: (Hunter, October 1998)

Between 1985 and 1989		Approx. Cost (M)
•	Addition of South Boston Bypass/Haul Road	23
•	Southerly Extension of I-93	130
•	Addition of I-90 HOV Facilities	262
Between 1989 and 1991		
•	Reconstruct Dewey Square Tunnel	59
•	Addition of I-90 Tunnel Covers	176
•	Hazardous Waste Disposal Program	141
Between 1991 and 1993		
•	Relocation of Utilities	85
•	New Charles River Crossing Design	508
•	Program Management Increase	263
•	Insurance Cost Increase	237
Between 1993 and 1995		
•	Fort Point Channel Design Changes	204
•	Added Scope Logan Airport Interchange	111
•	Additional Mitigation Agreements	63
•	Added Scope Maintenance/Police Facility	17
•	Added Scope Purchase St. Bypass	16
•	Differing Site Conditions/Changes to Contracts	93

The design-bid-build process has necessitated the coordination of many design and construction contracts. Each design change submitted by the contractor must be reviewed and approved by the section designer, the DPW/MHD, and all appropriate regulatory agencies. The management consultant must consider the impact the change may have on the entire project as well as that section. As a result of the pre-determined delivery strategy, the DPW/MHD and the management consultant are forced to manage the process.

5.3.4 Mitigation/Public Relations

Early discussions with business leaders and community groups identified the need for mitigation plans to reduce the impact of construction on traffic flow and the surrounding neighborhoods. The project passed through multiple residential communities and neighborhoods including the South End, Chinatown, East Boston, South Boston, the Waterfront, the North End, and Charlestown. "Achieving final consensus on the project, therefore, required reaching agreements with dozens of neighborhoods, businesses, and environmental groups as well as satisfying the concerns of hundreds of individuals whose property was near the project" (Luberoff et. al., 1993).

In response to community demand, DPW/MHD staff directed B/PB to conduct technical studies and at times change the project design (Luberoff et. al., 1993). There was an ongoing tension between working with and appeasing local neighborhood groups and with advancing the project. By June of 1990 the joint venture had completed around 130 design studies and well exceeded the man-hours budgeted for work on the SEIS (Luberoff et. al., 1993). As a result conflicts arose between the State and the management consultant as the state felt a greater obligation to respond to community concerns while the consultant desired to limit design changes to control the project cost and schedule.

The Charles River Crossing design provides a good example of the tension between satisfying the community and advancing the project. "Consideration of the crossing design has already delayed completion of the entire project by two to four years. After the six-month period to give all interested persons an opportunity to express their views, the time for argument has passed. Priority must be given to completion of the final plans as a prelude to construction" (Hesshaus, 1995) (Boston Globe, Dec. 20, 1994).

5.3.5 Constructibility/Best Value

CA/T officials have been criticized on their efforts to control costs. "Inspector General Robert A. Cerasoli has claimed that CA/T officials have followed through on only $325 million of a possible $2.8 billion in estimated savings project wide, as recommended by the project's own cost control program" (Hesshaus, 1995) (Boston Globe, Dec. 20, 1994). From the project's perspective, Peter Zuk notes that 64% of all value-engineering proposals have been accepted and acted on, saving over $300 million (ENR, 1994, 233(14)). In response to the Inspector General (IG) Zuk asserted, "What the IG doesn't state is that $1.4 billion, in value engineering recommendations, was for a bridge over the Fort Point Channel and Scheme Z, the Charles River Crossing. It is unclear if we would have been able to build the project had we accepted the VE recommendations" (ENR, 1995, 234(1)).

Project objectives that specifically required no displacement of local residents added to the complexity of the project's design. The communities were included in the design process and often requested, or required, design changes to gain their acceptance. The attacks on the DPW/MHD's and the management consultant's efforts to control costs may lead to the question, is Boston and the Government receiving the best value for its investment? The answer to this question lies in the political motives for pursuing the project and contractual arrangements between the DPW/MHD, the management consultant, the section designers, and the section contractors.

5.4 CA/T Case Study Analysis

5.4.1 Project Configuration Process

The course of the project's development reveals that once a general solution emerged, the DPW/MHD hired a management consultant in 1985 to conduct many alternative studies before complete Federal funding was secured in 1987. The delivery strategy places time, money and effort at risk before there is consensus on project scope or means of financing. The design-bid-build process also allows projects to receive Federal funding before the project is adequately defined and before it has received environmental approval. Under this arrangement two divisions of the government may work against each other. Congress, who approves the funding, does not really know the entire scope of the project as changes often occur during the environmental approval process conducted by State and Federal agencies.

The ten-year process needed to develop an acceptable CRC design provides a good example of the need to adjust how government agencies, private groups, and the public interact in the development process. The intention of the NEPA and MEPA processes is on target. The public needs to be informed of and given a forum to comment on potential public projects that affect the general community. However there must be a balance between public involvement and fulfilling a realistic identified need.

Although the project received approval for Federal financing in 1987, the extent of Federal support as of 1998 is uncertain, as the total Project cost has risen over the years. The State assumes future Federal support between $550 and $580 million per year, although proposals currently under consideration by Congress would provide between $392 and $552 million per year (Malone, 1998). This is not surprising, as the remaining costs to complete the project are also uncertain. The Commonwealth estimates expenditures to date at $4.775 billion with remaining costs anywhere between $5.6 and $7.6 billion (Malone, 1998). The current Commonwealth Official Statement places remaining costs at $6.844 billion, but with the assumption that future contract overruns will not exceed 10.7% of the original bid price, which is below historic rates for the Project (Malone, 1998).

As a result the State, in the middle of a major public works project, does not have guaranteed financing mechanisms in place. The costs for the Project must be continually re-evaluated in light of potential Federal support. The lack of secure funding forced the State Administration to hire the Commonwealth Group to serve as a lobby in Washington in regard to CA/T Project concerns (Malone, 1998). Although it may be financially prudent for the State of Massachusetts to spend money to gain a larger Federal share, is this a prudent use of resources as a national policy?

Recent developments indicate that although the design is almost complete for the entire project and construction has begun on most sections the scope of the project is still under consideration. The project's policy to include community groups, business leaders, and regulatory agencies in the design process seemed to develop a project that accommodated everyone. Recently, however, East Boston has indicated community officials may file a lawsuit and seek an injunction to halt the project. The community is requesting another re-evaluation of the design for the THT connection to Rte 1. Instead of constructing an at-grade and elevated structure the community would prefer the connection to occur underground (Helmich, October 5). In addition, in January 1993, Massachusetts Governor William Weld and Lieutenant Governor Paul Cellucci announced their commitment to explore the feasibility of a rail link between North and South Stations. The Central Artery Rail Link Task Force, composed of the MHD, MBTA, and B/PB conducted the study and began developing preliminary plans for a rail connection under the new depressed artery that was once considered technically infeasible. If approved, the funding for this, 1993 estimated $1.3 billion, project is anticipated to come from a public/private consortium consisting of the MBTA, Amtrak, and private financial partners (Task Force, 1993).

5.4.2 Misguided Objectives/Project Financing

Because the current method of delivering public projects requires public means of financing, how each project will be financed is part of the project identification process that should only be based on need. A powerful financial dynamic makes it difficult to pursue projects based solely on the basis of need and the appropriate fulfillment of that need. Interstate highway projects were eligible for 90% Federal funding, and the money allocated to them was not transferable to other projects. If the state does not use the money allocated for an approved project then the Federal government would take back the money and distribute it to other states that had viable projects.

It has become clear that, "highway planning and decision-making at the highest levels are fundamentally political processes. Ultimately the State's ability to win approval of the artery plan was inextricably linked to a host of other issues, agendas, and projects" (Luberoff et. al., 1993).

In actuality, it is not only 10 cent dollars that motivate the State to support such projects, but the residual effects of Federal money flowing into the State as well. In 1985 estimates indicated that the preferred alternative would generate $ 4.3 billion in industry sales and household earnings and about 77,000 person-years of employment. Net increases in income tax receipts to the Commonwealth from aggregate construction impacts were expected to total approximately $76 million (FEIS, 1985). This flow of money into the State will fund most of the State's 10% stake in the project.

A consequence of pursuing Federal support was that during the process of scope and design development the emphasis was placed on ensuring the Project could pass environmental review and that there would be no basis for critics to challenge the project in court (Sloan, 1997). Therefore, cost containment was not the focus of attention during the configuration process. A small-scale example of the influence of Federal financing on the project is the relocation and construction of a new Boston Edison transformer substation. According to the U.S. Department of Transportation Inspector General, rather than minimize project cost, the State instructed Boston Edison on how to maximize Federal participation in the relocation (Malone, 1998).

As the future percentage of Federal funding remains uncertain, the State may have to commit more resources to complete the Project. The State may need to consider revenue-generating options such as tolls, user fees, gas taxes, or private contributions. As a result of renovating the downtown area access has improved to inner Boston and the industrial waterfront area. Therefore the Commonwealth should also explore how private beneficiaries could contribute to CA/T Project costs (Sloan, 1997).

Although it has been stated here the Federal financing participation is uncertain, an important precedent to remember is that no approved Interstate highway project has ever been left incomplete due to lack of funds in the history of the U.S. Interstate Highway System (CA/THT Project, 1998).

5.4.3 Project Objectives

The DPW/MHD and the FHWA collectively establish design, construction and management objectives for the project. The distribution of written copies to management personnel should increase awareness of the objectives within the project team. B/PB also specified a set of project objectives in their Project Management Plan. These objectives are updated periodically to maintain relevance to the phase of the project.

Although in general these are good practices, the project team should share a common set of project objectives. Under the contractual arrangement for the project the management consultant acts as the DPW when it carries out management functions. This role should necessitate identical objectives for both organizations. It is also important to conduct a periodic review of these objectives from the perspective of the entire project team, consisting of the DPW, FHWA, and the management consultant, to incorporate lessons learned and to reflect the stage of the project.

5.4.4 Contracting Plan/Risk Allocation/Responsibility

The DPW/MHD's initial decision to hire a private consultant to manage the design and construction of the CA/T Project was reasonable and prudent for the following reasons:

- Once in a generation project
- DPW/MHD did not have the expertise or workforce
- Would have to hire then fire

- Private competition
- Private management and technical expertise
- Innovative and flexible response to DPW/MHD directives

At the time the DPW/MHD did not have the personnel or the capability to carry out the management of the project alone. Even if the department could find and hire the needed personnel what would they do once the project is finished? The DPW/MHD would be put in the position to increase its staff only for the duration of the project. Upon the project's completion many people would lose their jobs. In comparison, the private sector currently has the capability to provide management service for large-scale projects. Although a project may be a once in a generation project for a city or region upon completion, unlike a public agency, the private company can move on to the next city.

The public agency can also benefit from private sector competition to provide management services. If multiple firms compete for a contract to provide these service the market should provide an independent check to ensure the public agency is receiving the best value for its investment (Miller, 1997). With the right contract structure and incentives the private sector will provide innovative solutions to technical and management challenges. In the long run this will increase the quality of service and performance.

The public community has criticized the management consultant for assuming too much responsibility and for a lack of control over project costs. These two arguments are in conflict, it cannot be both ways. A report by Peterson Consulting Limited Partnership, in 1995, indicated that the project needed more effective oversight by the DPW/MHD and more accountability from B/PB (ENR, 1995, 235(26)). However, it is important not to confuse the roles of a management consultant and a construction manager. If the State had hired a construction manager, some or all of the construction risk could be transferred contractually to the private construction manager. However, the State's use of a management consultant left the responsibility and risk for project execution in the hands of the DPW/MHD.

Although the value of consultant contracts with the DPW/MHD has been criticized, as of August 1996 the project had been able to avoid major litigation. Project Director, Peter Zuk, stated, "I cannot monetize how much we saved as a result of partnering, but after awarding over $2 billion in construction, we have no lawsuits and no major disputes" (ENR, 1996, 237(8)). The adverse impacts of claims and litigation on project cost and schedule is widely recognized, therefore the project team's efforts to avoid disputes cannot be overlooked.

To avoid these accusations the DPW/MHD needed a clearer definition of services to execute sufficient control over the consultant. Understanding the scope of needed services and structuring a competition for a single contract for the management services may have resulted in a better understanding of roles and responsibilities within the project team. In general, the party who is accountable for the project scope and cost must have proper incentives to perform. Under the contractual arrangement for the CA/T

Project once mitigation measures began to require more money, it became difficult to control the project scope and cost. Unless contractually obligated, there is potential for cost control to become a lesser priority when everyone seems to gain from increases in the scope and more Federal money.

5.4.5 Project Management and Control

In response to the broad level of participation including Federal, State and City agencies, utility companies, private businesses, community groups, consultants, designers, contractors and suppliers B/PB developed a Project Management Plan (PMP) to guide the project in successfully executing design and construction of the CA/T Project on schedule, within budget, to the established quality and safety level (Project Manag. Plan, 1996). B/PB believed clear, concise and comprehensive procedures were essential.

Although on the surface this makes sense, it is important to ask why the project is complex. Is it complex because of the delivery process itself? The management consultant was involved when the scope was still unclear and the public and regulatory agencies were still changing the scope through the environmental review process. The environmental review of the CRC was still in progress in 1993 after almost all of the preliminary design, most of the final design, and some construction had taken place. Would the project be perceived as less complicated and require fewer procedures for control if it were well defined and environmentally approved before private participation?

5.4.5.1 Cost and Schedule

Massachusetts Officials used the 1985 cost estimate to obtain the required Federal support. However, the $2.564 billion figure was based on 1982 estimated construction prices and did not include potential increases for inflation (Sloan, 1997). By 1992, with engineering well underway and the start of construction, the estimate had grown to $7.74 billion. In 1996, after most of the final design had been completed and a significant amount of construction had begun, the total estimated cost reached $10.8 billion (Sloan, 1997).

The total cost to design and construct the CA/T Project is the result of multiple factors: (1) The Project required particular attention to design quality and construction techniques because of the Project's urban environment; (2) the expansion of the base scope over time; (3) the extension of the schedule to completion subjected the project to significant inflation; and (4) sensitivity to surrounding communities and the environment led to multiple mitigation agreements to smooth out the Project's impact. A study by the McCormack Institute of Public Affairs at the University of Massachusetts estimated that 30 to 35% of the project cost can be attributed to design and construction alone, about 25 to 30% to environmental and community mitigation measures, and about 40% due to inflation and cost escalation over the years (Sloan, 1997). It is also important to note that approximately 15% of the total cost is funded primarily by State and local transportation agencies, such as the Massachusetts Port Authority (MPA), the Massachusetts Bay

Transportation Authority (MBTA), and the Massachusetts Turnpike Authority (MTA), for their own projects within the scope of the CA/T Project (Sloan, 1997).

Early on the CA/T Project was recognized for increased costs and delays. The report by Peterson Consulting Limited Partnership stated, "To improve communications and project control, the CA/T must establish an area responsibility organization that would create a sense of 'ownership' and accountability to enhance budget and schedule controls. In addition, CA/T needs to develop an all-inclusive monthly management report that would end floating budgets and schedules. They need to make a commitment. Get the budget and schedule into the management report and live by it" (ENR, 1995, 235(26)). CA/T project director, Peter Zuk, supported the recommendations and despite the project's current critics, Zuk, has stated the project will stand at $7.7 billion plus inflation in 2004 (ENR, 1995, 234(9)). "'We believe that our aggressive cost containment program has worked'" as costs have dropped by $218 million in 1995 (ENR, 1996, 236(5)). The FHWA seems to be pleased with the project teams current efforts to manage and control project costs (ENR, 1995, 234(9)). The JV project control group consists of 50-60 people, most of whom are in the field. Thirty project engineers interface directly with section designers and contractors to monitor and control project costs (Helmich, March 24).

The reason for the increased costs cannot be solely attributed to poor management. Although the inclusion of multiple agencies and private interest groups in the design process has, for the most part, created an environmentally, technically, and aesthetically sound project the process has undoubtedly added to the enormous delays and cost increases. Well-defined project goals and scope, early introduction of consistent and effective management and control programs, in particular mitigation/public relations, and a clear and definitive project development schedule will help avoid these kind of cost and schedule overruns. The development of a Project Management Plan and project procedures regarding project control, quality assurance, engineering, constructibility/ value engineering, administration, procurement, change management, and document control by B/PB help standardize the processing and distribution of information within the project team.

On public projects there has to be a compromise that includes the public in the design process and allows the project to move forward. The example of the Charles River Crossing shows that the approach to public participation in the design process can lead to increased costs and delays. In this case the state sought Federal approval of Scheme Z before adequately resolving the design issues. After public opposition the state initiated a redesign of the river crossing and the interchange between Rte 93 and Rte 1 in Charlestown. The redesign significantly delayed the project and increased costs. Resolution of such issues during the project resulted in the estimated completion date to slide from 1998 to 2004. The added time and the required design studies significantly increased both the design and project management budgets.

Although the detailed planning, design studies, environmental reviews, and negotiations with community groups from 1985 to 1993 were necessary to advance the project through the environmental review and permitting process while maintaining political and community support, they were the driving force behind increased costs.

5.4.5.2 Change Management

It is important to note that the additions in scope were generally the result of extensive negotiation between the project designers and the affected interest groups, such as the FHWA, the U.S. Army Corp of Engineers, State agencies, as well as community, business, and environmental groups. However these important and difficult issues should be resolved prior to private involvement in the project.

The dynamic nature of the CA/T Project prevents static planning from being effective. The complexity of design due to the project's large-scale urban environment/confined space and community participation results in unforeseen events during implementation, which challenge initial assumptions and plans. These unforeseen events often lead to project changes. A proactive change management system is essential to identify change, react to change, and forecast potential change in a timely fashion.

However, the contractual arrangement itself inhibits quick turnaround on change requests by the contractor. The contractual separation of design and construction allocates design and construction responsibility to different parties. When a contractor encounters a potential change situation that request must be reviewed and approved by the designer, owner, and all other appropriate regulatory bodies. This process undoubtedly takes longer than a combined approach where the design-builder identifies a change and notifies the owner. When considering a design "improvement" the combined approach also eliminates the potential adversarial relationship between the designer and contractor that may lead to the designer defending its original design.

On large-scale projects where there are multiple designers and contractors the mere coordination and processing of changes becomes a major challenge. The time saved by having an effective change management program is key particularly when the schedule drives the design-construction process.

The change management program must have a process for identifying issues, which are actions or circumstances that can cause changes in scope, personnel, cost or schedule. Effective change management occurs when a source of change and its effect on the project are identified ahead of time. An effective change management program will reduce project delays, enhance project teamwork, improve project quality, and maintain project financial performance. A well-defined project, a good organizational structure, and a good project control system generally result in smooth classification and control of changes. However, even with all these elements in place it may be difficult to predict future changes and process changes efficiently. The design-bid-build process requires the participation of multiple parties that all require their own block of time. Needless to say, the process is extended if the changes are not approved as originally submitted. Much time could be saved if the designer and contractor had a relationship, contractual or not, that permitted an acceptable design to be completed before seeking owner approval.

5.4.6 Mitigation/Public Relations

It is important to include public agencies and community groups in the design process in order to obtain consensus or near consensus to support a reasonable project. The lack of an effective public relations program during the design of the Charles River Crossing resulted in lost time, money, and effort for the entire project.

"In managing the media the biggest challenge is to provide clear, easily understandable information" (Hesshaus, 1995) (Carr, 1994). A mitigation/public relations program can help identify public concerns, promote the project, maintain public support, and keep the public informed of project developments. During the early stages of a project it is generally a good idea to volunteer information at regularly scheduled press meetings. There comes a time, however, when the lead agency must take control over public perception and allow the consultants, designers, and contractors involved to proceed with the execution of the project. This transition must generally occur once the design is nearing completion. "Attempting to solve each and every minor issue can only lead to more problems and additional opportunities for confrontation" (Hesshaus, 1995).

5.4.7 Constructibility/Best Value

Under the existing process the use of value engineering is limited. The DPW/MHD and the management consultant conduct value engineering studies during the preliminary design. Each section design consultant completes the design for their respective section and submits a construction cost estimate for that design. Value engineering reviews are then initiated when the consultant's estimate exceeds the construction budget allocated to that section (Project Control Plan, 1991).

After reviewing the process the Massachusetts Inspector General and the Peterson Consulting study concluded that a separate value engineering study during final design could address details and assumptions not available during preliminary design (Ceralsoli, 1996). However, a separate value engineering study during final design would most likely increase the time needed to complete the design and receive environmental and permit approvals without incorporating the expertise of the contractor. On the other hand, combined methods of project delivery would allow value engineering to occur throughout the design process while incorporating the experience of the contractor that will execute the construction process.

CA/T officials have received criticism over controlling project costs. Critics claim that the value engineering program has been mismanaged and that potential saving have been ignored. However, sometimes decisions are made with other things in mind besides total cost. CA/T officials received two VE recommendations for the connection of I-90 and I-93 and implemented the one that saved less but provided a better alignment and less overall project impact (ENR, 1995, 234(1)). The history of the Central Artery project clearly shows the political nature of the project and at times cost savings and design simplifications had to be sacrificed for the project to become a reality. The real figures for potential VE savings are those that offer acceptable alternatives in terms of design standards, community and environmental impacts, and safety.

A good example of a VE proposal that is not a "real" option for the state was submitted by B/PB. B/PB proposed to remove the existing artery before depressing the new expressway. Estimates for the plan saved more than $1 billion and 4 years of construction time. Politically and practically it could not be accomplished as all traffic would be detoured through the streets of Boston and give the impression the city was closed for business (ENR, 1995, 234(9)). CA/T officials did accept a proposal from Modern Continental/Obayashi Corp. To minimize disruption in the downtown area, the proposal suggested that the roof of the depressed highway tunnel be built first and the tunnel excavated later. Reengineering cost Modern/Obayashi about $2 million and the VE proposal would save $3 million. This allowed Modern/Obayashi to regain its costs, reduce the schedule by nine months and share $1 million with the owner (ENR, 1996, 236(12)).

A legitimate concern may be that as the project is structured there is no one in a position to initiate actions to secure such savings. Most of these savings require changes in the project design. The management consultant is not free to change the design and the state has the conflicting interests of appeasing local community groups to maintain project support and controlling project costs. History has shown that, for most of the CA/T Project, community concerns have outweighed potential savings. The timing of the VE process does not optimize the potential benefits. The segmentation of design and construction within the delivery process forces contractor value engineering to occur after 100% designs are complete. The design-bid-build process dictates that construction contractors compete based on a price developed from 100% complete designs. The contractor cannot contribute value engineering knowledge during design development when the contractor has not yet been identified. The Modern/Obayashi example shows that from experience contractors may develop and propose alternative construction methods. Introduced at such a late stage however a $3 million VE savings is reduced to $1 million shared between the contractor and the owner due to high reengineering and design costs.

The design-bid-build lump sum procurement process for contractors, which relies on low bids, is in conflict with the need for high quality construction of a complex project. In order to be low bidder and honor that bid a contractor may sacrifice quality to reduce costs. The process does not allow contractors the chance to provide input on construction methods or materials. Suggested changes in construction methods or materials need to be formally approved and this process often delays execution of the work.

Other project delivery methods allow for a formal or informal constructibility review or value engineering process performed by the contractor to incorporate their experience in to the design. Other delivery methods also allow selection of contractors to be based on the best value instead of lowest cost. The State can use lifecycle cost analyses and contract incentives to ensure quality construction.

Even within the design-bid-build process, the State must remove the fear that another contractor will submit a low bid and provide incentives for contractors to accurately and honestly estimate the cost to complete the work. One simple method to accomplish this is to remove the lowest bid, if deemed to be unreasonable. This, however, involves the arbitrary discretion of the State agency and could be subject to criticism.

5.4.8 Lessons Learned

On large-scale projects different people or groups encounter similar challenges and problems at different times. The communication of previous actions taken and lesson learned is essential to improving operating procedures, decision making, and general performance. The CA/T Project team updates and distributes a lessons learned manual every 9 months. This is important because owners must evaluate the effectiveness of management and control activities and incorporate the lessons learned into future decisions as well as the planning efforts of future projects. Time, financial, and human resources are always limited therefore, it is essential that management personnel make the best decisions. Knowledge of past experience is an essential reference. Only through continuous refinement and improvement will the project team obtain the greatest benefit from planning, management and control activities.

5.5 CA/T Project Configuration Conclusions

1. The design-bid-build procurement process was started before the scope was determined. For example, the environmental review of the CRC was still in progress in 1993 after almost all of the preliminary design, most of the final design, and some construction had taken place.
2. The design-bid-build process was started before receiving all necessary environmental and permit approvals.
3. The design-bid-build process was started before funding was secured.
4. Government regulations requiring the separation of design and construction and Federal funding programs result in project objectives that focus on Federal funding.
5. Although no Federally assisted project has been left unfinished, the government does not know the scope or the total cost of the project it is funding. The design-bid-build process allows a project to receive Federal funding before the project is adequately defined and before it has received environmental approval. Under this arrangement two divisions of the government may work against each other.
6. The initial design process followed a decide-announce-defend cycle.
7. There must be a balance between public involvement and fulfilling a realistic need.
8. Project costs were increased due the effects of inflation and changes over the prolonged schedule.
9. The lack of a clear Project Configuration Process where the DPW clearly defined the project objectives and scope set the stage for the uncertainty concerning the role of the management consultant.
10. In hindsight the long project duration, project changes, and less than complete scope at the time of competition for the management consultant contract severely limits the potential of competition. A scenario could develop where the focus is shifted to

obtaining the contract at any cost. Under these circumstances it is very difficult to conduct a fair competition and for the government to understand the value of the procured services.

11. The design-bid-build process limits the effectiveness of value engineering and the potential to obtain the "best-value" for public money.

6 Tren Urbano: Case Study 2

6.1 Background

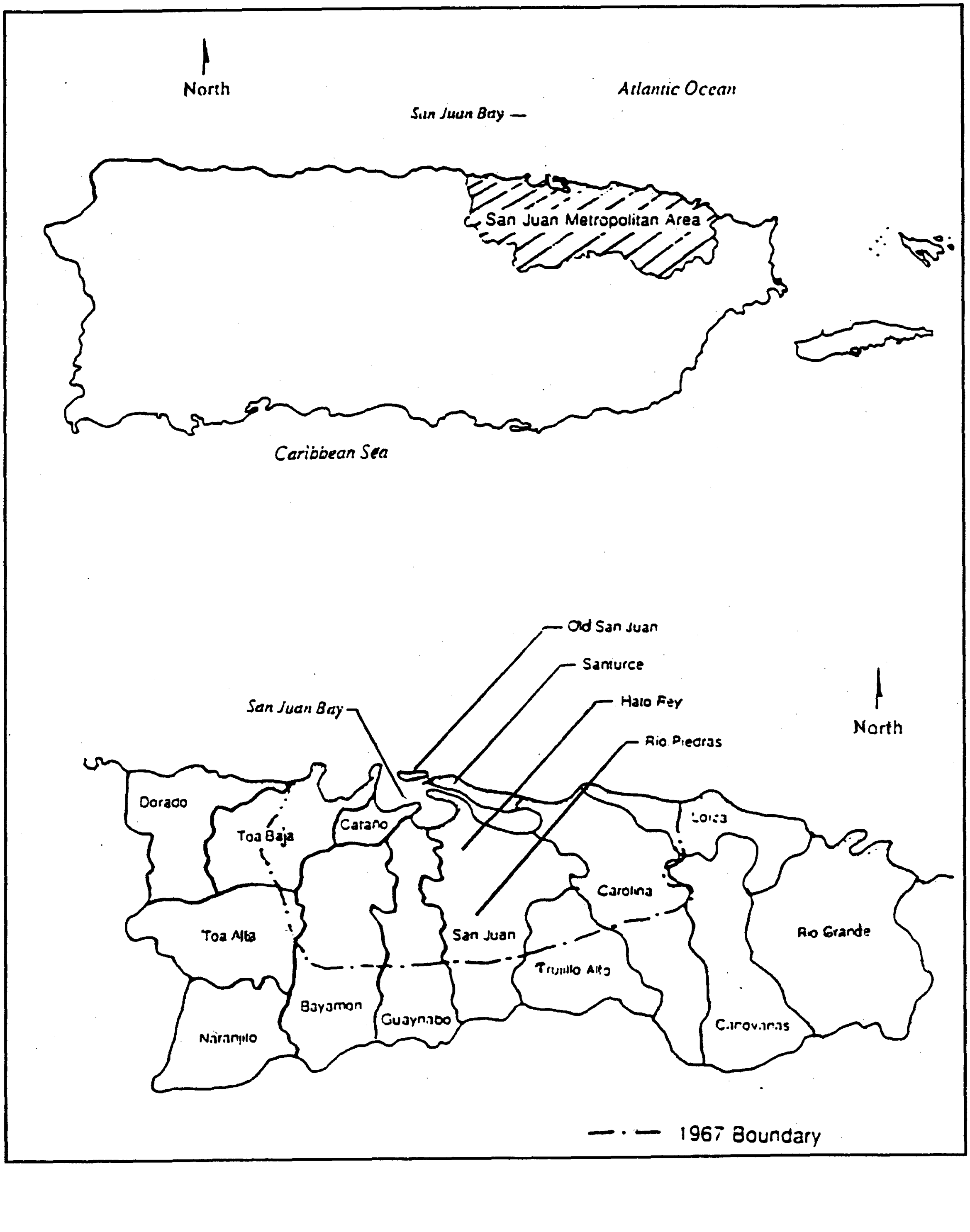
6.1.1 Identification of Need

Puerto Rico, though only 160 kilometers long by 56 kilometers wide, has a population of about 3.8 million. One third of the island's residents live in the San Juan Metropolitan Area (SJMA). The region on the northeast coast of the island, shown in Figure 6-1, encompasses 13 municipalities covering 400 square miles (DTPW, 1998). Surveys from 1990 estimate the population to increase by 20 percent, to 1.55 million people by 2010. While the population growth is expected to occur on the fringes of existing urbanized areas, the population density of the SJMA presently averages 3,230 people per square mile and contains some zones exceeding 20,000 people per square mile (Barton, 1993). Currently an estimated 4,200 vehicles per square mile and approximately 3.2 million trips to the central SJMA per day, create one of the most congested urban road networks in the world (TUO, 1994).

The need for transportation improvements in the region is the result of many factors including topography, waterways, development patterns, and a series of inadequate transportation facilities (FEIS, 1995). Development has spread from the major population centers of Old San Juan, Santurce, Hato Rey, and Rio Piedras, to the east to Carolina and west to Bayamon. Mountains form a natural barrier to the south and the Atlantic Ocean is to the North. Three bridges cross the waterways that separate Old San Juan from the main island. The combination of the region's development patterns and natural barriers have resulted in significant congestion for roadway vehicles (FEIS, 1995).

The major problem is that the existing infrastructure network is not capable of handling the mobility needs of the surrounding public. Travel demand cannot be satisfied by the current capacity of primary and secondary roads (Guadalupe, 1996). Highway improvements have not kept pace with traffic growth; only 23 percent of the major street system has four or more lanes in the SJMA (Barton, 1993). The current public transit system consisting of buses and publicos is subject to the same traffic congestion as the private vehicles. Many of the major roads and intersections throughout the SJMA are operating most of the day at a level F service rating (FEIS, 1995). This rating indicates that traffic flow is almost nonexistent during these time periods. With total regional travel expected to increase by 45 percent by 2010, more of the system will be congested for loner periods of time, unless major transportation investments are made (Barton, 1993). In 1993, a study by Barton Aschman Associates, Inc. concluded "Increased congestion and unsatisfied travel demand cannot continue indefinitely without imposing economic hardship on the normal conduct of business and without lowering the quality of life for those who live and/or work in the area. Failure to provide access to the economic center of the SJMA will result in the withering and ultimate decline of this vital part of the region and its tax base."

Figure 6-1 Puerto Rico and the San Juan Metropolitan Area
Source: (Decker, 1996)



A major constraint on improving the transportation network for the region is the fact that the highway and road networks of the densely developed centers in the SJMA are not capable of being expanded to serve the demand. Significant increases in highway system capacity are not feasible because of intolerable community and environmental impacts.

Public officials agreed the new mode of public transportation must provide access to the economic centers and not be restricted by the congestion of the existing highway and road networks to effectively address these concerns. However, for over 20 years any project addressing the problem remained in the planning stages. Each study conducted since 1967 concluded that a rail transit system in the Bayamon Crescent should be a priority for the region (GMAEC, 1994). The study by Barton Aschman Associates, Inc. concluded "The demand levels to be served and the development densities and land use patterns in the regional center require some form of high-capacity, grade separated guideway transit to meet travel needs through 2010 and to provide reserve capacity for longer-term growth well into the 21st century."

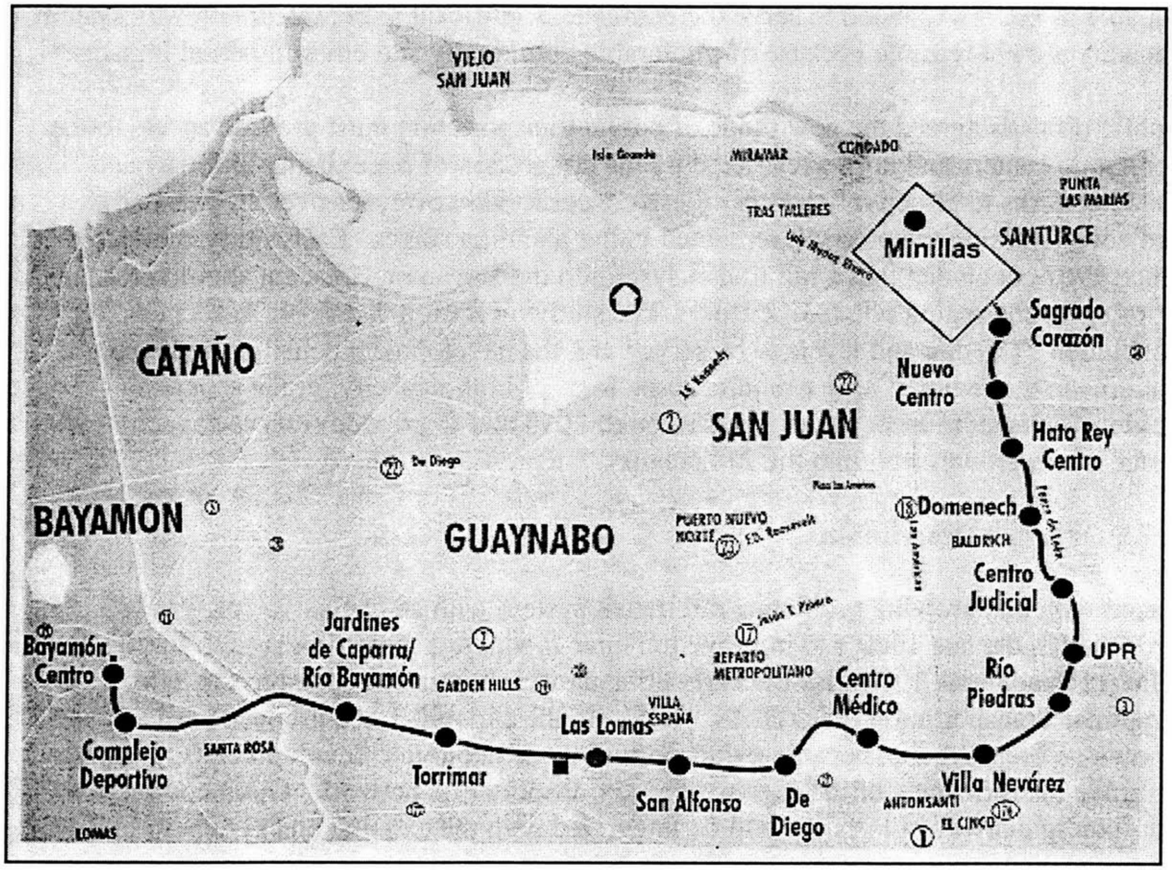
6.1.2 Project Description

Faced with this growing problem a rail transit system with an exclusive corridor was proposed in the late 1960's to improve the inter-modal transportation system for the SJMA (Guadalupe, 1996). By the early 80's, a rail solution was added to the SJMA Regional Transportation Plan (DEIS, 1995). In the early 90's, the proposed rail system, known as Tren Urbano, became a transportation and economic development solution to improve the efficiency of the region's entire transportation network. Upon completion, the fixed-guideway rail system will be integrated with the existing bus system to link San Juan's major activity centers.

The Puerto Rico Department of Transportation and Public Works (DTPW) and the Puerto Rico Highways and Transportation Authority (HTA) made the decision to construct Tren Urbano in phases. The first phase extends over 17 kilometers and will provide service for an estimated daily ridership of 115,000 passengers, at a capital cost of approximately $1.5 billion (Fosbrook, 1998). Tren Urbano will be fully automated with a double track, fixed-guideway system and 16 stations. It will operate 20 hours per day and maintain a headway of 4 minutes between cars during the morning and evening peak hours.

The Phase I base alignment serves the four main metropolitan municipalities of Bayamon, Guaynabo, San Juan, and Santurce with stops at the major centers of Rio Piedras and Hato Rey. The transit corridor, an inverted-C, is shown in Figure – 6.2 and includes each of these commercial, high-density employment centers that have historically been the focus of the region's public transportation system. The line will tie together most of the region's major activity centers including residential, retail, business, government, and medical, as well as, sports facilities and the main campus of the University of Puerto Rico. Approximately 60 percent of the project is elevated above the main roads while the remainder is at or near grade level, except for underground sections at Centro Medico and Rio Piedras. The first phase is projected to be operational by the

Figure 6-2 Tren Urbano Alignment
Source: (DSEIS, 1998)



fall of 2001, while several extensions of the system to Minillas, Carolina, Old San Juan, and the Luis Munoz Marin International Airport are in the planning stages.

In 1993, the FTA designated Tren Urbano as a Turnkey Demonstration Project. As a result the Federal government has committed to support 1/3 of the project cost. The Intermodal Surface Transportation Act (ISTEA) passed in 1991 included a section that directed the Federal Transit Administration (FTA) to develop a Turnkey Demonstration Program. The program is intended to test and evaluate the application of turnkey procurement strategies for major transit projects. The FTA believes the delivery of transit systems would benefit from new advancements in technology and lower delivery costs as a result of combining design and construction into a design-build relationship. The program presently includes four transit projects including new start systems and extensions of existing systems. In addition to Tren Urbano, the program includes: Bay Area Rapid Transit Airport Extension, Baltimore Light Rail Extensions, and Los Angeles Green Line.

An overview of the key events surrounding the development of Tren Urbano is described by the timeline in Appendix E.

6.1.3 Project Benefits

Tren Urbano attempts to reconcile local concerns and objectives with those of Federal and local agencies, financiers, consultants, system suppliers, architects and engineers, contractors, subcontractors, operators, and users (Guadalupe, 1996). Tren Urbano is expected to reduce congestion due to the availability and use of a high-quality public transit system.

Tren Urbano is expected to result in an annual 310 million kilometer reduction in total vehicle kilometers traveled (FEIS, 1995). This reduction will result in improved air quality in the form of a reduction in carbon monoxide, hydrocarbon, and nitrogen oxide emissions. Due to efforts toward intermodal integration Tren Urbano should positively affect other modes of public transit increasing efficiency and daily travel mode share. The reduction in traffic congestion for the SJMA is estimated to result in annual travel time savings of 8.78 million hours (FEIS, 1995).

The Full Funding Grant Agreement signed with the FTA in March 1996 has secured Federal funding of 1/3 of the project's cost. The inflow of Federal money into San Juan will benefit the economy of Puerto Rico. Tren Urbano is expected to have a positive impact on the economic development of the SJMA. The HTA estimates the Project will generate \$2.15 of economic output for every dollar spent constructing Tren Urbano, resulting in about \$2.4 billion. During operation Tren Urbano is expected to add \$340 million annually to the economy and create 2,172 new jobs (FEIS, 1995) (DTPW, 1998).

6.1.4 Contracting Plan

The Tren Urbano Office (TUO) was created within the HTA to oversee the design, construction, and operation of Tren Urbano. The TUO Project Director, Dr. Rafael Jimenez, reports directly to the Secretary of the Department of Public Works, Dr. Carlos Pesquera.

In August of 1994, the HTA contracted with the General Management Architecture & Engineering Consultants (GMAEC) to provide planning and preliminary design services, engineering and contract/bid document development, as well as project control services throughout the detailed design and construction periods. The GMAEC assisted the HTA in developing the hybrid turnkey or design-build-operate/design build procurement strategy being implemented on Tren Urbano. The unique turnkey strategy developed for Tren Urbano attempts to maximize quality, value, and local participation by dividing the project geographically into seven alignment sections and contractually into a portfolio of contracts containing six design-build contracts and one design-build-operate contract, the Systems and Test Track Turnkey Contract (ST^3).

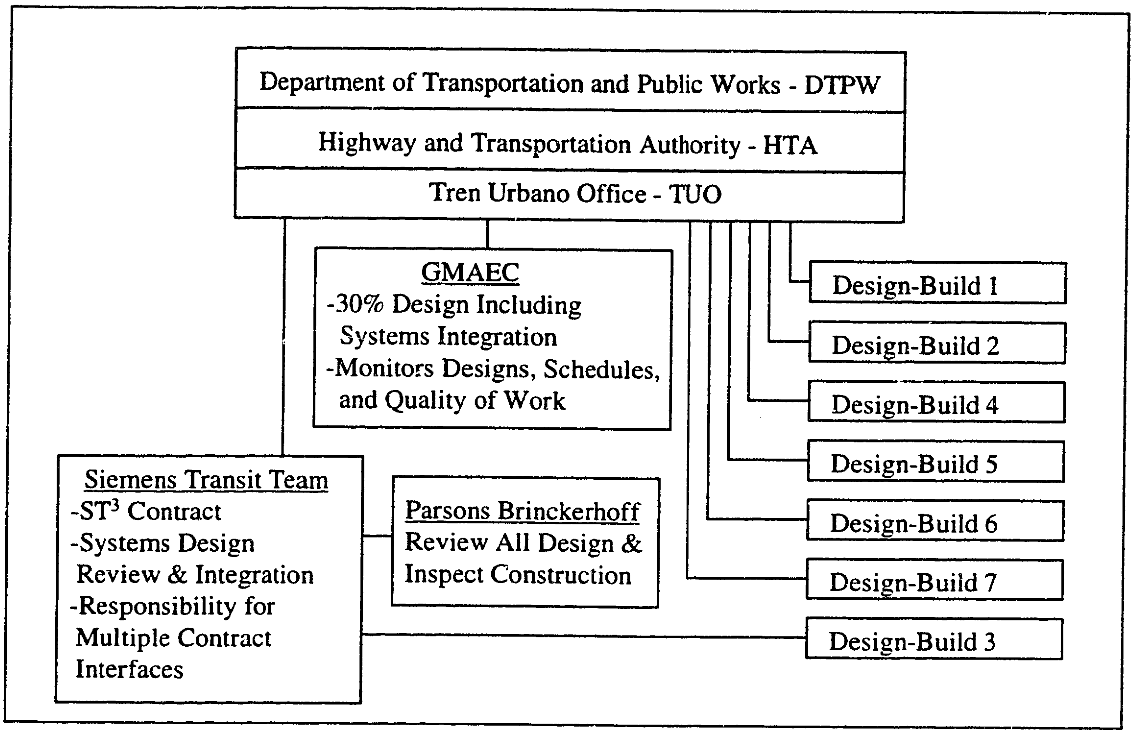
The HTA awarded the turnkey contract to the Siemens Transit Team (STT), a group led by Siemens Transportation Systems (STS). The principle parties included in the ST^3 Contract are the Puerto Rico Highways and Transportation Authority hereafter referred to as the HTA; and Siemens Transportation Partnership Puerto Rico (STPPR), a partnership between Siemens Transportation Systems and Alternate Concepts, Inc., hereafter referred to as Siemens. The ST^3 Contract includes the civil work for one of the alignment sections, the systems work throughout all of Phase I, and operation of the transit system for the first five years with an option for five more. The six other design-build contracts were awarded to contractors (ASCs) which include design and construction services for each respective alignment section. Table 6-1 displays summary characteristics for each alignment section.

Table 6-1 Tren Urbano Alignment Contracts
Source: TUO, Alignment Section Contracts, 1998

Contract	Lead Contractor	Station	Alignment	Dist. (km)	Cost ($M)	Start/Finish
ST^3	Siemens-PB	Torrimar	At Grade	2.6	544	08/96-07/2001
		Las Lomas	At Grade			
1	ICA-Miramar Metro San Juan Corp.	Bayamon Centro	Elevated	2.9	68	09/96-09/99
		Complejo Deportivo	Elevated			
2	Redondo/Entrecanales	Rio Bayamon	At Grade	1.7	37	02/97-09/99
3	Redondo/Entrecanales	San Alfonso	Elevated	2.5	72	01/97-09/99
		De Diego	Elevated			
		Centro Medico	At Grade			
4	Redondo/Entrecanales	Villa Nevarez	Elevated	1.9	72	06/97-09/99
5	Kiewit, Kenny, H.B. Zachary	Rio Piedras	Undergound	1.8	226	04/97-09/99
		UPR*				
6	Nesco/Redondo	Centro Judicial	Elevated	3.6	117	05/97-04/2000
		Hato Rey Centro	Elevated			
		Nuevo Centro	Elevated			
		Sagrado Corazon	Elevated			
		Domenech*				
		* Station Added After FEIS				

Siemens, for the most part a supplier of transit systems, contracted with local contractors to perform the civil work for their alignment section and Parsons Brinckerhoff (PB) to incorporate PB's experience in the design and construction of transit systems through the performance of design and construction reviews and facilitating the coordination of the interfaces between the multiple designers and contractors. A summary of the contractual relationships between the HTA, GMAEC, Siemens, and the ASCs is shown in Figure 6-3.

Figure 6-3 Tren Urbano Contract Structure



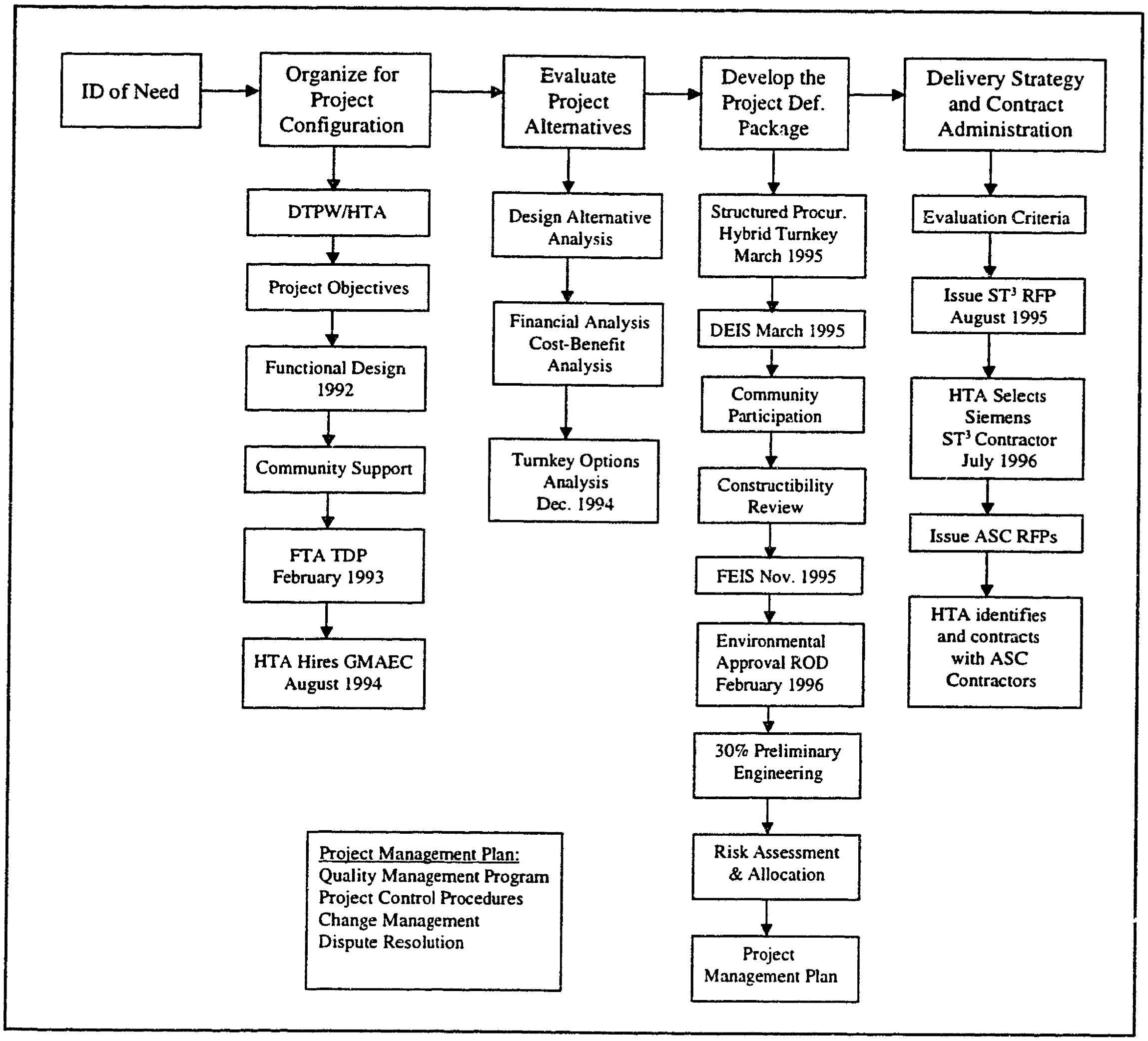
6.1.5 Project Status

The Project passed the first major milestone in February 1996 when it received environmental approval, signified by the FTA's Record of Decision. The HTA has completed the procurement process for all of the major contracts for Phase I. The HTA contracted with a consortium led by Siemens for the ST^3 Contract on July 15, 1996. The Bayamon alignment section contract was awarded in August 1996, prior to the Fall political elections. All the alignment section civil contracts were awarded by June 1997 and the final design was complete by December 1997. At this point, regardless of the political party in office the Project is likely to progress forward. Current schedules forecast that construction of the entire alignment will be complete by July 2001, tested by September 2001, and operating by October 2001.

6.2 Level of Project Configuration

The process that initiated Tren Urbano began over 30 years ago. A regional rail system was first proposed in 1967 as a solution to improving San Juan's transportation network. The feasibility of a rail system for the region was reaffirmed in the 1979 Transit Alternatives for Metropolitan San Juan study. The rail concept was then incorporated into the official Regional Transportation plan in 1981 (DEIS, 1995). In 1989, the DTPW contracted with Parsons Deleuw, Inc. to develop conceptual designs for a light-rail system. However, sufficient support to initiate a rail transit project was not developed until 1993. The general configuration process developed here for Tren Urbano is displayed in Process Diagram 6-1.

Process Diagram 6-1 Tren Urbano Project Configuration Process



In January 1993, Governor-elect Pedro Rossello requested that the DTPW/HTA review and revise the current conceptual planning for a rail system to develop a "world-class" transit system based on advanced technology, quality design, and innovative project management (DTPW, 1998).

In order to obtain consensus concerning the value of a rail transit system, as opposed to alternative investment strategies, the mayors of several large municipalities and representatives of the commonwealth went on a tour of cities with new rail transit systems such as San Diego, California, and Saint Louis, Missouri (Decker, 1996). A strong consensus supporting a rail transit system developed among Puerto Rico Officials during the trip. As a result, support for Tren Urbano has been an issue of bi-partisan consensus (Decker, 1996).

In February 1993, the FTA selected Tren Urbano as one of four Turnkey Demonstration Projects. By early 1994 the HTA had completed some of the preliminary engineering and the FTA had granted the HTA $10 million for planning and preliminary engineering costs. In its 1994-98 Capital Improvements Program, the HTA assigned $160 million for Tren Urbano from tolls, gasoline taxes and vehicle registration fees (TUO, 1994). The HTA retained control over the functional design of the system. Major design decisions regarding the guideway and station locations, the type of systems, and the aesthetic character of the entire rail system were best performed by the HTA to ensure the public's needs and concerns are addressed.

Once the government made the commitment to pursue Tren Urbano, the DTPW and the HTA proceeded with the environmental permitting process. In April of 1994 the DTPW/HTA selected a consortium of consultants referred to as the GMAEC to perform the work of planning, preliminary engineering and contract/bid development.

In partial satisfaction of NEPA regulations the HTA/GMAEC developed the DEIS in March 1995 and directed the public participation process in response to the DEIS. The purpose of the DEIS is to explore and evaluate potential solutions to ensure the most appropriate action that effectively addresses potential environmental impacts is selected. Upon publication of the DEIS the GMAEC facilitated the public participation process to allow for public input to enhance future development decisions.

Only two alternatives were developed in the DEIS. The proposed Tren Urbano system was compared with a no-build alternative, which included several programmed highway improvements to the existing network (DEIS, 1995). Another public transit concept focusing on public buses and HOV lanes was considered but not developed. The alternative was rejected because improvements would result in intolerable disruptions to the existing network and the new system could not effectively avoid existing congestion (DEIS, 1995).

The DTPW/HTA submitted the FEIS in November 1995 for Federal approval. The purpose of the FEIS is to incorporate and respond to regulatory agency and public comments on the DEIS. The goal of the FEIS is to identify a preferred alternative and expand the analysis of impacts generated from construction and operation of the preferred alternative. The FEIS was made available to Federal, Government of Puerto Rico and municipal agencies; advocacy and business organizations; and the general public to continue the public participation process and to build consensus.

The HTA used a three-step process to identify the preferred alternative. First, the HTA considered the DEIS comments from the general public and government agencies at the municipal, Commonwealth, and Federal levels. Second, the HTA received additional public feedback from a variety of special topic discussions. Third, the HTA compared project modification alternatives against one another using the identified project goals (FEIS, 1995). The effectiveness of the preferred alternative was then evaluated by three criteria: 1) financial feasibility, the ability of known funding sources to meet anticipated capital and operating funding requirements of the Project; 2) effectiveness, the degree to which Tren Urbano achieves the goals and objectives established for the Project; and 3) cost-effectiveness, the cost associated with achieving the benefits of Tren Urbano (FEIS, 1995).

A particular importance was placed on lifecycle costs so design decisions would reflect the total cost of design, construction and operation. The HTA felt that if the total cost implications of design decisions could be reasonably estimated, the final system would operate more economically and efficiently.

From 1992 up to the publication of the FEIS more than 100 public meetings in addition to dozens of general public/press events have been held to obtain consensus within the academic, business and public communities (FEIS, 1995). HTA officials have met with the FTA, the FHWA, the Regional Transportation Study Technical Committee, the Metropolitan Planning Organization, the College of Engineers and Architects, publico associations, Rio Piedras Merchant Associations, bankers associations, mayors of local municipalities, and local neighborhood residents since the publication of the DEIS (FEIS, 1995). The public review and comment period on the DEIS lasted from March 24 through May 27, 1995.

The review period did not generate any significant issues that required major redesign or consideration of other alternatives. The FTA issued a Record of Decision (ROD) in October 1995 to the HTA signifying Federal authorization for final design and construction. The Federal ROD marked the completion of the NEPA environmental review process.

At the same time the HTA/GMAEC finalized the turnkey procurement strategy in early 1995 and then began the procurement process for the turnkey contractor in the spring of 1995.

The HTA through the GMAEC had narrowed the project scope by completing functional and preliminary designs. The HTA determined the project would include steel-wheel rail technology with a third rail power system and the alignment would pass through the designated right-of-way previously shown in Figure 6-2. The preservation of design options took a secondary position to defining the project scope in order to obtain environmental approval and to advance the project (Decker, 1996).

The turnkey approach is considered very important in the development of Tren Urbano, as it is expected to accelerate the design and construction processes and the development of efficient operations. The start of construction was a politically sensitive issue, as the administration wanted to secure a commitment to the project before the November 1996 election (Decker, 1996). The political environment within the government of Puerto Rico is very partisan. Time became an important factor in driving the Project through the configuration process to award contracts before the next election. The Governor at the time, Pedro Rosello, was concerned that if the next administration did not support the Project, it might be altered or cancelled. The HTA completed the procurement of the ST^3 Contract, using a two-step-negotiated process based on qualifications, when it contracted with a consortium led by Siemens on July 15, 1996. All the design-build civil alignment section contracts were awarded by June 1997.

The last remaining configuration factor for the HTA was to assemble a viable financing package. Tren Urbano will be financed by 3 main sources, which include revenues from HTA motor vehicle registration fees and gas taxes, U.S. DOT surface transportation funds awarded annually by formula, and FTA Capital Program Funds from its Section 3 Discretionary Funds Program. The HTA obtained a Full Funding Agreement with the FTA, authorized by 49 U.S.C. 5309, which secured FTA capital program funds totaling $307 million (DTPW, 1998).

6.2.1 Public Participation

The HTA established the Community Communication and Participation Program (CCPP) to facilitate public input into the EIS process and to create a mechanism to inform the public of project developments during design and construction. The program's major goal is to establish a reasonable and productive dialogue between project officials and the local communities. The program is expected to generate public support for the Project and increase the Project's responsiveness to community needs (DEIS, 1995).

The public participation plan includes:

- Public information distribution
- Meetings with special-interest organizations and special materials for the meetings
- A project-wide Tren Urbano Advisory Committee (TUAC)
- Area subcommittees and special materials prepared for these areas

The TUAC will focus on project-wide planning, design, construction, and operational issues, while the area subcommittees will focus on local design issues (DEIS, 1995). The goal of the CCPP is to channel the inherent controversies generated by a large public works project into a constructive process that will inform and improve the system design, making it more responsive to citizens' actual and perceived needs (TUO, 1994).

6.2.2 Staffing Plan/Organizational Structure

Dr. Carlos Pesquera, the Secretary of the DTPW and Dr. Sergio Gonzalez, the Executive Director of the HTA, lead the Tren Urbano Office (TUO). The TUO is the combination of HTA and GMAEC staff along with a few experienced consultants who had worked in the Boston area during the development of the Central/Artery Tunnel Project. The TUO management structure uses a matrix organizational framework with contract mangers, functional field, design and interface, systems and O&M personnel. As local participation and technology transfer were important objectives for the HTA, Puerto Rican professional firms are an integral part of the TUO (HTA/GMAEC) team.

The HTA contracted with the GMAEC to advance the Project through the configuration phase and with Siemens Transit Team to execute the ST^3 Contract. The GMAEC is composed of four main consultants and twenty-two sub-consultants. The key members of the GMAEC and Siemens Transit Team are shown in Table 6-2 and 6-3.

Table 6-2 GMAEC Lead Consultants
Source: (TUO, 1994)

Firm	Location	Expertise
Daniel, Mann, Johnson & Mendenhall	Los Angeles	Project Management & Coordination of large transit projects
Frederick R. Harris, Inc.	Boston	Transportation Infrastructure
Eduardo Molinari y Asociados	San Juan	Architecture
Barret & Hale Consulting Engineers	San Juan	Engineering

Table 6-3 Siemens Transit Team Members
Source: (Guadalupe, 1996)

SIEMENS TRANSIT TEAM	
Siemens Transportation Systems, Inc.	Lead Contractor, Systems Supplier
Juan R. Requena Associates	Lead Designer
Alternate Concepts, Inc.	Lead Operator
Parsons Brinkerhoff Quade and Douglas	Sub., Design/Construction Consultant
Redondo Construction	Sub., Construction
Perini Corporation	Sub., Construction
Lord Electric of Puerto Rico	Subcontractor
Mass Electric Construction	Subcontractor
Gullermety, Ortiz & Associates	Subcontractor
St. James Security Services	Subcontractor
Banco Popular de Puerto Rico	Subcontractor
Central Communications	Subcontractor
Sozo and Co., Ltd.	Subcontractor
El Taller Colaborativo	Subcontractor
Wallace, Floyd Associates	Subcontractor
SESCO	Subcontractor
Railquip	Subcontractor
Safetran	Subcontractor
Siemens Empros	Subcontractor

Carrillo/Digeronomo	Subcontractor

Organizational management is significant on a large public works project, particularly when multiple designers and contractors are involved. The organizational structure of the HTA-GMAEC is shown in Figure 6-4. The organizational structure of Siemens Transit team is represented by Figures 6-5 and 6-6.

Figure 6-4 TUO (HTA/GMAEC) Organizational Structure
Source: (Fosbrook, 1998)

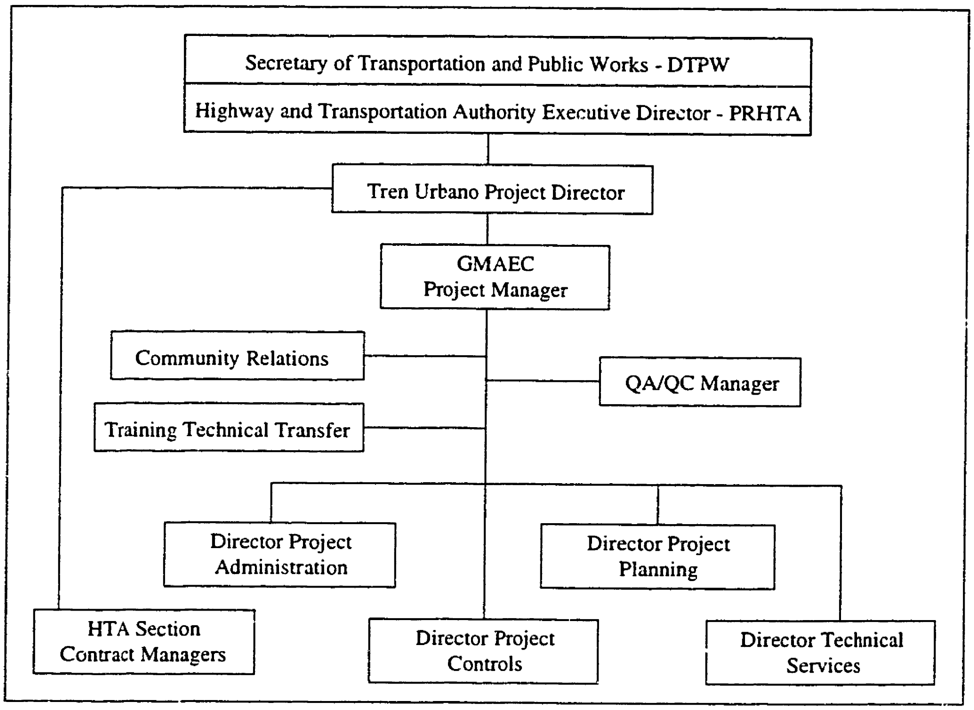


Figure 6-5 STT Project Management Structure
Source: (Koegl, 1997)

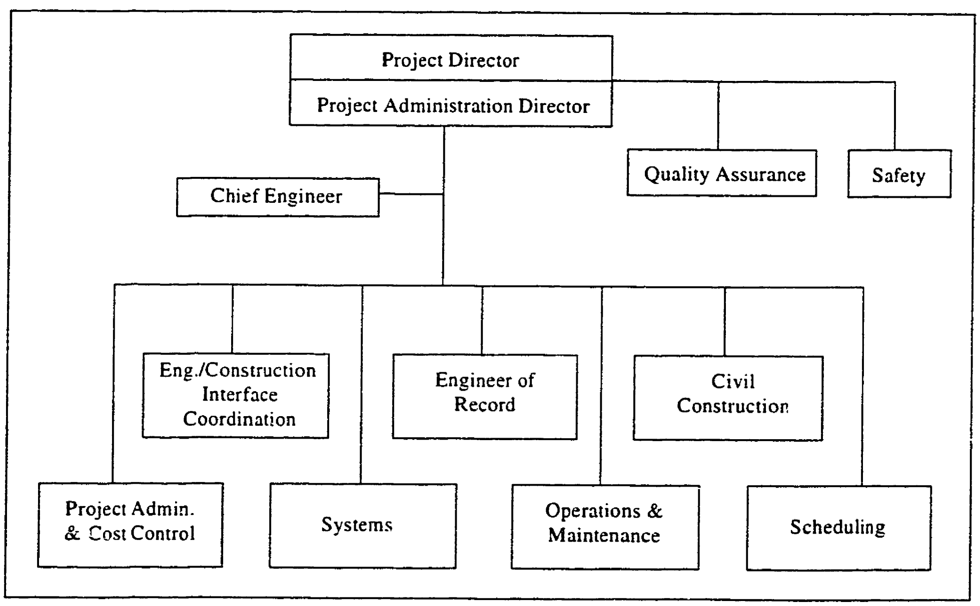
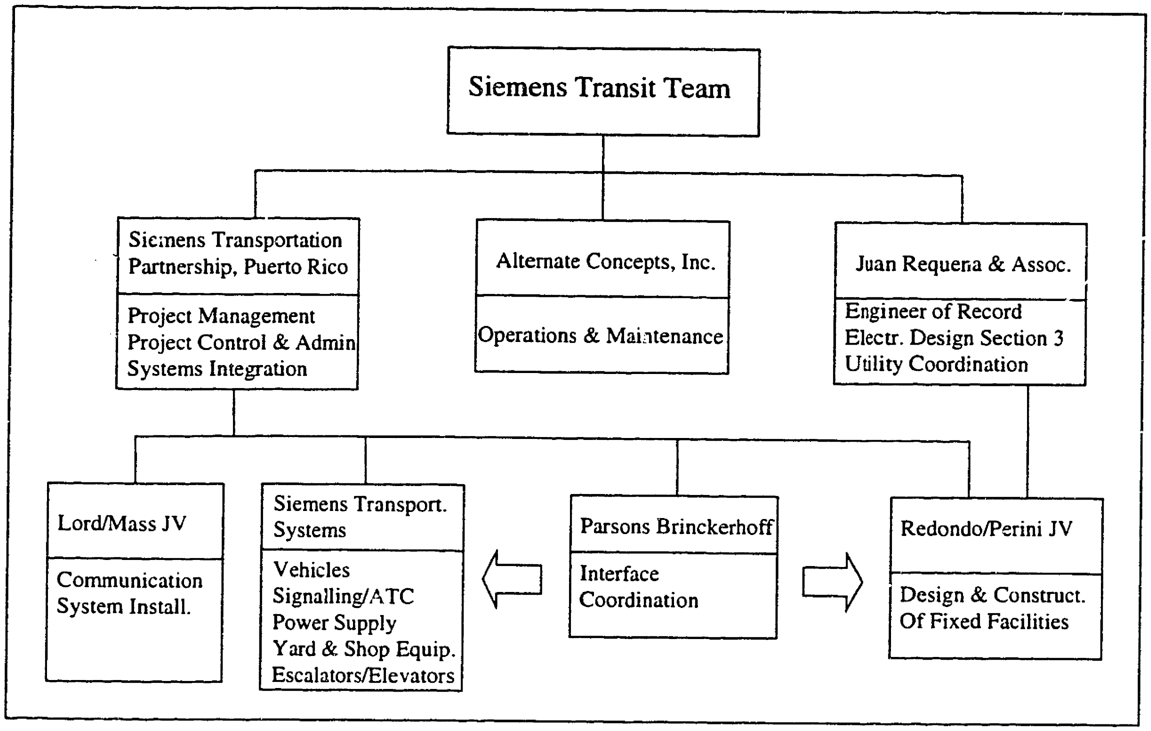


Figure 6-6 STT Contractual Partners
Source: (STT, 1997)



6.2.3 Project Objectives

The HTA has defined a successful project to be one that provides the best completed system on schedule and within budget, and for the HTA to emerge from the project as a better organization, better prepared for the future.

Six project goals and their associated specific objectives were identified by the HTA/GMAEC. The goals were developed from previous planning studies and input from the public participation process (DEIS, 1995). The goals and objectives, shown in Table 6-4, are identified in both the DEIS and the FEIS without being changed by the public and agency comment period. The goals were used to develop and evaluate the potential alternatives.

Table 6-4 TU Project Goals and Objectives
Source: (DEIS, 1995)

Goal	Objectives
1. Improve mobility within the San Juan Metropolitan Area	▪ Maximize regional public transit ridership ▪ Reduce travel time for transit patrons ▪ Connect key institutions and job centers with residential populations ▪ Improve service to disabled & other transit-dependent populations ▪ Reduce financial burden of auto ownership on low-income families ▪ Provide alternatives to congested highway trips
2. Provide for a major expansion in public transit service capacity	▪ Provide capacity to accommodate existing transit demand ▪ Provide capacity to accommodate future passenger volumes ▪ Provide flexibility to allow for expansion to other travel corridors
3. Improve public transit service efficiency, convenience, and reliability	▪ Increase service frequency ▪ Improve operating speeds and schedule reliability ▪ Promote integration of all public transit services & improve intermodal facilities
4. Minimize impacts on Puerto Rico's natural environment	▪ Maintain regional air quality standards by reducing vehicle-kilometers traveled ▪ Minimize the need for highway construction and associated environmental and community disruption ▪ Promote efficient land use ▪ Minimize impacts on significant wetlands
5. Support economic growth in the San Juan Metropolitan Area	▪ Stimulate job growth through project construction and operation ▪ Support future economic development ▪ Enhance access to employment opportunities
6. Design, construct and operate in an efficient and effective manner	▪ Accelerate the construction and opening schedule ▪ Maximize opportunities for local architecture, engineering and construction firms ▪ Bring transit experience to Puerto Rico through technology transfer

The HTA/GMAEC chose to explore a turnkey procurement approach combining design and construction. The procurement objectives used to develop the hybrid turnkey strategy are shown in Table 6-5 (TUO, 1998).

Table 6-5 TU Procurement Objectives
Source: (GMAEC, 1994)

Objectives
▪ Control Interfaces (Quality) ▪ Maximize Technology Transfer ▪ Maximize Owner Control ▪ Accelerate Start of Construction ▪ Operationally Driven Design ▪ Encourage Private Funding

6.2.4 Contract Administration

There was a significant amount of competition for the General Management Consultant (GMC) contract. The HTA received 10 Letters of Interest, issued 6 RFPs, and received 4 proposals. The selection process incorporated a pre-qualification stage, a proposal evaluation stage, and a final negotiation period (TUO, 1994).

In August 1994, the DTPW/HTA contracted with the GMAEC to provide planning, environmental/permit, preliminary engineering, and contract/bid development services. The initial contract was for a duration of 2 years and for price of $42 million. The HTA retains the option to extend the contract term and to amend the scope of services to include new responsibilities as the Project develops (TUO, 1994). The GMAEC worked with the HTA to structure the procurement for Tren Urbano. The government of Puerto Rico committed to pursuing a turnkey strategy to obtain partial Federal funding, increase private involvement, and accelerate the project schedule.

The HTA and the GMAEC selected the hybrid-turnkey delivery strategy. A variety of turnkey options were explored including, single turnkey, split turnkey, and hybrid turnkey. The options were compared with the traditional procurement process and evaluated against each other based on the effectiveness of each strategy to address the specified procurement goals. Each turnkey strategy accelerates the schedule, as the contractors can be procured before preliminary design is complete, and permits operationally driven design as the operator can be identified prior to the completion of the final designs. The hybrid turnkey strategy developed for Tren Urbano is divided contractually into a portfolio of contracts containing six design-build contracts and one design-build-operate contract, the ST^3 Contract. The strategy is expected to accelerate the construction and start-up schedule, and introduce greater managerial and technological innovation (DEIS, 1995).

Procurement of the ST^3 Contract used a two-step process. The HTA/GMAEC reviewed the technical sufficiency of each proposal before the price proposals were opened. The second step involved negotiations between the HTA and each proposer prior to the submission of a final offer consisting of a fixed lump-sum price for the agreed upon services (TUO, 1998). Procurement of the Design-Build Section Contracts used a one-step RFP followed by a negotiation process (GMAEC, 1994).

Similar to other public projects, fair competition was a primary concern for Tren Urbano, but unlike other projects fair competition was complicated by the innovative procurement strategy. It was essential for the RFP to contain both a clear scope of work as well as clear and rational evaluation criteria. To this end, after a few bidder conferences the HTA pre-negotiated the terms of the ST^3 Contract to be signed with the winner (Decker, 1996). Therefore all potential bidders should have understood the contractual obligations of the competition. The RFP describes 3 categories of evaluation criteria. The first includes the evaluation of the technical and managerial proposals. The second evaluated the proposal's financial feasibility. The third was a price comparison between the competing proposals (Decker, 1996).

After starting with 6 consortiums, there were 3 final proposals that were considered. A merger, a withdrawal, and an elimination due to non-conformity reduced the competition to proposals by Siemens Transit Team, Tren Urbano Consortium, and Grupo Tren Urbano.

The HTA awarded the turnkey contract to the Siemens Transit Team on July 15, 1996. In hindsight, the selection of the hybrid turnkey strategy over a single turnkey arrangement did not reduce competition for the systems turnkey contract and successfully increased opportunities for local firms.

6.2.5 Risk Allocation/Responsibility

An important aspect of any procurement and contract process is the identification and allocation of risks between the public and private parties. Traditionally, major risk categories such as design errors, differing site conditions, and unforeseen events have been borne by the public owner. The traditional design-bid-build strategy divides design, construction, and operation into separate contracts, therefore the owner must accept responsibility for the project upon completion of each phase. The re-introduction of combined procurement strategies allows a re-evaluation of the recent notions of risk allocation. Public entities can shift more risk to the contractor using combined methods of delivery. It is important to note, however, that when more project risk is shifted to the contractor the owner loses a certain amount of control and generally pays more for the contractor's services. A comparison of common risk allocation between a design-bid-build and a turnkey strategy is shown in Table 6-6.

Table 6-6 Turnkey Implications on Risk Allocation
Source: (Decker, 1996)

Risk	Traditional Allocation	Turnkey Allocation
Political	Owner	Same
Funding	Owner	Shared (Potentially)
Financing	Owner	Shared (Potentially)
Right-of-way	Owner	Same
Speculative Effort	Owner	Shared
Bids Exceed Estimates	Owner	Same
Geotechnical	Owner	Negotiable
Hazardous Materials	Owner	Negotiable

Underground Utilities	Owner	Negotiable
Inflation	Owner prior to award, between stages	Full Transfer to Contractor
Federal, State, Local Regulations	Regulatory Changes Only	Full Compliance
Design Integration, Coordination	Owner	Full Transfer to Contractor
Changed Requirements	Owner	Same
Construction Performance	Shared	Same
Subsystem Testing	Contractor	Same
System Integration	Owner	Full Transfer to Contractor
Schedule Slippage	Negotiated	Full Transfer to Contractor
Construction Safety	Contractor	Same
Site Security	Contractor	Same
Act of God	Contractor	Same
Failure to Complete	Contractor	Same
Seismic	Shared	Same
Operating	Owner	Negotiable (DBO)
Market (Ridership/Revenue)	Owner	Negotiable (BOT)

The unique organizational structure of Tren Urbano creates some difficulty in clearly defining the roles, responsibilities, and distribution of authority among the parties involved. Siemens, Parsons Brinckerhoff, HTA/GMAEC, and the ASCs' designers each have some responsibility for design. Siemens-PB also has the responsibility of physical systems integration throughout the entire project as well as contract interface coordination, although it does not have a direct contract agreement with the civil Design-Build contractors and does not possess the full authority to accept or reject their work. Therefore, it is important to identify the design responsibilities of each party as well as the management processes used to ensure high quality construction. The general allocation of responsibility between the HTA, GMAEC, Siemens-PB, and the ASCs is shown in Table 6-7.

Table 6-7 General Allocation of Responsibility

What	Who
Project Objectives	HTA
Functional Design	HTA
EIS Process/Permits/Environmental Approval	HTA/GMAEC
Right-of-way Acquisition	HTA/GMAEC
Staffing Plan/Organizational Structure	HTA/GMAEC
Procurement Objectives	HTA/GMAEC
Risk Assignment-Allocation within Contracts	HTA/GMAEC
Community Participation	GMAEC
Training & Technology Transfer	GMAEC
Alternative Design Studies	GMAEC
Procurement Strategy Analysis	GMAEC
Financial Feasibility Analysis/Cost-Benefit Analysis	GMAEC
Constructibility Studies	GMAEC
30% Preliminary Engineering/Specifications	GMAEC
Operations Analysis/O&M Specifications	GMAEC
Site Investigation/Utility Mapping	GMAEC
Alignment Master Plan	GMAEC

	System Design Specifications/Performance Criteria	GMAEC
	System Analysis and Testing Program	GMAEC
	Development of Scope Material	HTA/GMAEC
	Accuracy of Scope Material	Siemens/ASCs
	Contract/Bid Document Development	GMAEC
	Project Control Procedures	GMAEC/Siemens/ASCs
	QA/QC Program Plans	GMAEC/Siemens/ASCs
	Review of Contractor Designs	HTA/GMAEC/Siemens-PB
	Approval of Contractor Designs	HTA
	Manage Contract Compliance	HTA/GMAEC
	Approval of Submittals	HTA/GMAEC
	Approval of Contractor QA/QC Programs	HTA/GMAEC
	Accept/Reject Work Performed	HTA/GMAEC
	System Design/Procurement/Const./Testing/Start-up	Siemens
	Fixed Facilities Design/Proc./Const./Testing/Start-up	Siemens/ASCs
	Configuration and Interface Management	GMAEC/Siemens/ASCs
	Systems and Fixed Facilities O&M	Siemens
	Completion on Schedule	Siemens/ASCs
	Completion on Budget	Siemens/ASCs
	Progress Monitoring	HTA/GMAEC/Siemens
	Tests/Site Inspections	HTA/Siemens/ASCs

The decision to use a hybrid turnkey strategy as opposed to a single turnkey arrangement represents a conscious decision to reduce the scope of the turnkey contract. "The project can be adequately described as a reduced-scope turnkey procurement in which potential turnkey benefits have been balanced with the concerns of local participation, early commencement of the work, and reasonable risk allocation" (Decker, 1996). The HTA and the GMAEC wanted to create a contracting strategy that reflected reasonable risk allocation.

6.2.5.1 FHWA

As a result of participating in the FTA demonstration program the project will be tracked from development through completion, and the results will be evaluated. To determine the value of the turnkey strategy, Tren Urbano will be compared with similar non-turnkey projects. The comparison will focus on the potential benefits expected from implementing the turnkey strategy. The program will attempt to quantify cost and schedule benefits, as well as identify the distribution of risk and responsibility between the Owner and Turnkey Contractor. The FTA will monitor and periodically evaluate the project. Monitoring activities will include on-site visits, document reviews, and administration record evaluations. The monitoring activities are intended to generate both general and specific recommendations concerning the implementation of the turnkey method (Guadalupe, 1996).

6.2.5.2 HTA/TUO

Representing the government, the HTA has chosen to accept risk in order to retain control of the project and reduce associated cost premiums for transferring risk. In particular, the government has assumed the risk of ridership levels and the operator will receive a fixed fee to run the system regardless of the actual ridership.

In general, the HTA is involved in preliminary design, Right-of-way acquisition, permit preparation/approval, the EIS process, and construction management. With the assistance of the GMAEC the HTA is responsible for the approval of contractor designs, the management of contract compliance, the approval of contractor submittals, the approval of contractor QA/QC Programs, the monitoring of QA/QC Programs, and the acceptance or rejection of work performed (Dewitt, 1997).

Responsibility for the HTA's obligation to the contractors is divided between Sergio Gonzales, the Contracting Officer (C.O.), and the Authority's Representative (A.R.), the HTA Section Contract Managers. The HTA Contract Managers are the onsite representative of the HTA and have the authority to make the day-to-day decisions on behalf of the HTA. All official and binding communication to the contractor must be through the contracting officer, with appropriate signatures of both the A.R. and C.O. (DTPW/HTA, 1996).

The HTA uses documentation, meetings, reports, and the implementation of the QA/QC programs as contract control devices. Documentation includes design and construction submittals, as well as final design and construction documentation. The HTA has required a Start-up, Initial Schedule, Design Progress, Pre-Construction, and bi-weekly Construction Progress meetings. The HTA requires monthly progress reports, test and inspection reports, and nonconformance reports.

6.2.5.3 GMAEC

The HTA contracted with the GMAEC to perform planning, environmental compliance, permit preparation, preliminary design, and contract/bid document development services. The GMAEC is responsible for the execution of the EIS, community participation, permit approval, and preliminary design development processes prior to final design and construction. The GMAEC is to advance the design to 30% completion and prepare the necessary documents for the HTA to conduct the procurement process for all seven contracts (TUO, 1994). This level of detail is expected to ensure that the individual station designs will accommodate successful integration of the common system elements that extend through the entire project and not only that alignment section. The GMAEC, as a consultant to the HTA, is to approve contractor designs, manage and direct contract compliance, approve submittals, approve contractor QA/QC programs, and participate in the acceptance or rejection of the work.

To execute the General Management Consultant contract responsibilities, the GMAEC will develop and maintain a manual of operational procedures, a Staffing Plan, a Work

Program, a Master Budget, a Master Schedule, the Project Control Milestones, a computerized Management Information System, payment procedures, and a Change Management Program (TUO, 1994).

6.2.5.4 Siemens-PB

The ST^3 Contract documents designate Siemens' responsibilities throughout the life of the Project:

1) the design, procurement, construction, test and start-up of the Project system components and the test track and two stations (Alignment Section 3)
2) the coordination with, and the interface, of the Work under this Proposal with the design and construction for the stations and alignment sections to be performed by other contractors
3) the maintenance of all project facilities between acceptance and the start of revenue service
4) the operation and maintenance of the completed Project for five years, with an option for an additional five years

The ST^3 Contract includes 64 heavy rail vehicles and requires the design, manufacture, and construction of 17.2 kilometers of track and 2.5 kilometers of rail guideway. Siemens will be responsible for the construction of two stations, Las Lomas and Torrimar, the yard and maintenance facilities, and an operations control center.

The role of the ST^3 Contractor includes responsibility for quality control of all contract interfaces to ensure the required standards for operational performance are met. Siemens, as the ST^3 Contractor, will be responsible for interface coordination, design integration and review, construction inspection, as well as operations and maintenance impact assessments (DeWitt, 1997).

The Contract documents state that Siemens is responsible for the management and administration of the design, manufacturing, supply, construction, installation, testing, acceptance, demonstration and completion of the Fixed Facilities and Systems. The Fixed Facilities shall include all fixed structures and improvements to be furnished or constructed for Alignment Section 3 such as the guideway structures, stations, equipment rooms, etc. not including systems. The Systems shall include the vehicles, track work, contact rail, guideway equipment, traction power, power distribution systems, train control systems, operations control system, communication systems, fare collection equipment, escalators and elevators and all other support systems. Siemens is responsible for the fully integrated and coordinated design, manufacturing, supply, construction, installation, and start-up of the Systems for all of the Alignment Sections. This extends the scope of Siemens' work across the entire project. Siemens is to furnish and install these systems onto the work completed by the ASCs. Therefore Siemens and the ASCs will share the same workspace. Siemens has a vested interest in the quality and progress of each of the ASCs' work. Should the ASCs fall behind on their schedules and Siemens' access to the alignment section sites is delayed, Siemens shall take all practicable precautions, efforts and measures to reschedule the work in a manner so as to avoid or mitigate delays and costs in completing the work (DTPW/HTA, 1996).

Contractually Siemens is given contract administration responsibility and authority in the form of interface design reviews, interface systems compatibility and interface management to control the risks. Each alignment section is transferred over to Siemens so the entire system can be tested before the initiation of operations.

Siemens contracted with PB to perform services regarding interface coordination, design review, and site inspection. Due to their experience in the design and construction of transit systems, PB is to be involved in the review of designs and the inspection of all construction and installation activities for Phase I. PB is to control the interfaces by maintaining an Interface Control Manual for each alignment section and by conducting by-weekly interface meetings with each of the ASCs. PB personnel work directly with the HTA contract managers to review designs for compliance with interface requirements and transit related standards. PB personnel also conduct site inspections along with the ASCs' quality control supervisors to determine the inspections and tests to be performed and to develop daily inspection reports and logs. PB monitors the survey staff of each ASC to ensure a continuous link between the sections. However, PB's role does not replace the ASCs' contractual obligations.

6.2.5.5 Alignment Section Contractors

Each ASC is to complete geotechnical, sub-structure, super-structure, and electrical and mechanical work for the guideway; archtecture and urban design, civil and structural work, and the electrical and mechanical work for the stations; and the required utility and landscape work within their respective section.

Each ASC is to provide the final civil design required for the site work for their respective alignment section. The design of the Fixed Facilities is to be in accordance with applicable criteria and standards, and to provide for incorporation of components, equipment and systems. The ASCs are to coordinate the design and construction activity with Siemens, the ST^3 Contractor, to ensure compatibility with the system designs and installation. The main structures include the stations, aerial and at-grade guideway, the tunnel for Rio Piedras, and the roadway structures leading to the stations. The guideway elements shall include site preparation and improvements, grading, drainage, invert and aerial deck slabs with stirrups, ballast and sub-ballast (DTPW/HTA, 1996).

Each ASC is responsible for providing the labor, superintendence and products necessary for completion of their work, as well as, all construction supplies, equipment, tools, machinery, materials, and utilities required for construction. Each ASC is to coordinate the execution of their work with those public utilities, governmental bodies, private utilities, and other contractors performing work on, and adjacent to, the Alignment Section. The ASC is to eliminate or minimize delays in their work and conflicts with those utilities, bodies, and contractors (DTPW/HTA, 1996).

6.2.6 Management and Control Programs

6.2.6.1 Interface Coordination

Management of the interface coordination for Tren Urbano required that it receive specific focus as a task or project goal in order to effectively integrate the civil and system designs. The large scale and complexity of the project requires detailed and innovative methods of control. Methods for the quality assurance/quality control of the physical systems that are common throughout the entire project include submittals, design specifications, the Interface Control Manual, construction oversight, performance standards, operational testing, or review and audits. It is imperative that the design and construction processes be planned, organized, and managed as a single integrated task to effectively and efficiently meet the overall project goals.

Failure to control interface conditions so that they remain coordinated and compatible may lead to conflicts requiring redesign, reconstruction, revised equipment configuration, inadequate performance and other unwanted concerns, that will impact the project cost and completion schedules. The HTA delegated responsibility for control of the interfaces by designating that the contractors are responsible for the coordination of the work internal to each contract scope and by assigning Siemens the responsibility for the various contractual interfaces that exist where Siemens furnished systems components are to be installed permanently within, on, or at fixed facilities (i.e. civil works) designed and constructed by the six other design-build ASCs. Consequently, during the design phase Siemens provides coordination for all design interfaces between Siemens and the other Contracts. During the construction, post-design, phase Siemens is responsible for field review regarding interface compliance (DTPW/HTA, 1996).

To assist the coordination of the interface work, Siemens developed the Interface Control Manual to be used by the ASCs in the design of the work under their respective contracts. The Interface Control Manual (ICM) is used as a documentation and reference tool as it is intended to become a comprehensive source of information regarding the interface control procedures for the execution of the civil construction and system contracts. The existence of the ICM recognizes that this procurement strategy requires close coordination of the scheduling and performance of design, construction and installation activities of all the contractors if the Project is to be developed efficiently as a fully integrated rail transit system.

The ICM attempts to ensure that all of the elements of the transit system are accounted for, are included in the appropriate contract package, and the responsibilities of each contractor at the contract interfaces are defined. The ICM is a collaborative effort by the GMAEC, Siemens-PB, and the ASCs so that all required interface concerns are specifically documented, nothing is overlooked, and at the same time nothing is duplicated by being included in two or more contract packages. The implementation of a comprehensive interface control procedure will ensure that work at the project interfaces is fully coordinated and integrated to achieve first time quality. The ICM will contain information pertaining to civil-to-civil interfaces relating to interactions between the

ASCs, civil-to-systems interfaces relating to interactions between Siemens and the ASCs, and systems-to-systems interfaces to be used by Siemens and the HTA to ensure compatibility of system elements.

6.2.6.2 Dispute Prevention/Resolution

In order to avoid disputes the HTA intends to promote cooperation and trust between Siemens, the ASCs, subcontractors, the HTA Contract Managers, and the Contracting Officer. The goal is to achieve common and individual objectives on a non-confrontational basis. To reach this goal the HTA encourages the use of partnering techniques during the course of the Contract. The HTA will conduct a team-building workshop for Siemens' key on-site staff, key designers, and senior corporate officers as well as the HTA's key representatives and Contract Managers.

In the event that disputes do arise between a contractor and the HTA the dispute resolution process will be enacted. During the dispute resolution process the contractor is still required to proceed with the work and shall receive timely payment for such work from the HTA. The first step of the dispute resolution process is the placement of the issue on the agenda of the next Construction Progress Meeting. At this meeting technical personnel of the parties involved in the dispute will identify the issues involved, consider impartially the countervailing positions, and achieve a resolution of the dispute. If the technical personnel fail to resolve the dispute within 90 days the matter is referred to the contractor's Project Manager and the Contracting Officer for resolution. If the contractor's Project Manager and the Contracting Officer cannot resolve the dispute within 14 days either party may refer the dispute to the contractor's Project Executive and the Executive Director of the HTA. If the dispute is not resolved within 150 days after enacting this process the aggrieved party shall have the right to file a court action seeking judicial resolution (DTPW/HTA, 1996).

6.2.7 Mitigation Programs

The HTA has developed mitigation programs to address Project impacts on air quality, noise and vibration, visual aesthetics, and local ecosystems. Each contractor is responsible for mitigation activities during construction to minimize the disruption to the SJMA.

Although most of the land use impacts consist of incorporating vacant land into the alignment corridor there are some impacts to private facilities. The implementation of constructing Tren Urbano will require a number of displacements and relocations along the project corridor. The HTA estimates total displacements of around 82 residential buildings (FEIS, 1995). The Government of Puerto Rico will provide relocation assistance to any displaced resident in accordance with Federal law.

6.3 Project Challenges/Control Issues

6.3.1 Large-Scale/Urban Environment

The large-scale of the project requires quality specifications and precision design and construction. The fixed price is complicated by the integration of operational requirements, the inclusion of the design and construction impacts on operations and maintenance costs, the long life cycle, and the intensive management necessary to coordinate design and construction activities.

The urban environment of the project increases the potential disruptions of sewer, water, telephone and electric utility services and problems with traffic congestion, dust, construction noise, uncontrolled storm water runoff, and danger to the neighborhood children over a sustained period of time (Salvucci, 1997). Accurate information disseminated to the community in a timely manner and good press relations should help alleviate potential complications and maintain an essential base of political support.

6.3.2 Organizational Structure

The contractual arrangement and technical complexity of Tren Urbano has resulted in the participation of many different parties. The major project participants are the HTA, the GMAEC, Siemens-PB, the ASCs and external specialty consultants.

The creation of a hybrid turnkey structure with a systems supplier as the lead turnkey contractor has presented the HTA with a challenge to efficiently allocate responsibilities and clearly define the Project's organizational structure. Although it is not reflected by Figures 6-4 and 6-5, the perception of the organizational structure within the Project Team is not uniform. The TUO is a combination of HTA and GMAEC staff which results in mixed lines of authority that cross agency or consultant firm affiliations. As the success of technology transfer is a high priority, there is a need for the HTA and the GMAEC to interact as one organization.

Redondo is performing the civil work for Siemens as a sub-contractor as well as 4 of the design-build contracts as a prime contractor to the HTA. Siemens must communicate with Redondo as a sub-contractor and an HTA prime contractor. Siemens has a contractual relationship with Redondo for Section 3 but does not for the other 4 sections just like the other ASCs. Redondo's prior relationship with the HTA and current direct connection with the HTA may cause conflicts in the execution of the work.

The turnkey approach allows the owner, the DTPW/HTA, to contract directly with a single entity for design, construction, and operation of the system. Siemens holds the responsibility for quality control of all contract interfaces to ensure the required standards for operational performance are met. In effect Siemens is a contractor, a manager, and a temporary partner in ownership.

The organizational structure has also complicated the task of quality control. The HTA requires each ASC to provide an independent quality assurance/quality control inspection team to evaluate the quality of the work performed. The HTA assigns personnel to each alignment section that are designated for field oversight of the contractor. The HTA and the GMAEC perform oversight of the entire design and construction process, monitoring designs, schedules, and the quality of the work. PB, a subcontractor to Siemens, conducts design reviews and field inspections of all construction and installation activities with a particular focus on the interfaces. There is overlapping responsibility for field inspections and as a result the ASC's receive comments from multiple inspection teams. The value of these comments varies with the interests of the party conducting the review or inspection. The channel through which the ASC receives these comments is complicated as well and the value of the comments may be lost in the process.

6.3.3 Contracting Plan/Risk Allocation/Responsibility

The project contract and organizational structures create multiple challenges to obtaining the HTA's project goals of obtaining a high quality transit system, completed on time and within budget, with significant local involvement in performing the work.

In effect, Tren Urbano's hybrid turnkey delivery strategy is a mixture of two procurement strategies, implementing a parallel prime structure that is composed of design-build contracts. The design-build-operate/design-build hybrid procurement strategy is unique. High quality relies on good design, and by definition, in a design-build contract the design is not yet complete. The highest quality standards must be met during the design phase with a particular focus on systems and fixed facilities design integration. During the execution of the EIS preparation process the GMAEC completed preliminary engineering, marking approximately 30% design completion. This level of design development prior to the award of the contacts predetermines most of the major design elements. Although 30% design eliminates most of the potential design incompatibilities, it also restricts the contractors' creativity and freedom to innovate.

The turnkey and multiple civil package approach was successful in providing more opportunities for local participation and for technology transfer, however the approach externalized interfaces between the systems and civil segments and between the civil segments themselves. The HTA/GMAEC dismissed the significance of the coordination of the interfaces stating that, "While some interfaces occur between packages, these are typical for any job and are not difficult to manage" (GMAEC, 1994). Although the statement is true when it states contract interfaces within a project are not new, the procurement structure of Tren Urbano create interfaces between design-build contracts and between a turnkey contract and design-build contracts. This fact stresses the need for efficient and effective risk allocation and distribution of responsibility so each participant is capable of performing their work and managing their risk.

The design-build nature of the contracts allocates design responsibility to a designer for each alignment section. The contracts indicate overlapping design responsibility as each designer will perform services for the design of the guideway structure, ductbanks and conduits for power and communication cables, and provisions to accommodate the installation of system elements for the ST^3 Contract. Figures 6-7 and 6-8 show the general obligations and the obligation for the power distribution system between the HTA, Siemens, and the ASCs. The GMAEC, PB, and the TUO/HTA Contract Mangers are all involved in the design review process. Design completion responsibility and review are therefore divided among the GMAEC, Siemens, PB, each ASC designer, and the HTA.

Another challenge of implementing an innovative procurement strategy is that it is difficult to change old practices to reflect the new distribution of responsibility. The HTA has retained control to ensure local participation and technology transfer and that the design is responsive to the community. The decision to divide the Project into multiple packages created interfaces that need to be managed. The HTA chose to allocate the risk of interface coordination to the contractors. Siemens has overall responsibility for interface management and the ASCs are to cooperate with Siemens and each other in terms of design and schedule. Unlike a single turnkey contract however, Siemens, the lead turnkey contractor, does not have direct contractual control over the entire project.

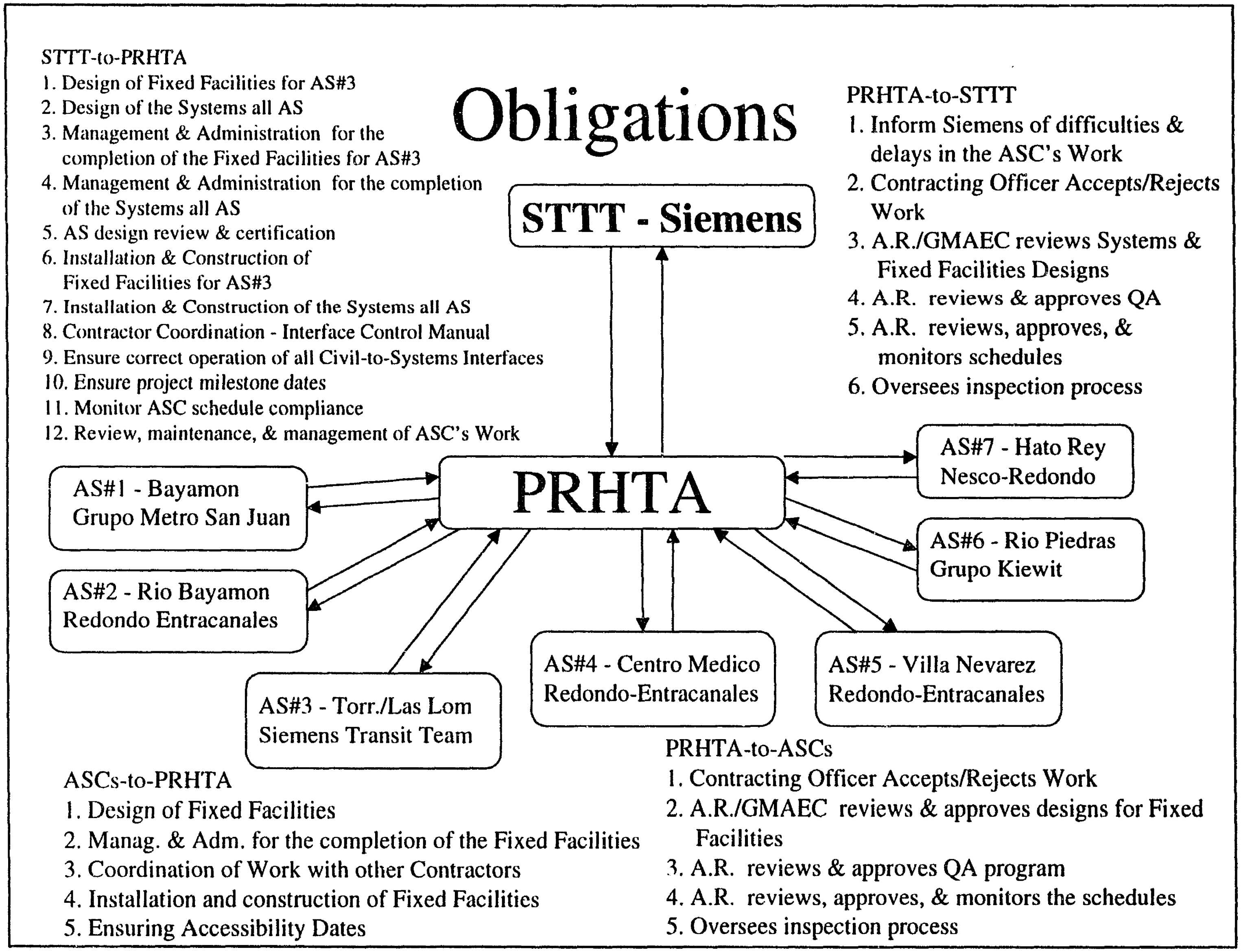


Figure 6-7 General Contractual Obligations

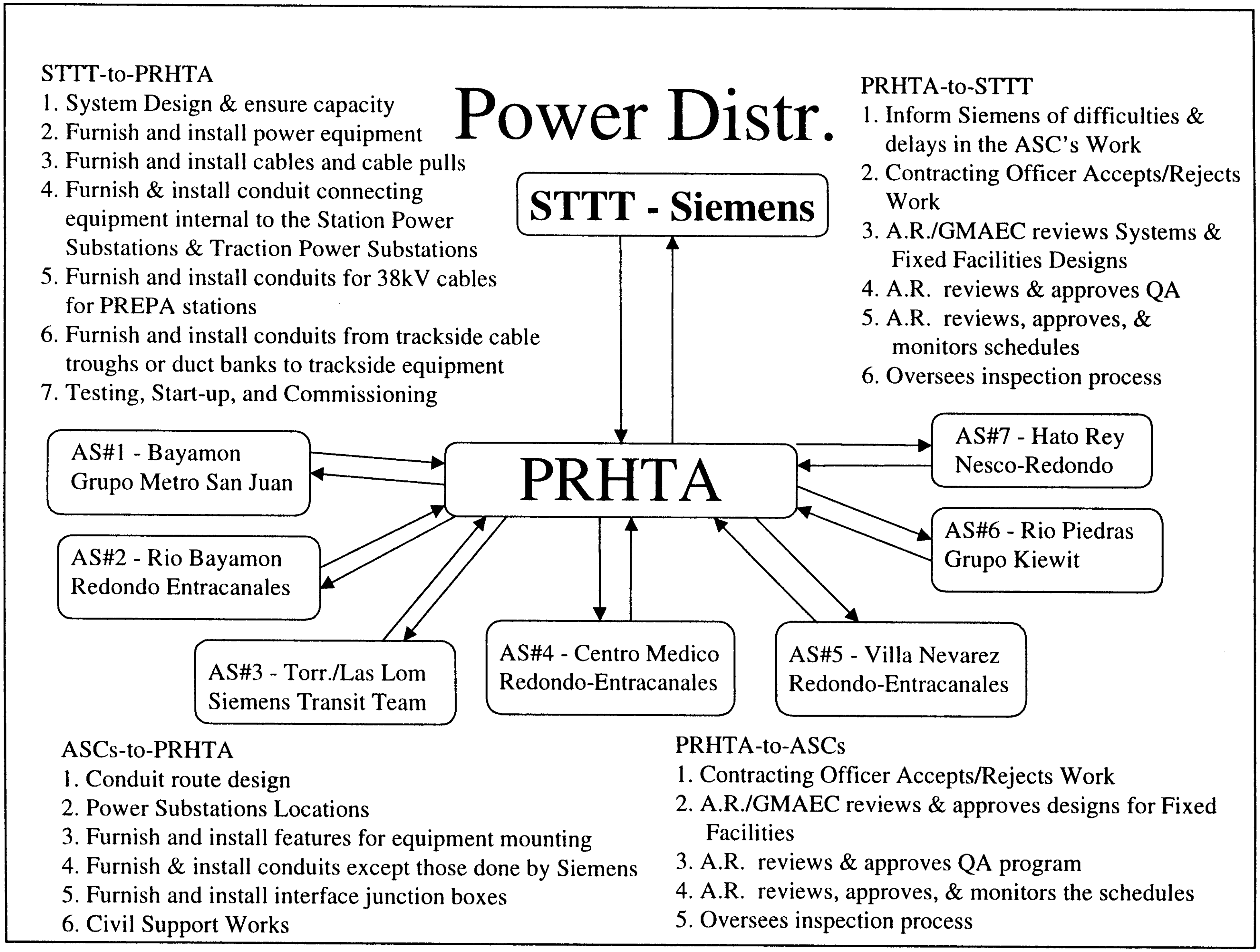


Figure 6-8 Power System Obligations

One example of responsibility overlap concerns field inspections. Each contractor is contractually obligated to hire independent inspectors, PB is performing inspection on behalf of Siemens, and the HTA is often performing their own. An example of how the relationship between the HTA and Siemens does not reflect a traditional turnkey strategy concerns the review and acceptance of the ASCs' work. The Contracting Officer and Siemens will review the work of the ASCs prior to the transfer of the work to Siemens. Siemens may submit exceptions and qualifications, indicating conditional acceptance, to the HTA. The HTA may submit these exceptions and qualifications to the ASC for remedial action. If, however, the HTA disagrees with Siemens' exceptions and qualifications the HTA may disregard them or refer the matter to the dispute resolution process. If Siemens prevails in the dispute resolution process the HTA shall remain liable to Siemens for the consequences of disregarding such exceptions and qualifications (DTPW/HTA, 1996).

Another problem is that the incorporation of the GMAEC's expertise into the final design and construction process is limited by their exposure to risk. The GMAEC does not want to approve or disapprove the systems designs (Gregson, March 24). The contracts designate the contract designers as the designer of record. The GMAEC does not want to "approve" the designs for the GMAEC would then be partially responsible for those designs (Gregson, March 24). Under this arrangement the GMAEC comments on the designs but does not accept responsibility for or the liability associated with the system designs. The GMAEC uses three basic criteria to review the system designs: first, does the design meet the required specifications; second, will the design "work"; and third, does it appear that the final documents will be sufficient for operations. The GMAEC sends the comments from the design review to Siemens. Siemens and the GMAEC can then discuss these comments at the design review meetings, which are often conducted at the monthly progress meetings. After the meeting, Siemens is to respond in writing to the GMAEC's comments.

6.3.4 Project Management and Control

6.3.4.1 Coordination

Quality is of extra importance for Tren Urbano to be successful. The project must attract riders to be considered useful, and the ridership will depend on the quality of service provided. A transit project requires very precise specifications, as the operating quality will depend on the quality of design and construction.

The contractual arrangement for Phase I creates the need for interface coordination between adjacent alignment sections as well as each alignment section with the systems work of the ST^3 Contract. The design-build nature of the contracts allocates design responsibility to a designer for each alignment section. The contracts indicate overlapping design responsibility as each designer will perform services for the design of the guideway structure, ductbanks and conduits for power and communication cables, and provisions to accommodate the installation of system elements for the ST^3 Contract. The project control needs to ensure successful integration of the systems work and the coordination of the work of multiple designers and contractors will potentially be unique as Tren Urbano requires coordination of design and construction activities.

The similarity of the contract structure to a traditional design-build and a multiple parallel prime contracting relationship highlights a known challenge to successfully delegate the responsibility for the coordination of design and construction activities. The HTA has delegated the responsibility for coordination to each of the contractors. Each ASC is to coordinate their work activities with their neighbors. The HTA has delegated overall coordination responsibility, with a focus on the interfaces between alignment sections and the ST^3 Contract, to Siemens. This delegation of coordination responsibility to multiple parties is very rare in large construction projects. The division of responsibility increases the need for design reviews, progress reporting, and inspection certification.

The multiple package arrangement creates more interfaces within the project and between the project and the surrounding communities. Civil interfaces between contract packages are typical in construction, however, the design-build nature of the contracts require special attention to design coordination to ensure that the project design is consistent. A consistent civil interface with the ST^3 Contract work is essential. Siemens must install the system elements for the entire alignment, which relies on the performance of each section contractor. The transit system must operate effectively as one system, although it was designed and built in sections.

The multiple civil packages may impact the consistency of the Project's interface with the public. The response to community involvement in design and construction mitigation may vary. This is important for any public project in an urban setting will significantly impact the surrounding communities during construction.

The use of multiple design-build contracts creates coordination challenges between designers and contractors due to interrelated schedules and activities. The complexity of the hybrid structure creates interreliance between the quality (and schedule and cost) of the different contractors, generating unique issues of interface control that must be carefully managed (Salvucci, 1997). For example the quality of the track, signal, and power installations by Siemens are strongly affected by the quality of the civil work completed by the ASCs. Siemens is responsible for design review and integration, construction inspection, coordination of the interface work, and the assessment of operations and maintenance impacts. The ICM is to assist in the coordination of design and construction activities between Siemens and the ASCs.

6.3.4.2 Cost and Schedule

Cost and schedule responsibility for each section lies with the contractor for that section. Each contractor is responsible for poor performance, but the HTA has remained involved in the design and management of construction and therefore is responsible for scope changes, incomplete scope, and owner review and approval delays. Design or construction error can result in delays and cost overruns. Other delays such as the weather are unavoidable. The result of the multiple interrelated schedules is the increased possibility for finger-pointing if or when delays occur.

6.3.4.3 Change Management

In a traditional design-bid-build procurement strategy the owner is responsible for design changes and change orders. In a single turnkey procurement strategy after preliminary design the owner transfers design responsibility to the contractor. As a result changes that occur because of design or construction are the responsibility of the contractor. The hybrid turnkey strategy used for Tren Urbano divides responsibility for changes between the owner and the contractor. Because the turnkey contractor does not have control over the entire project the turnkey contractor cannot assume full responsibility. The strategy intends for the responsibility of each change to lie with the party who initiates the change.

Therefore the contractual arrangement complicates change management. A change by an ASC or the HTA has potential affects on Siemens' contract, as Siemens is eventually responsible for the initial operation of the entire system.

6.3.5 Constructibility/Best Value

While the GMAEC completed the preliminary engineering, particular importance was placed on lifecycle costs so design decisions would reflect the total cost of design, construction and operation. The HTA felt that if the total cost implications of design decisions could be reasonably estimated, the final system would operate more economically and efficiently.

However, during the final design and construction process the incorporation of the GMAEC's expertise is limited by their exposure to risk. The GMAEC will not comment on whether they "like" the methods or specifics of the system designs as long as they meet the required specifications. The GMAEC will also not comment on whether they have a better method of implementing the design or construction of the system elements. It is not the GMAEC's place to perform these tasks, and the GMAEC would run the risk of directing the contractor if it proposed design or construction changes, which could result in financial liability for the cost associated with those changes (Gregson, March 24).

6.4 Tren Urbano Case Study Analysis

6.4.1 Project Configuration

Tren Urbano is moving toward the new model for project configuration. Because the Project is only in the early stages of construction it is hard to determine whether the Project as a whole will be considered a success or failure. However, to date many critical milestones have been surpassed in a short period of time.

The HTA/GMAEC succeeded in advancing the project through the major activities involved in the project configuration process. The HTA/GMAEC identified the project goals, completed the functional design, obtained community support, received community input, obtained environmental approval, selected a project delivery strategy, and secured project financing.

The HTA recognized that certain tasks such as determining the functional design, obtaining environmental approvals and permits, right-of-way acquisition, and utility relocation were best performed internally to avoid imposing open-ended risks on the private sector (DTPW, 1993). Completing the preliminary engineering prior to issuing proposal and bid documents permitted the HTA to establish the vertical and horizontal alignment, select the technology and systems desired, and develop detailed information on utilities and geotechnical conditions (DTPW, 1993).

The GMAEC and the HTA reviewed the advantages and disadvantages of traditional procurement and various forms of turnkey procurement in light of the identified project objectives. Although all objectives could not be maximized, the Secretary of the DTPW chose the hybrid turnkey structure for it offered an acceptable compromise. The fundamental concept of evaluating and selecting a procurement strategy to satisfy a set of project objectives is present even if all procurement options were not explored.

Project objectives must be determined carefully or the means to address them may compromise a fair and efficient procurement process. The HTA placed great importance on starting the project by early 1996. Therefore, the TUO recommended that the HTA have flexibility to adjust the contract structure during procurement. If negotiation with the turnkey contractor were delayed the HTA could remove civil packages and advertise them separately, or the GMAEC may advance the design of the packages (TUO, 1995). This was intended to prevent the HTA from being held "hostage" by the turnkey entity during negotiation. However, this also adds to the uncertainty of the procurement process. Competitors rely on knowing what the scope of the competition is and on what the competition is based.

The HTA/GMAEC efficiently and effectively executed the EIS and public participation processes. The DEIS was used to present a design alternative that addressed the identified need. The FEIS, published six months later, effectively addressed public and regulatory agency design issues identified during the review period. The preferred alternative was modified to include community supported alignment alternatives for Bayamon, Rio Piedras, and Hato Rey, to relocate the maintenance yards and shops, and to power Tren Urbano by an electrified third rail as opposed to an overhead catenary (FEIS, 1995).

The HTA/GMAEC recognized the value of supporting an operations-driven design. Cost-effectiveness, the cost associated with achieving the benefits of Tren Urbano, was an important criteria in defining the design elements. A particular importance was placed on lifecycle costs so design decisions would reflect the total cost of design, construction and operation. The HTA felt that if the total cost implications of design decisions could be reasonably estimated, the final system would operate more economically and efficiently.

Adding the choice and analysis of all potential delivery strategies would increase the value of the project configuration process and increase the HTA's flexibility in order to develop a procurement strategy that effectively addresses the project objectives. It is important for the HTA to consider risk allocation when selecting a procurement strategy and to ensure that the distribution of authority reflects the allocation of risk. Each party must have control over their risks in order to manage them, mitigate them, and successfully execute the project.

6.4.2 Organizational Structure

There is nothing inherently wrong with the chosen delivery strategy or with the concept of a matrix organization. The issue is the varying perceptions of the organizational structure among the Project Team, the redundant performance of certain tasks, and the resultant potential for conflict within the Project Team. The TUO is a combination of HTA and GMAEC staff which results in mixed lines of authority that cross agency or consultant firm affiliations. As the success of technology transfer is a high priority, there is a need for the HTA and the GMAEC to interact as one organization.

Although the current use of turnkey procurement is new and preconceived notions as to what turnkey procurement is may not exist, the academic definition of turnkey includes a certain level of contractor autonomy and control. The turnkey contractor in sole responsibility for the financing and execution of design, construction and start-up of a facility and upon completion the owner must only "turn the key" to begin operation.

To avoid conflicts, the HTA must clearly define the organizational structure for the Project Team. One perception is necessary to standardize communication and reporting lines as well as the type of information to be reported.

6.4.3 Project Objectives

Six project goals and their associated specific objectives were identified by the HTA/GMAEC. The goals and objectives are identified in both the DEIS and the FEIS without being changed by the public and agency comment period. The HTA/GMAEC were successful in clearly establishing the design, environmental, and procurement objectives for the project that led to an expedited environmental review, obtainment of public support, and completion of design.

6.4.4 Misguided/Conflicting Objectives

Part of the GMAEC contract with the HTA was to develop the procurement strategy for the design and construction of Tren Urbano. Although the GMAEC examined alternative strategies, the GMAEC only explored the various potential combinations of turnkey strategies. Participation in the FTA Turnkey Demonstration Program and the associated

Federal funding dictated that the primary procurement structure be some variation of a turnkey strategy. Although the potential for Federal funding did not necessarily result in the selection of the "wrong" delivery strategy for Tren Urbano, as a fundamental objective it often limits the options available, alters the project objectives, and results in misguided decisions.

The HTA's project goals are to ensure quality control, to optimize technology transfer and the participation of local firms, and to accelerate the start of construction. The HTA/GMAEC stated the procurement goals for Tren Urbano were to control the interfaces, maximize technology transfer, retain owner control, accelerate the start of construction, create an operations-driven design, and enhance project financing with private funding (GMAEC, 1994). The objective concerning technology transfer is very important to the HTA as Phase I of Tren Urbano is the first phase of the first rail transit system on the island. The HTA believes that the long-term success of Tren Urbano is dependent on the development of Puerto Rican professionals and technicians that are trained in the planning, design, construction, and operation of the rail transit system (Pesquera, 1998).

A turnkey strategy is typically used when the owner desires a complete facility that is ready for operation without owner involvement in the process. In a single turnkey arrangement the owner contracts with a private entity to deliver the desired facility. The private entity assumes responsibility for the financing, design, construction and start-up of the facility. The owner generally retains the risk of operations and in particular for a transit system the public owner will assume the ridership and revenue risk. Although a single contract, turnkey or traditional, would simplify contract administration, risk allocation, and interface coordination, it would also limit competition and local participation.

In a split hybrid arrangement the owner may choose to separate the systems and civil elements into separate contracts. This strategy allows for greater owner involvement as the owner can use different strategies for contract administration. The owner may choose to perform the preliminary design of the system elements and leave the final design and interface responsibility to the systems contractor. The civil contractor(s) is then responsible for the design and construction of all the civil elements.

Although the HTA pursued a turnkey procurement strategy, the structure of the final arrangement and the execution of the contracts do not reflect the traditional notion of a turnkey strategy. The hybrid structure used for Tren Urbano uses a single turnkey arrangement for the systems and part of the civil elements. The remaining civil elements are procured using a design-build strategy. The HTA/GMAEC considered vendor financing as an option, but apparently it was one the HTA was unable or chose not to pursue. The hybrid turnkey procurement strategy allows the HTA to achieve a balance between retaining control and minimizing the time required to complete construction and commence revenue operation. However, due to the importance of the project objective concerning technology transfer, the HTA/GMAEC has remained heavily involved in the management of the project. The relationship between the HTA and the GMAEC is structured to ensure that the HTA retains a high-level of input and control in the planning, design, construction, and operation of Tren Urbano (TUO, 1994). Although the initial GMAEC contract with the HTA only included planning, environmental/permit, preliminary engineering, and contract/bid development services, the HTA retained the option to extend the contract term and to amend the scope of services to include new responsibilities as the Project developed. As a result the GMAEC has been involved in the oversight and management of final design and construction.

Some of the objectives and needs of the HTA may be inconsistent with the turnkey approach or at least with using Tren Urbano to evaluate the effectiveness of the strategy. The goal of the FTA Turnkey Demonstration Program is to determine whether turnkey procurement strategies are effective in accelerating project development, reducing project costs, and result in more efficient risk allocation between the public and private sectors. The problem may lie in the fact the FTA has a loose definition of what constitutes a turnkey project. The FTA's interpretation allows almost any project that does not follow the design-bid-build format to be considered as a turnkey project (Dietrich, 1998). The implementation of the hybrid turnkey procurement process for Tren Urbano resembles more of a design-build-operate/design-build hybrid strategy. Although this is only a slight difference in definition and notation, the more important point to evaluate is the implementation of the strategy. The procurement process is intended to evaluate the advantages derived from turnkey procurement, however the complication due to interface management between contracts may reduce the value of this "demonstration" to testing the viability of multiple primes.

6.4.5 Contracting Plan/Risk Allocation/Responsibility

Every construction project possesses a unique set of drivers, variables, and potential risks that need to be evaluated before selecting the appropriate method of project delivery. These factors often include the owner's in-house capabilities to manage and monitor the design and construction of the project, the requirements placed upon the owner by those who are providing the financing for the project, the owner's risk tolerance, and the sensitivity with respect to the time for completion.

The contractual and organizational structure for Phase I of Tren Urbano was selected with the intent on maximizing the participation of the HTA in the design and construction process. With future extensions in the planning stages, the development of Puerto Rican professionals with transit experience was valued with great importance. The intent of a turnkey strategy places the turnkey contractor in sole responsibility for the financing and execution of design, construction and start-up of a facility and upon completion the owner must only "turn the key" to begin operation. Although the design-build-operate nature of Siemens contract does not include financing, the transfer of ownership of each of the alignment sections to Siemens prior to systems installation supports the view that Siemens is the owner during the design and construction phases. However, the HTA, the final owner, is deeply involved in the design and construction activities, retaining the authority held by the "owner". The HTA has contracted with the GMAEC to help perform project management/project control services throughout the design and construction process.

The importance of the project duration is reflected by the project objectives. The traditional method would have taken longer as the design is separated from construction. The design would have to be 100% complete before construction starts. The turnkey approach permits faster execution of the entire project. The method combines design and construction under one contract, which allows construction to begin before the design is 100% complete. With a shorter project schedule the SJMA will realize the benefits of the new mass-transit system earlier and project cost increases due to inflationary pressures will be reduced. The DTPW estimates that the combination of design, construction, and operations and maintenance in one procurement process has reduced the total project cost by 30% and the project schedule by almost 2 years (DTPW, 1998).

The turnkey approach allows the owner, the DTPW/HTA, to contract directly with a single entity that will deliver a totally functioning system defined by the scope of work that satisfies performance specifications, budget, and delivery schedule. In this case the turnkey contractor, Siemens, is responsible for a fixed-price delivery of the cars, systems, control operations center, maintenance yards and shops, and at least five years of operations and maintenance within the specified contract schedule. The turnkey contractor also has interface management responsibilities among all the civil alignment sections to ensure that the entire project functions as one system. In effect, Siemens is a contractor, a manager, and a temporary partner in ownership.

The general intent of turnkey procurement is to allow the focus of the public agency to shift from construction management and oversight to strategic planning and the determination of the overall project goals and needs. The flexibility of the turnkey construction contract allows risk to be distributed to the party that is most capable of mitigating that risk. The risk of systems integration is therefore transferred from the owner to the turnkey contractor.

Two statements in the GMAEC Procurement Strategy Paper indicates the GMAEC understood the advantages and disadvantages of the hybrid turnkey strategy (GMAEC, 1994):

- "As its name suggests, hybrid turnkey attempts to garner the best advantages of turnkey and of traditional procurement by having multiple contracts, and by assigning risk according to which party can most readily control it, or has the strongest incentive to do so."
- "It can just as readily be argued that hybrid turnkey has neither the advantages of traditional nor single turnkey, and that it introduces potential layers for interface problems with little compensating advantage."

The GMAEC notes that a hybrid turnkey strategy moves closer to the advantages of the traditional method such as owner control and distribution of the work but also approaches the disadvantages such as greater interface requirements, lesser innovation, longer schedule, and potentially higher costs (GMAEC, 1994).

Siemens-PB's role as turnkey contractor must be explicitly defined. The HTA could have simplified project execution and achieved most of the same goals, with some loss of direct control, if the alignment section contracts had been through the turnkey contractor. As the turnkey contractor and the operator for at least ten years, the Siemens consortium should execute the project as an owner's representative. Both Siemens and the HTA's interests and objectives should be aligned.

The contractual arrangement has also led to each entity conducting it own field inspections to ensure quality. The arrangement limits the effectiveness of this redundancy, for PB, the entity with the most expertise, cannot directly control quality on the alignment sections, as it does not have a contractual relationship with the ASCs.

The merit of using a turnkey approach is open for debate. Traditional project management literature suggests that an owner secure a single point of responsibility for design and construction services and allocate project risks to the party most capable of managing the risk. In theory and practice the method has the potential to reduce the schedule, lower total costs, and encourage design innovation relative to traditional design-bid-build. However, the traditional method is widely known and accepted and clearly defines the project scope with "100%" designs before construction which helps establish "known" cost, schedule, and quality.

6.4.6 Project Control

6.4.6.1 Coordination

The intention of the hybrid turnkey procurement strategy is for the interfaces between alignment sections to be controlled through the single systems contract, which provides the HTA a single source of responsibility for interoperability and continuity between sections.

If systems integration were the only criterion to choose a procurement structure a single turnkey arrangement would eliminate or internalize these interfaces and simplify management processes. However, the hybrid strategy seeks a balance between the procurement goals, which include control of the interfaces and maximizing local participation and owner control. Local participation is supported through the larger number of smaller contracts that represent opportunities for local firms. Owner control is secured through the multiple direct contracts with the GMAEC, Siemens, and the ASCs.

In the Procurement Strategy Paper the GMAEC noted that if the HTA were to pursue a split turnkey arrangement the HTA/GMAEC should assume responsibility for (GMAEC, 1994):

- Vertical interfaces between system and civil packages

- Horizontal interfaces among the multiple packages
- Design consistency and approval
- Approval of change orders between design and construction
- Schedule or cost changes due to interface problems
- Liability due to interface problems

These factors lead to the following recommendations for improving the allocation of responsibility for interface coordination.

1) The HTA should either retain responsibility for coordination of the interfaces or
2) Restructure the procurement strategy so the design-build alignment section contracts are through the turnkey contractor.

6.4.6.2 Cost and Schedule

One of the attractive advantages of the turnkey procurement strategy is that it allows for an accelerated project schedule. Overall costs are reduced as a result of the shorter schedule and the constructiblity/value engineering contributions of the contractor and operator. A single contractor is generally held accountable to the owner for the cost and schedule. For Tren Urbano the existence of multiple interrelated schedules complicates the evaluation of Project Status and who will ultimately be held responsible.

6.4.6.3 Change Management

Under a single turnkey arrangement change management is not an issue for the owner. The responsibility for design and construction lies with one entity and typical reasons for change orders such as design deficiencies or contractor constructibility/value engineering proposals are internalized within the turnkey contract. However, Siemens does not have direct contractual control over the entire Project. Changes may arise on any of the alignment sections due to unforeseen conditions, owner request, or alignment section contractor request. Therefore, change management is an issue for Tren Urbano and the intention is for responsibility to lie with the party who initiated the change.

6.4.7 Constructibility/Best Value

Each turnkey strategy accelerates the schedule, as the contractors can be procured before preliminary design is complete, and permits operationally driven designs as the operator can be identified prior to the completion of the final designs.

The accelerated schedule of the hybrid turnkey strategy allows the Commonwealth to receive the Project benefits earlier and avoid the inflationary costs associated with a prolonged schedule. The DTPW estimates that the combination of design, construction, and operations and maintenance in one procurement process has reduced the total project cost by 30% and the project schedule by almost 2 years (DTPW, 1998).

The O&M design review by Siemens has resulted in operational improvements to the stations, vehicles, Operations Control Center, maintenance yards and shops, the power systems, and the train control systems. A value engineering proposal concerning the maintenance yards and shops saved the HTA approximately $268,000 (Altshuler, 1997).

The downside is the 30% preliminary designs completed by the GMAEC reduces the contractors' ability to impact the design. Most major system decisions have been determined before the contractor and the operator's experience is incorporated. In this way the, Federal EIS process, of which 30% design is a requirement, currently limits the effectiveness of combined delivery strategies.

6.4.8 Lessons Learned

The system procured in Phase I will essentially define the technology for future phases. It is essential to consider the long-term effects of satisfying the region's transportation needs as well as the ease and flexibility of future expansions. One advantage is that construction, structural, and operational issues will be similar. Lessons learned about the procurement, construction, and operation of Phase I should facilitate improvements in the entire process for future phases.

However, there are no official processes for recording or evaluating lessons learned for Tren Urbano. This does not mean that the Project Team does not learn from past experiences, but there is no organized effort by the HTA to document and evaluate their experiences.

The hybrid turnkey procurement strategy has created a situation where different entities are performing identical functions in different geographical locations. This creates an environment which could benefit greatly from lessons learned both good and bad.

It is generally considered good practice to perform some form of internal evaluation. The implementation of organizational, administration, management and control programs should not be considered an end, as they should contain feedback and continuous improvement mechanisms. Although effective and efficient use of lessons learned requires a high level of cooperation within the Project Team, this cooperation should lead to effective identification and distribution of lessons learned as well as to the successful execution and completion of the project at hand.

The GAMEC states that, it is hoped that the turnkey "lessons learned" in Phase I will serve as a model for procurement in future phases (TUO, 1994). While this statement is true, the HTA/GMAEC is not implementing a formal lessons learned program. The HTA must extract valuable lessons learned from Phase I to improve upon the delivery process for future phases.

6.5 TU Project Configuration Conclusions

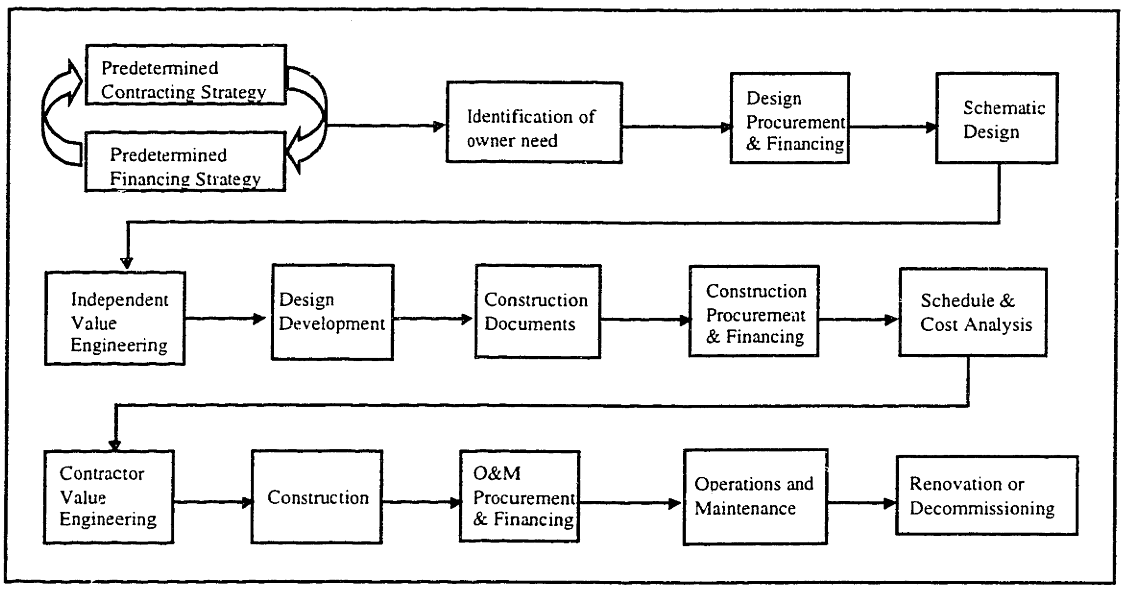
1. Tren Urbano is moving toward the new model for project configuration.
2. Tren Urbano was limited to Turnkey delivery options. Adding the choice and analysis of all potential delivery strategies would increase the value of the project configuration process and increase the HTA's flexibility in order to develop a procurement strategy that effectively addresses the project objectives.
3. The identified project objectives and the benefits of Turnkey procurement are not directly aligned. Owner control, technology transfer, and local participation vs. single point of responsibility and internal interface coordination.
4. The procurement process is intended to evaluate the advantages derived from turnkey procurement, however the complication due to interface management between contracts may reduce the value of the "demonstration" to testing the viability of multiple primes.
5. To avoid conflicts, the HTA must clearly define the organizational structure for the Project Team. One perception is necessary to standardize communication and reporting lines as well as the type of information to be reported.
6. The GMAEC is to advance the design to 30% completion. This level of design development prior to the award of the contacts predetermines most of the major design elements to ensure successful integration of the common system elements that extend through the entire project. Although 30% design eliminates most of the potential design incompatibilities, it also restricts the contractors' creativity and freedom to innovate.
7. The GMAEC does not have a contractual relationship with any other party in addition to the HTA. In effect, the GMAEC is reluctant to direct any of the contractors for they do not want to accept responsibility for any recommendation.
8. The GMAEC, PB, and the HTA Contract Mangers are all involved in the design review process. Design completion responsibility and review are therefore divided among the GMAEC, Siemens-PB, each ASC, and the HTA. Multiple designers and redundant responsibility for design increases the duplication of effort, increases the need for design review, increases the need for coordination of design and construction activities, and complicates the designation of professional liability for the design.
9. The HTA should allocate the responsibility for systems integration and systems performance with the entity that holds the contracts, in other words the party who can control interface quality. The HTA should either retain responsibility for coordination of the interfaces or restructure the procurement strategy so the design-build alignment section contracts are through the turnkey contractor.
10. Siemens' authority must match its mixed role as contractor-manager-temporary partner in ownership.
11. The HTA recognizes that Tren Urbano will most likely operate under a deficit and appropriately assumed the ridership and revenue risk. This allows the agency to focus on providing high-quality transit service which is most likely to reduce congestion, increase accessibility, and in general fulfill the initial identified transportation need. If the private sector were to accept the risk of ridership there may be conflict between offering the "best" service and generating a profit. This conflict would be a barrier to satisfying the initial need for improvement.

7 Research Conclusions

7.1 The New Configuration Model

In general, when difficulties arise on a project it can be attributed to the fact that the project participants did not properly plan for such occurrences. The typical design-bid-build lifecycle limits the effectiveness of project planning. The sequential process does not easily accommodate lifecycle planning efforts. The current public infrastructure delivery strategy, shown in Figure 7-1, utilizes a design-bid-build strategy, which is supported by public funds. As the delivery and financing processes are pre-determined there is great potential for the project to develop according to the requirements of these processes, which may or may not result in the most efficient delivery of the project for the "best value".

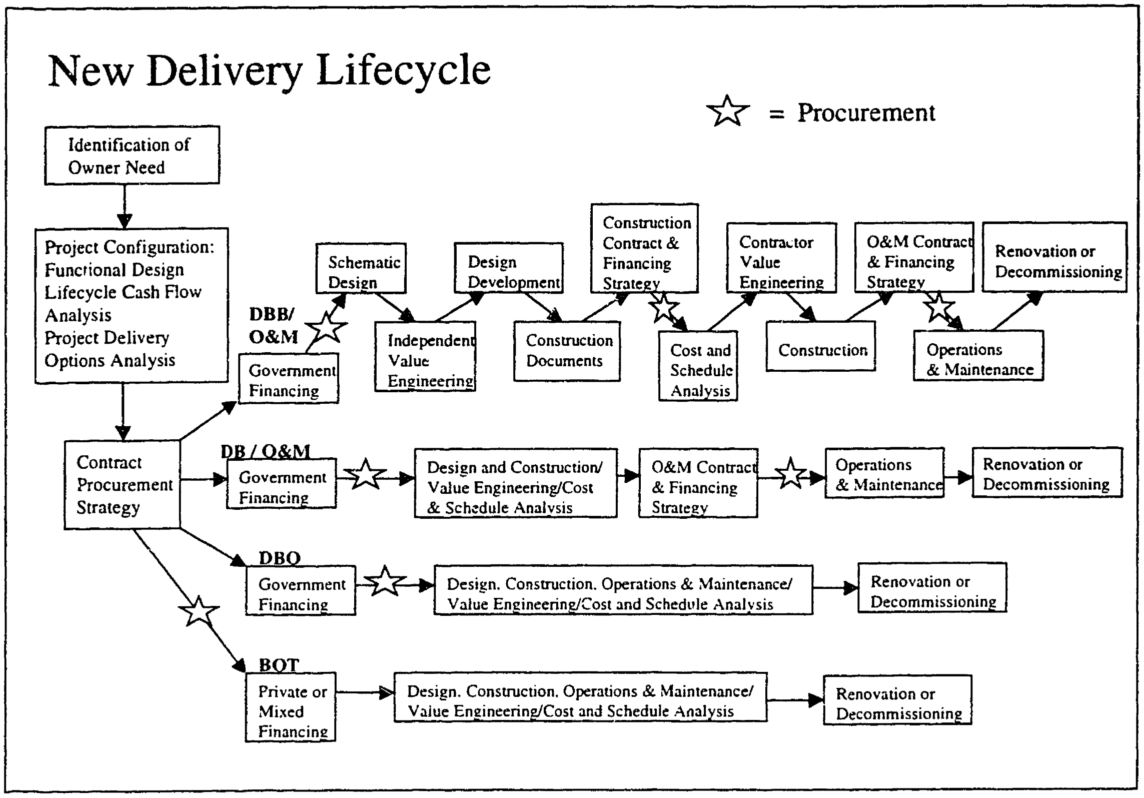
Figure 7-1 Design-Bid-Build Lifecycle



A fundamental element of a sustainable infrastructure delivery strategy is the notion that the method of delivery is a variable to be analyzed and managed. The ideology behind allowing the public sector to use all of the available contract procurement strategies is based on the belief that the public and private sectors can collectively provide the best services to meet the growing needs of infrastructure in America. Providing public owners the choice among various project delivery strategies including; design-bid-build, design-build, turnkey, design-build-operate, build-operate-transfer, and other variations will provide the best potential value in terms of infrastructure quality, level of service, and development of technology.

These concepts lead to the creation of a new generic project lifecycle, Figure 7-2, that depicts the multiple possibilities for a project's development.

Figure 7-2 New Project Life Cycle

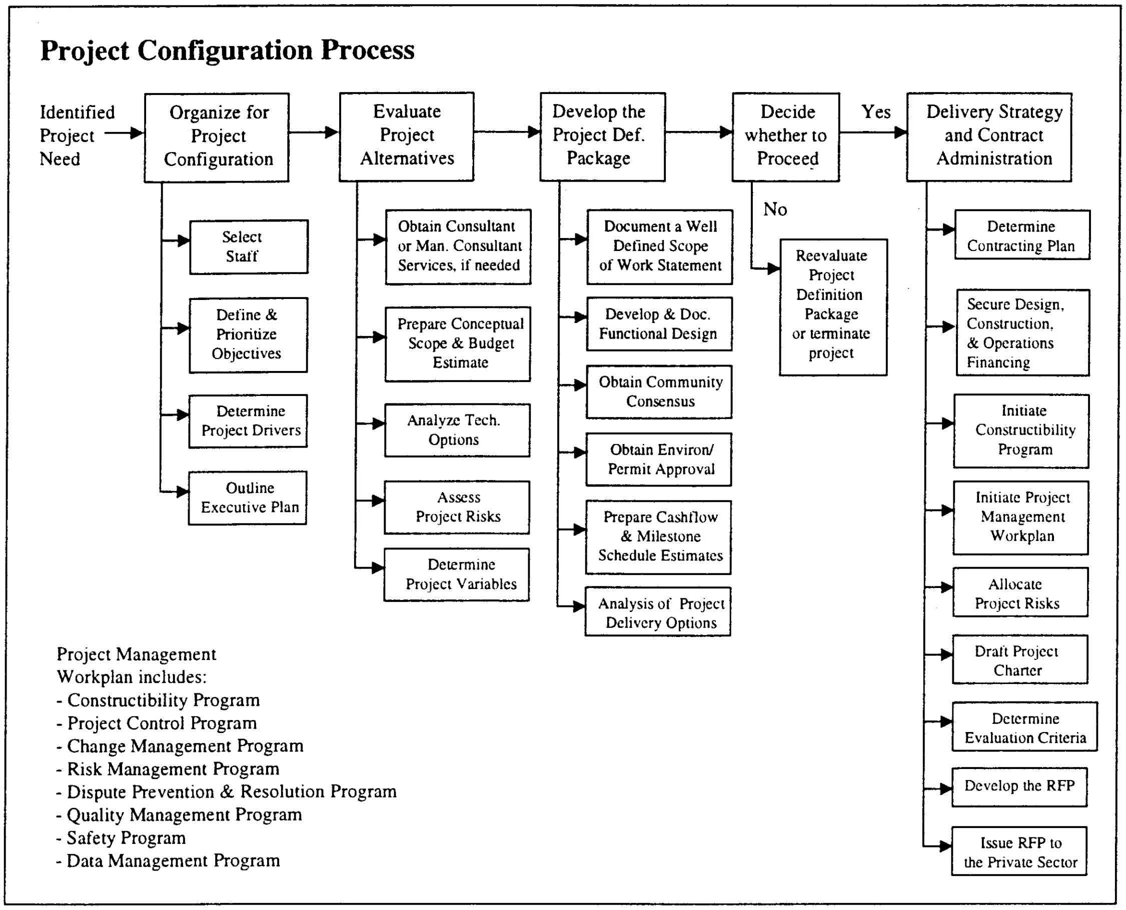


To effectively chose a delivery method, an owner must look at all of the possible delivery systems and consider the planning, management, procurement, risk allocation, type of specifications, acceptance, and responsibility for quality of each alternative. In order to maximize the benefit of treating project delivery as a variable an owner must:

- Understand the advantages and disadvantages of the available delivery strategies
- Be able to estimate the value of the project – budget, lifecycle cost, franchise value
- Understand the competitive market
- Clearly define project objectives
- Clearly define the project drivers
- Create a team atmosphere
- Encourage communication within the project team
- Clearly indicate and delegate responsibility
- Clearly define documentation and performance expectations
- Initiate the development of essential control programs

The ideal is to develop a structured planning process, shown in Figure 7-3, and practical tools that address critical problems, objectives, and situations under conditions of uncertainty with all delivery methods. The transparency of a consistent process will allow the private sector to know what to expect and better prepare to meet the owner's needs, the owner will be able to chose the best method to delivery the project, and the groundwork will have been established to manage the project.

Figure 7-3 Project Configuration Process Model



Contracts should not be procured before the owner has adequately completed the project configuration stage. There is greater potential for increased cost if contracts are procured too early for example before environmental approval, secured financing, or definition of functional design.

It is important to remember that the project configuration process is neither an end in itself nor does it have a definitive end. It is an ongoing process that involves all project participants, but is also a process that must begin with the owner. The owner can direct the course of the project by determining the project objectives, completing the functional design, obtaining environmental/permit approval, estimating the project budget and cashflow, and selecting the most appropriate delivery strategy. Effective execution of the project configuration process by the owner will increase the probability of a successful project for all project participants.

7.1.1 Public and Private Role

The model allows the government to adequately identify and define the public need, allows for options to meet these needs, clearly indicates government support of selected projects and delivery processes, allows for fair private sector involvement, and encourages the dedication of private sector resources to generate innovation in technology and design, as well as, construction and operation processes. The model allows both the public and the private sectors to contribute in ways that are amenable to their inherent strengths. The public sector can best:

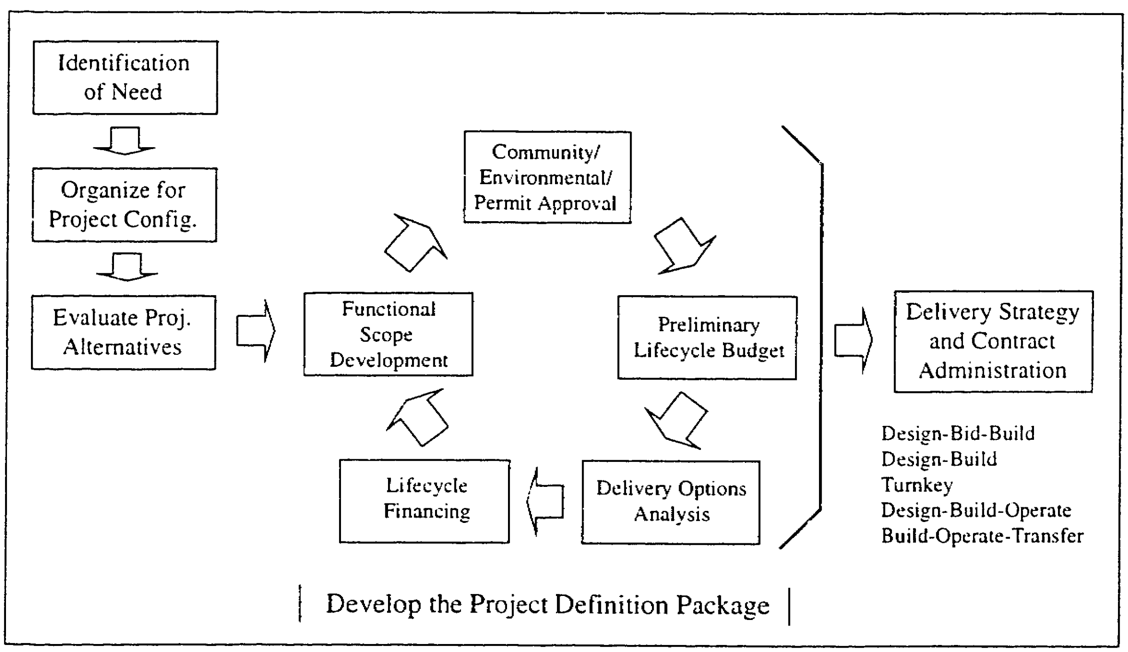
- Identify public need and viable projects
- Align economic and infrastructure strategies
- Establish government commitment to viable projects and delivery processes
- Provide a fair, competitive environment for private sector participation
- Establish reliable commitments for infrastructure financing

The private sector can best:

- Provide an independent competitive check on the technical and economic viability of projects
- Provide an alternative source of financing
- Develop and introduce innovations in technology, design, construction, and operation processes

As shown in Figure 7-4, scope development, the EIS process, financing, and the delivery strategy are linked together. Each element progresses incrementally, which affects the other parts, until the project configuration process is complete.

Figure 7-4 New Configuration Cycle



It is essential that the owner become actively involved in the development of clear and realistic objectives and commit to the development of a well-defined Scope of Work Statement during the project configuration phase. The completion of the design to the functional level at this stage will help define the scope and increase the comparability of bids or proposals during the procurement phase. The functional design stresses size and capacity decisions, technology, and architectural concepts. An owner who has established these elements before proceeding onto the following phases will obtain the best value from the remaining variables – the choice of Procurement Strategy, the development of a Project Team and Organizational Structure, and the development and implementation of a Project Management Strategy.

If it is not clearly evident that the owner organization has adequate and appropriate staff to support the specialized needs of the project, owners should augment and supplement their internal capabilities with services from a professional construction management firm.

The project management strategy must be flexible to accommodate the specific needs of the current project. Knowledge of project management principles and best practices will allow owners and project managers to develop management strategies that are likely to achieve the project goals. Integration of project management programs is essential. Similar goals and activities must be identified and pertinent information must be shared and accessible to maximize the benefits of each program. Structure is a key element to successful project management strategies, and will become increasingly important as projects grow in size and technical complexity.

An open decision making process will encourage collaboration within the project team. The project team must be open to improvements throughout the entire project. Team member endorsement of the project charter and project management workplan represent the essential commitment to and validation of the project. It is important to remember that people are the key to a successful project. People are the most important resource and when combined with appropriate technology and project management techniques and focused on quality the probability of a successful project is increased.

7.1.2 Benefits of the New Model

7.1.2.1 Simplify the Process

The goal is to simplify the planning/configuration process. The strategic planning process allows the public sector to consider options to deliver and finance projects, establish known expectations, and standardize information collection and distribution.

The private sector will adjust to provide services under these market conditions. The design-bid-build method dictates to the contractor what their business strategy is. They have no choice but to be a low cost service provider. This does not encourage innovation or allow for differentiation, which improves service quality in the long run.

It can be argued that adding more options would complicate the process. However, it can also be argued that the problems or complications are inherent in the current process and the addition of delivery options would not add confusion but would allow projects to be matched with the best delivery strategy. The new method may reduce the confusion because projects will not be forced to take a certain path.

7.1.2.2 Aligned Project Objectives and Delivery Strategy

Perhaps the greatest benefit of the new configuration process is that the owner can align the delivery strategy with the key project objectives. An owner can evaluate the advantages and disadvantages of each delivery option in light of the identified project objectives. The choice of delivery strategy allows the public owner to maximize the potential for project success by aligning these two key elements.

Combined methods of delivery also allow owners to consider new objectives. The choice of project delivery will allow owners to effectively address issues such as lifecycle costs, constructibility, and the consolidation of responsibility, as project objectives.

7.1.2.3 Estimate of the Project Costs and Value

After completing the functional design the owner can complete a conceptual budget and lifecycle cost analysis of project. Completion of a budget at this stage will identify the near-term financial boundaries of the project and provide the owner an estimate of the project's costs. A lifecycle cost analysis will identify long-term benefits and costs of the project to provide the owner an estimate of the project's potential value.

These initial efforts will provide a baseline from which to compare proposals or bids from the private sector. From another perspective Professor John Miller at MIT focuses on the private sector's potential to provide the public owner with an independent check on the project's engineering and budget. Through the implementation of combined procurement strategies the government, can obtain multiple, independent private sector confirmations that (Miller, 1997a):

a) the project is technically feasible
b) the government's estimate of the entire capital cost is realistic (or not)
c) the estimated life cycle cash flows to build, maintain, and operate the facility are realistic (or not)

7.1.2.4 Focus on Team Effort

One of the key elements of the new configuration process is the focus on a team effort. This focus is reflected by the definition of project success stated in Chapter 1.

- Success is determined by the level of satisfaction among the project participants toward the completion of a fully operational and functional facility, with the least number of changes, rework, cost overruns, delays, and disputes.

The new definition of project success places emphasis on relationships. The configuration process relies on a team effort, open communication, and the proper balance of responsibility and risk sharing. This research supports the belief that strong, team-oriented relationships will lead to shared objectives, fewer conflicts, and faster dispute resolution.

As the project enters the design and construction phases the project team becomes essential. An owner cannot design and construct the project alone and must assemble a project team to perform essential functions. How the team performs and interacts during design and construction is dependent on how well the owner structured the project and how the project risks are allocated among the members of the project team. When allocating specific project risks it is important to remember that risk should be assigned to the team member who is most qualified to assume the risk and perform the work.

7.1.2.5 Focus on Mission and "Best-Value"

This public sector mission statement, suggested in Chapter 1, supports the belief that public owners should be able to choose from multiple project delivery strategies, not just design-bid-build.

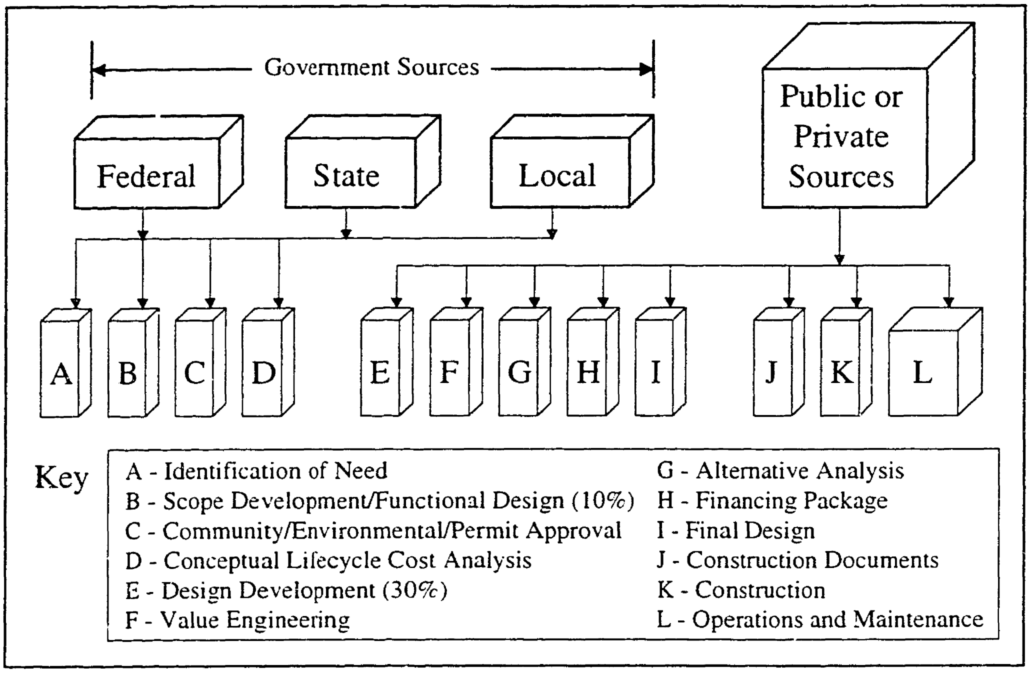
- Collectively, the Federal, state and local government's mission is to maximize the resources available to provide the greatest infrastructure value, in terms of cost and service quality, to the public.

The project configuration process allows public owners to align the delivery strategy with the project objectives. If projects are properly structured before the private sector becomes involved the potential for successful projects is increased. The public and private sector must together strive to improve the quality of the American infrastructure portfolio through proper allocation of financial risk and the encouragement of developments in technology and innovation throughout design, construction, and operation processes. For example, if the government can push financially viable, large capital projects into the private sector, more public funds can be directed to a large number of smaller projects that cannot support themselves.

The option to utilize combined delivery methods also allows public owners to generate operationally driven designs. Through incorporating the knowledge of contractors and operators through value engineering, constructibility reviews, and lifecycle cost analyses the government increases the value it receives for its financial resources.

Figure 7-5 (adapted from Miller, 1997b) represents an example of the potential sources and timing of project financing.

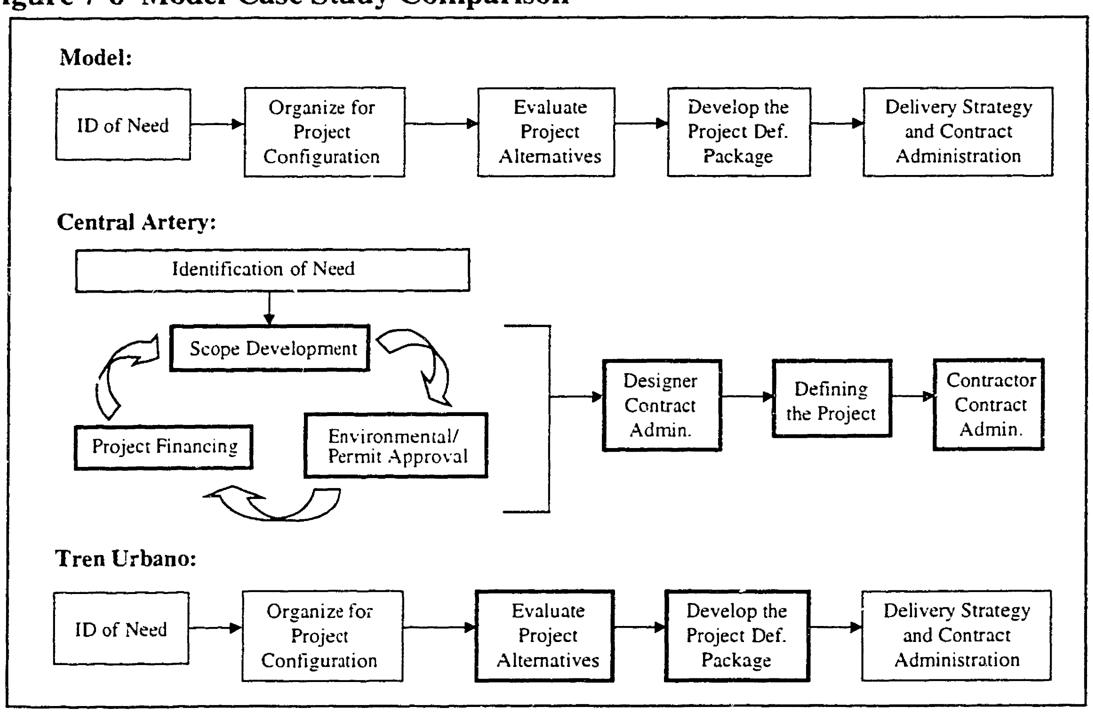
Figure 7-5 Potential Sources of Funding



7.2 Model-Case Study Comparison

Figure 7-6 displays a comparison of the configuration process for each of the case studies with the proposed project configuration model developed in Chapter 3. The highlighted boxed represent the key variations of each case study from the proposed process.

Figure 7-6 Model-Case Study Comparison



The CA/T Project's development process is quite different from the proposed configuration model. As shown in Figure 7-6, the project drivers are not clear. Massachusetts State law (M.G.L. Ch. 30B Sec. 5) forced the Massachusetts DTPW to utilize the traditional design-bid-build delivery method. The figure shows the circular dynamic between obtaining environmental and public approval, obtaining Federal financing support, and developing the scope of the project. Therefore it was not clear whether the project development process originated from a basic set of objectives that addressed the identified need. The case study showed that, at times, the scope evolved through the public participation and environmental approval process and included pieces from the outset that would increase the probability of Federal financial support.

The Massachusetts DTPW was not given the opportunity to conduct an analysis of delivery options or develop a delivery strategy that matched their specific objectives. The use of design-bid-build forced the separation of design and construction. In the process of satisfying multiple governmental agencies, funding requirements, the affected public, and conducting contract administration for the segmented procurement process, it became a difficult challenge for the DTPW to obtain the "best-value" for public funds.

The new configuration model addresses the configuration problems for the CA/T Project identified in Section 5.5. The model offers the public owner the opportunity to align the project objectives with the delivery strategy. The process requires the identification of the functional scope requirements, environmental and public approval, and a conceptual budget and lifecycle cost analysis prior to the entry of private designers and contractors. If combined methods of delivery are used the private sector can not tolerate the risk and uncertainty of changes in the project scope due to environmental approval and public consensus. Obtaining environmental and public approval of the entire project prior to initiating the project will also eliminate the potential for a partially completed project to be held hostage by later approvals. The focus of the new model on appropriate risk allocation and a Team effort will increase the potential for open communication and the identification of common objectives within the Project Team. A unified Team effort that can take advantage of operationally driven design and efficient project management practices will increase the value received by the public owner over the project's lifecycle.

Tren Urbano is moving toward the new model for project configuration. There was a conscious effort by the Puerto Rican DTPW to advance the project through the scope development and approval stages in short period of time. This time constraint increased the need to adequately define the project, obtain community support, obtain the required environmental approvals, and secure the needed financing. Figure 7-6 shows that Tren Urbano deviates from the proposed model in the execution of the Evaluation of Project Alternatives. The Puerto Rican DTPW limited the analysis of delivery options to exploring turnkey strategies and comparing them with the design-bid-build method, in part to participate in the Federal Turnkey Demonstration Program. As a result the advantages of using a turnkey strategy such as a single point of responsibility and internal interface coordination are not aligned with the project objectives such as owner control, technology transfer, and local participation. However, the hybrid turnkey strategy was successful in allowing the Project to advance through the early stages of development in a short period of time. Tren Urbano also differed from the proposed model in the development of the Project Definition Package. A key part of the new model is that the public agency views design and construction as a Team effort and carefully assigns risk to the Team member that is capable of managing the risk. The assignment of responsibility for the interfaces and a completed project by the specified date is complicated for the turnkey contractor by the multiple design-build contracts. Although to date the Project has surpassed many critical milestones, the Project is only in the early stages of construction, therefore it is hard to determine whether the planning-configuration process and the Project as a whole will be considered a success or failure.

The new configuration model addresses the configuration problems for Tren Urbano identified in Section 6.5. Again the model offers the public owner the opportunity to align the project objectives with the delivery strategy. The choice of delivery options and through conducting an analysis of delivery options the public agency can align the project objectives with the advantages of a delivery strategy. The new model places a strong emphasis on a Team approach to design and construction. Appropriate risk allocation to the Team member most capable to manage the risk is a key element. A unified Team effort that can take advantage of operationally driven design and efficient project management practices will increase the value received by the public owner over the project's lifecycle.

7.3 Current Barriers Lead to Other Benefits

7.3.1 Current Legislation

One of the most significant barriers to implementing the new project configuration process is current legislation. Federal and state regulations preclude the combination of design and construction services, which would eliminate the use of delivery option analysis. The Brooks Act, *Public Law* 92-582 (40 U.S.C Sec. 541-544), enacted in 1972 required the separation of design from construction for public projects. Many states also have regulations that require the separation of design and construction. Massachusetts State law (M.G.L. Ch. 30B Sec. 5) forces the DTPW to utilize the traditional design-bid-build delivery method.

The benefits of the proposed configuration model are inextricably tied to regarding project delivery as a variable that can be aligned with the owner identified project objectives. Therefore, once the Federal and state governments enact new legislation that commit to variable delivery, the potential value of the configuration model will be realized. This will lead to flexible legislation that will allow for the introduction of new delivery strategies beyond those used today.

7.3.2 Environmental Approval/EIS Process

As a result of the National Environmental Policy Act's (NEPA) Environmental Impact Statement (EIS) process the design is advanced to 30% completion. This level of design development prior to the award of the contacts predetermines most of the major design elements. Although 30% design eliminates most of the potential design incompatibilities, it also restricts the contractors' creativity and freedom to innovate, one of the driving forces behind using combined delivery methods. In this way the, Federal EIS process, of which 30% design is a requirement, currently limits the effectiveness of combined delivery strategies.

The intention of public participation in the NEPA process is on target. The public needs to be informed of and given a forum to comment on potential public projects that affect the general community. It is important to include public agencies and community groups in the design process in order to obtain consensus or near consensus to support a reasonable project. However there must be a balance between public involvement and fulfilling a realistic identified need. There comes a time when the lead agency must take control over public perception and allow the consultants, designers, and contractors involved to proceed with the execution of the project. This transition must generally occur once the design is nearing completion.

The proposed project configuration model requires public owners to obtain the necessary environmental and permit approvals before the private sector becomes involved. The participation of multiple groups will require a streamlined environmental approval process that will benefit owners, contractors, and the public.

7.3.3 Political Nature of Funding Process

Federal funding programs and the political power to allocate and obtain public funds is another barrier to implementing the proposed model. Current Federal funding programs that provide 90 cents on every dollar will influence many public projects to adhere to the program requirements. The current process is often mixed with politics as public officials use Federal money as a political tool to improve their local image and to improve the local economy in the near-term.

The new model would essentially eliminate the influence of the source of financing while configuring the project. The source of financing would be a concern while evaluating the potential of the various delivery strategies.

7.3.4 Perception of Privatization

There has been a considerable amount of discussion concerning privatization of government infrastructure functions over the last few years. The perception of privatization that has evolved from this debate may present a barrier to opening the public infrastructure to all delivery strategies. Many people feel that privatization is a method to use private capital to turn inefficient government services over to the private sector. Others feel that privatization is a loss of governmental control and the private sector will not respect the needs of all individuals.

This research assumes the answer will not be privatization, but the substitution of a contracting strategy in place of privatization. The public owner will have the option to use all delivery strategies to fulfill the public need. Charles Rendhall, of Daniel, Mann, Johnson, & Mendenhall, said it best, "Government is essential, but it is time to redefine the role of government from a producing entity to one of management and oversight. It is time for government to partner with the private sector in order to get the most efficient services for the most cost-effective price" (Rendhall, 1996).

Glossary of Terms

- **Build-Operate-Transfer** – The combination of design, construction, and operations and maintenance within a contractual arrangement to obtain a single point of responsibility for these services; indirectly financed
- **Combined Strategy** – The combination of design, construction, and/or operations and maintenance within a contractual arrangement
- **Construction Management** – Services provided by or to an owner during the final stages of design, the bid/award phase and the construction phase of a project when the owner holds a number of prime contracts with trade contractors
- **Critical Project Success Factors** – Are elements that an owner has identified as critical to the success of the project and that can be influenced by the owner's response to configure the associated project variables
- **Design-Bid-Build** – Segmented design, construction, and operations and maintenance with a single business entity acting as the contractor in complete and sole charge of construction
- **Design-Build** – The combination of design and construction within a contractual arrangement to obtain a single point of responsibility for these services; directly financed
- **Design-Build-Operate** – The combination of design, construction, and operations and maintenance within a contractual arrangement to obtain a single point of responsibility for these services; directly financed
- **Direct Financing** – Government financial support of a project
- **Indirect Financing** – Private sector financial support of a project
- **Parallel-Prime Contracting** – also multiple-prime contracting – The owner enters into multiple direct contractual arrangements with contractors, subcontractors, and a designer(s) to complete the project
- **Procurement** – Divided into two parts: 1. Contract procurement – contracts for labor and services; 2. Purchasing – purchasing of equipment, materials, supplies required for construction and operations
- **Program Management** – Services provided by or to an owner that has more than one project underway at the same time, and wants to standardize criteria and maintain consistent control, reporting, and contract administration
- **Project Delivery Strategy** – The contractual, financial, and management strategy used to complete a project. The means and methods of developing a project from concept to completion.
- **Project Charter** – The definition of a project's objectives and scope as well as the definition and commitment to goals, roles, and relationships within the project team is the

chartering process; the written documentation of these definitions and the commitment of project team members is the project charter.

- **Project Configuration** – The planning, defining, and organizing of project objectives, scope, functional design, financial analysis, and delivery strategy

- **Project Configuration Activities** – Useful owner activities that lead to the development of project resources, referred to as the project configuration deliverables, that promote the delivery of a successful project.

- **Project Configuration Deliverables** – Resources or tools that an owner and project manager can implement to promote the delivery of a successful project.

- **Project Configuration Principles** – Good project management principles or concepts that lead an owner to define project needs and that can be associated with CPSFs.

- **Project Execution** – The realization of project planning and design through construction activities

- **Project Management** – Services provided by or to an owner during the planning, design and construction phases of a single project when the owner intends to use one or more contractors to perform the construction

- **Project Phases** – A typical method a describing the development of a project, project phases can be sequential or have significant overlap

- **Project Success** – The level of satisfaction among the project participants toward the completion of a fully operational and functional facility, with the least number of changes, rework, cost overruns, delays, and disputes

- **Portfolio** – The collection of infrastructure projects initiated or controlled by the government

- **Public Owner** – An agency, department, or body within the Federal, state, or local government that initiates a project

- **Pure O&M Contract** – A contractual arrangement for operations and maintenance services only

- **Segmented Strategy** – A distinct contractual separation of design, construction, and/or operations and maintenance

Appendix A Executive Plan

Example of an Executive Plan – Modified from Rigby's Program Plan example (Rigby, 1998)

Executive Plan – Example Outline

1.0 Project Background

1.1 Identification

Identify the name and location of the project

1.2 Purpose

State the purpose for developing the project

1.3 Overview

Provide a brief introduction to the project and summarize the contents of this document

1.4 Relationship to other Projects

Identify any pertinent relationship between this project and any other project

2.0 Referenced Documents

Reference the applicable documents and reports pertinent to the management, design, or execution of the project

3.0 Objectives

Briefly summarize the owner's objectives for the project

4.0 Organization and Resources

4.1 Staffing Plan

Identify the individuals and staff positions within the owner organization

4.2 Organizational Structure

Identify the business organizations within the project team and indicate the relationships between them

4.3 Management Programs

Identify the specific management programs that will be used to ensure successful project completion

4.4 Criteria for Evaluating Conformance

- Technical objectives – Technical objectives shall be established for the project so that meaningful relationships between need, urgency, risk, and worth can be established

- Baselines – Functional and design baselines shall be developed progressively
- Technology – Specification requirements shall be delineated in light of acceptable technological risks defined by risk assessment
- Design Completeness – The design shall be complete from a total system element viewpoint
- Cost estimates – Cost estimates shall include acquisition and ownership costs; this shall include any established "design to" cost goals and current estimate of these costs
- Technical task and work breakdown structure compatibility – Elements of the contract work breakdown structure and associated technical tasks shall be identified and controlled
- Consistency and correlation of requirements – System and technical program requirements shall be consistent, correlated, and traceable throughout the contract work breakdown structure so that the impact of technical problems can be promptly determined and accurately appraised
- Technical Performance measurement – Progress in achieving technical requirements shall be continually assessed; problems and risk areas shall be identified
- Interface design compatibility – Intra-system and inter-system design compatibility of engineering interfaces shall be delineated as interface requirements in appropriate specification. Interface control requirements and drawings relate to:
    1. The major system elements and the contractor(s) responsible for them (design and construction responsibility)
    2. Equipment and procedural data furnished by the owner
    3. Project participants shall be coordinated and relationships maintained
- Communication – Clear lines of communication and timely dissemination of changes to the documents shall be maintained
- Historical Data – Historical engineering/operational data available to systems engineers shall be identified
- Responsiveness to change – Changes to system and program requirements in response to direct changes by the procuring activity, or problem solutions identified shall be evaluated for total program impact with respect to performance, cost, and schedules
- Compatibility with related activities – Engineering management activities shall be compatible with related project management activities such as cost and schedule control, system design criteria, contract administration, change management, etc.

5.0 Activities and Schedule

Identify major project tasks or activities and provide a milestone schedule that indicates the important dates

6.0 Notes

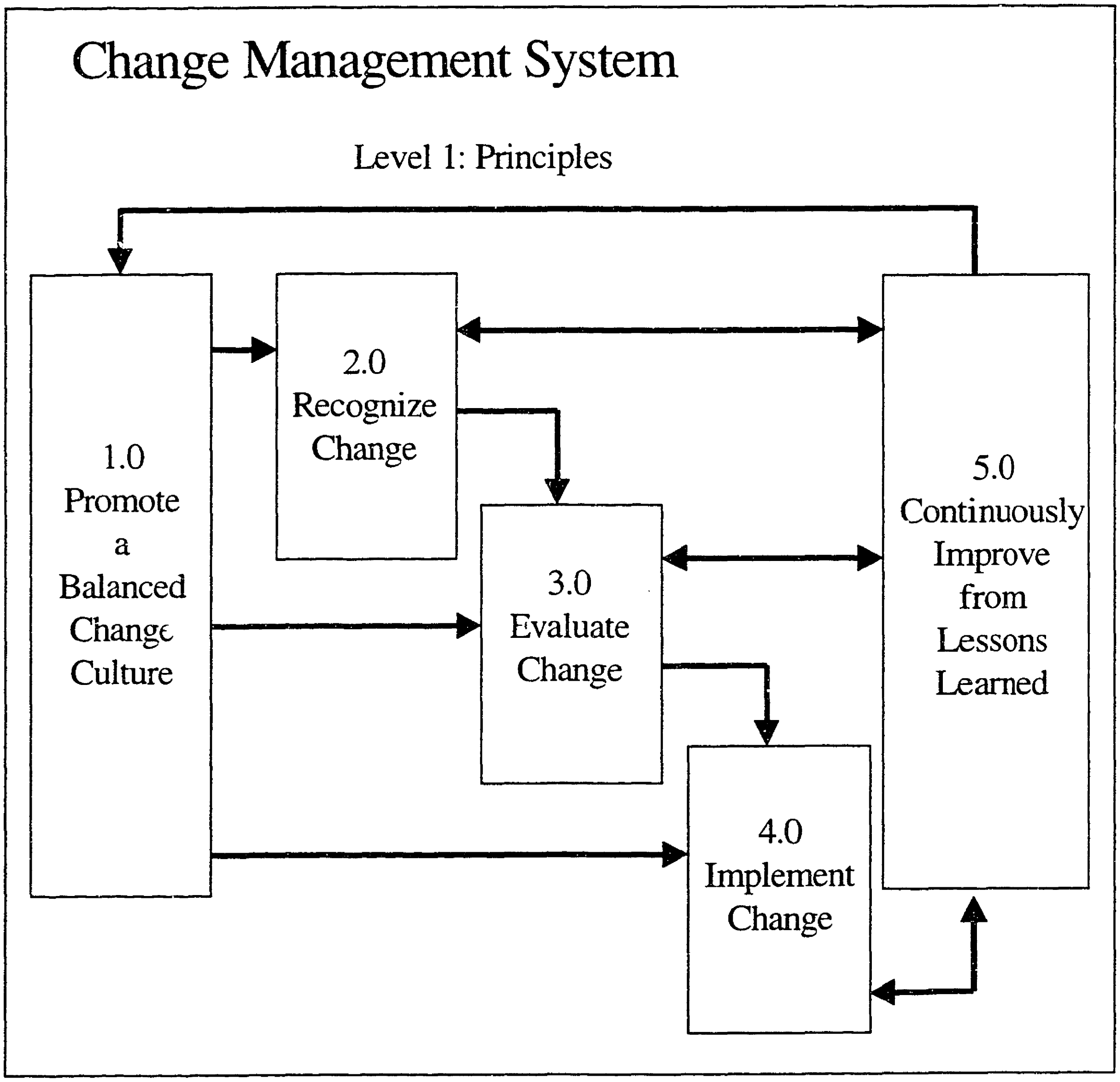
This section contains information of a general or explanatory nature

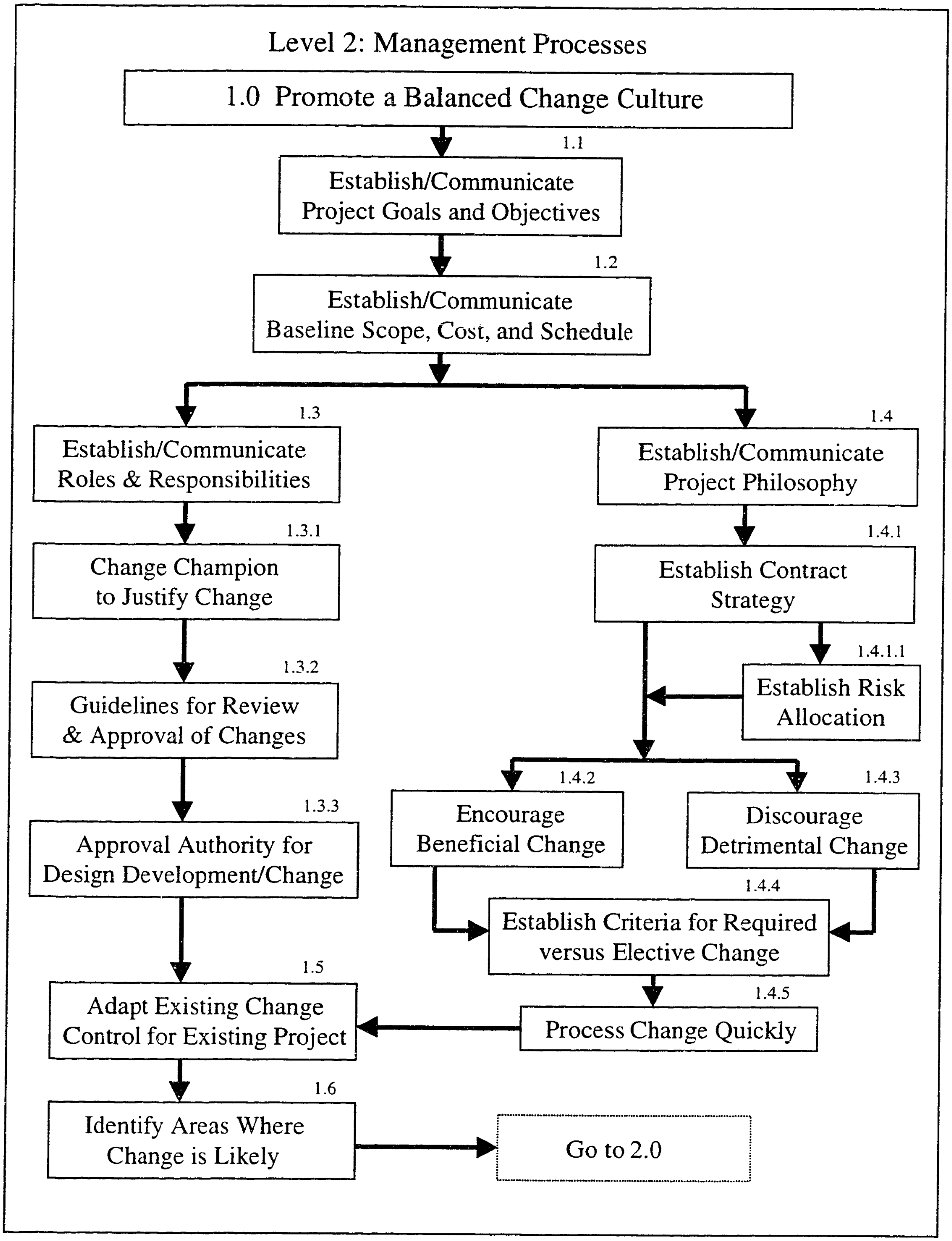
6.1 Definitions of Terms Used in this Document
6.2 Changes from the Previous Issue

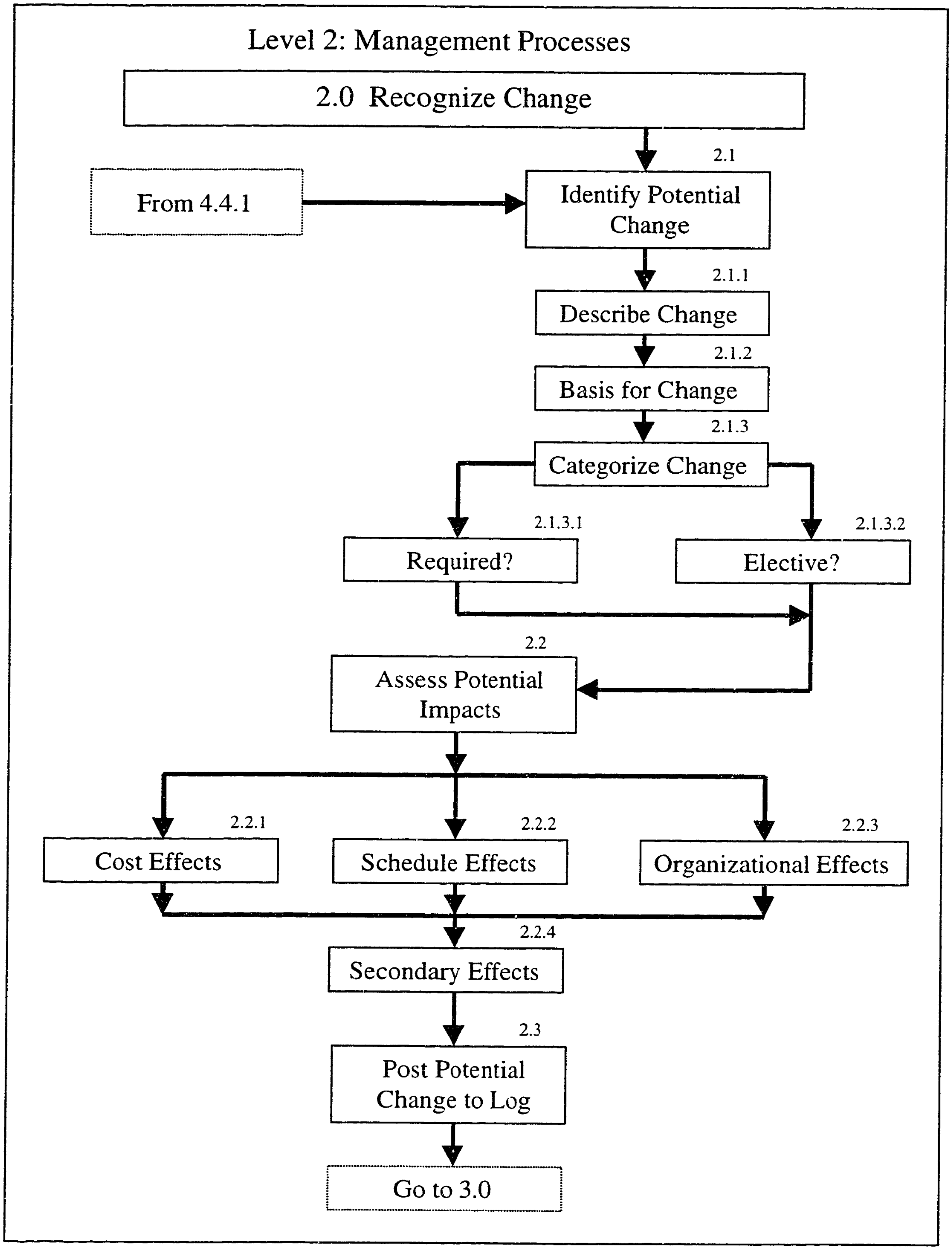
Appendix B Change Management Plan

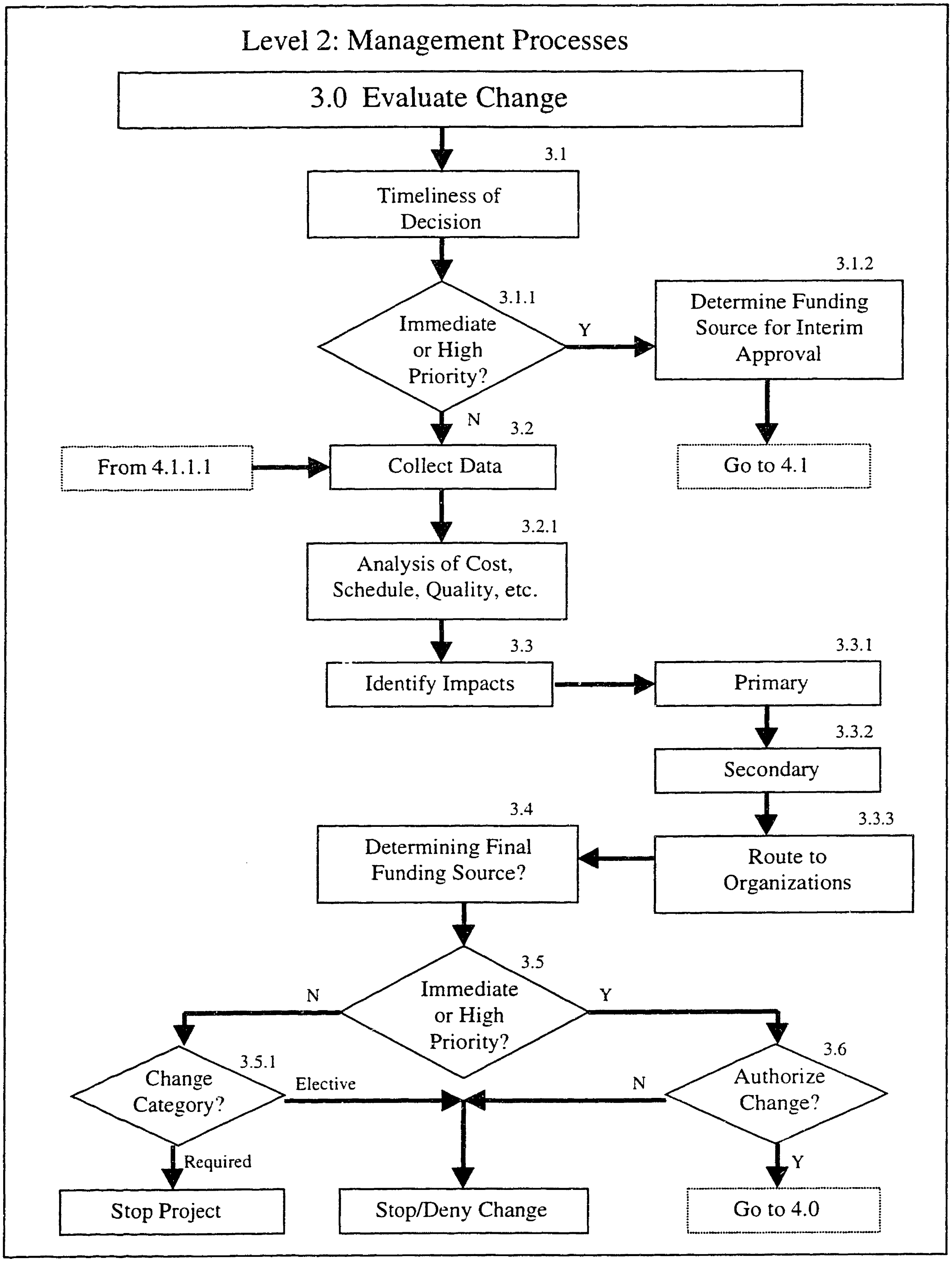
Example of Change Management Plan – developed from Ibbs' Change Management System (Ibbs et. al., 1994)

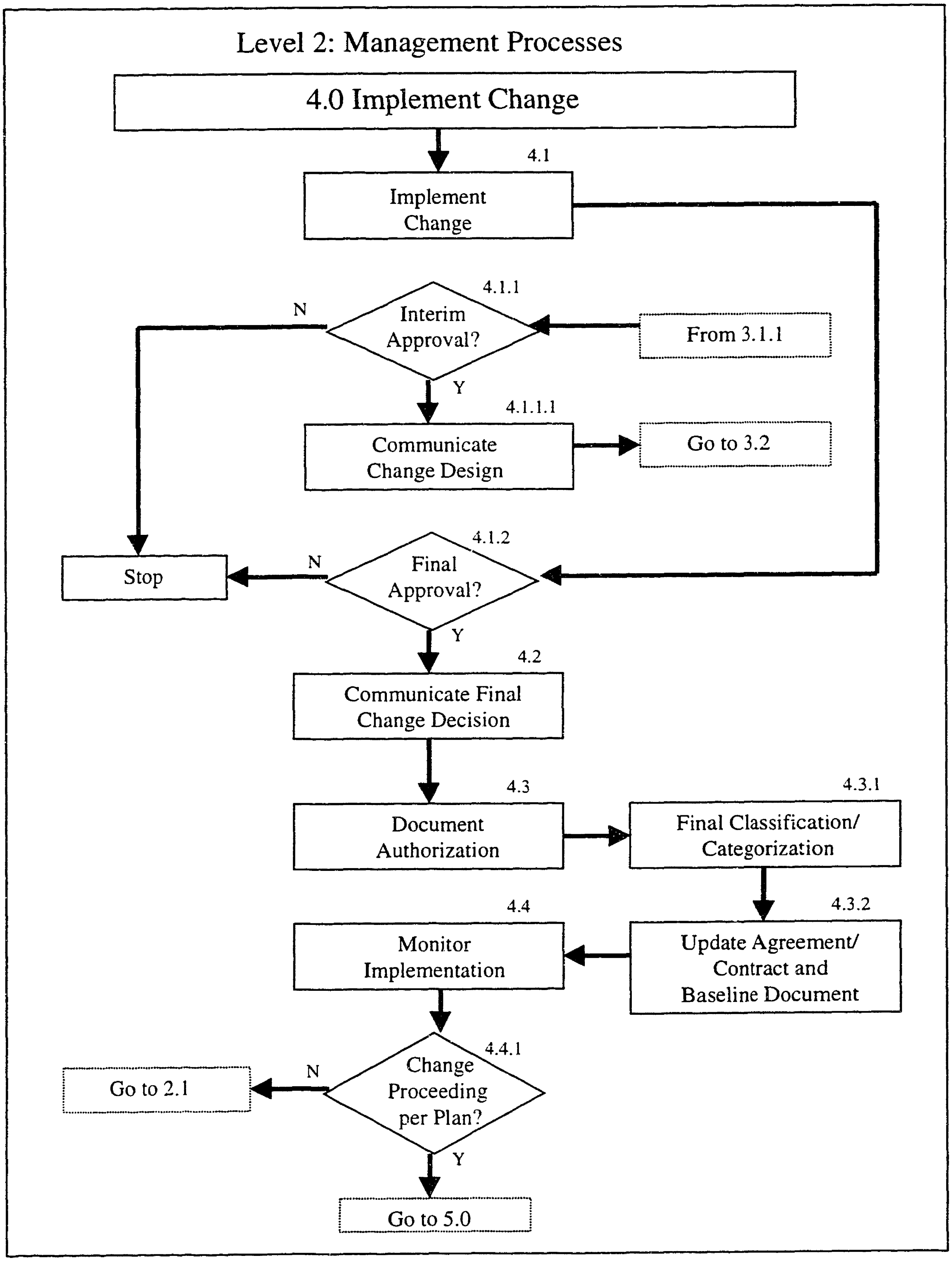
Change Management Plan – Example

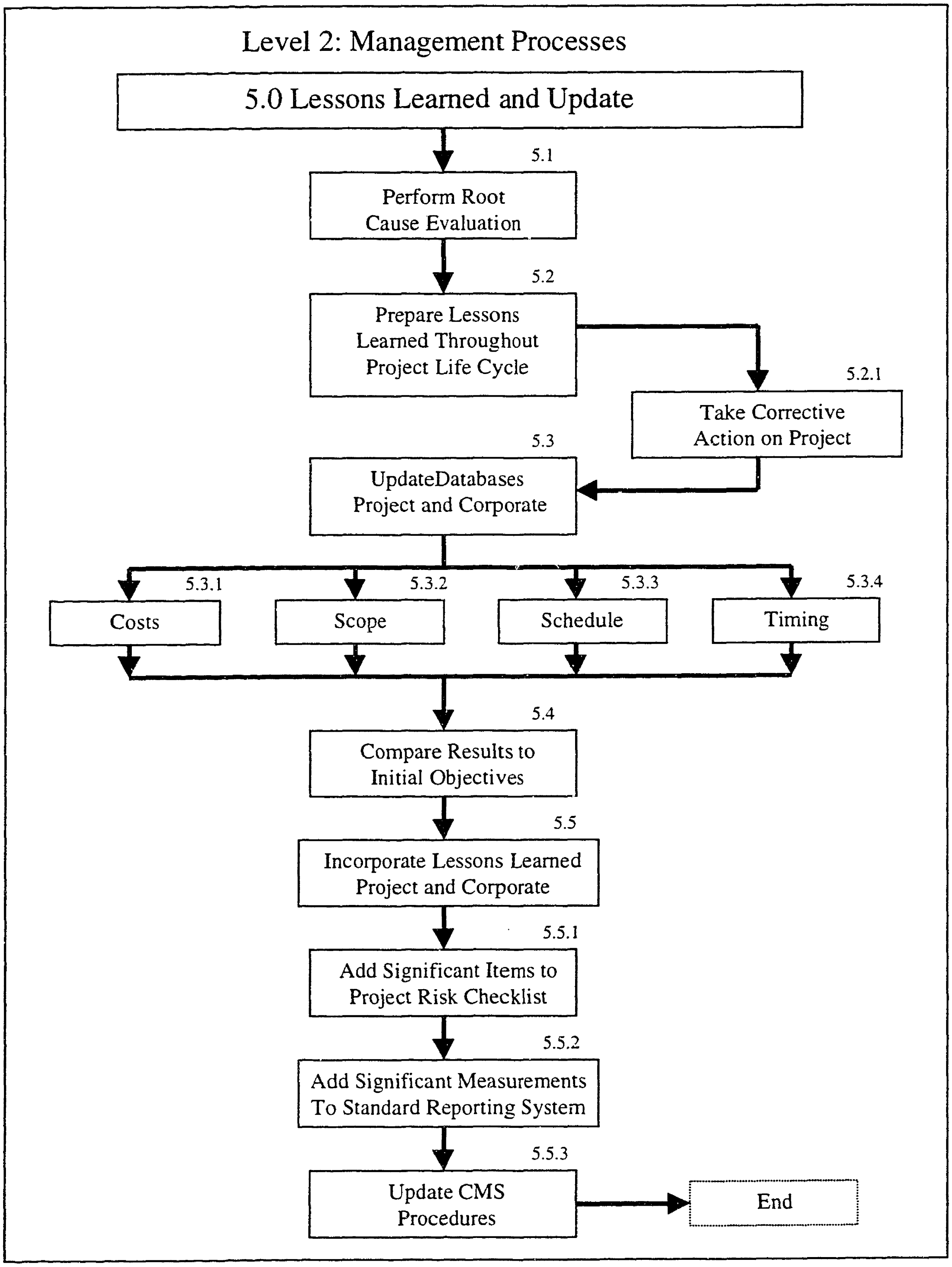



Level 2: Management Processes
1.0 Promote a Balanced Change Culture
1.1
Establish/Communicate Project Goals and Objectives
1.2
Establish/Communicate Baseline Scope, Cost, and Schedule
1.3
Establish/Communicate Roles & Responsibilities
1.3.1
Change Champion to Justify Change
1.3.2
Guidelines for Review & Approval of Changes
1.3.3
Approval Authority for Design Development/Change
1.4
Establish/Communicate Project Philosophy
1.4.1
Establish Contract Strategy
1.4.1.1
Establish Risk Allocation
1.4.2
Encourage Beneficial Change
1.4.3
Discourage Detrimental Change
1.4.4
Establish Criteria for Required versus Elective Change
1.4.5
Process Change Quickly
1.5
Adapt Existing Change Control for Existing Project
1.6
Identify Areas Where Change is Likely
Go to 2.0


Level 2: Management Processes
2.0 Recognize Change
2.1
From 4.4.1
Identify Potential Change
2.1.1
Describe Change
2.1.2
Basis for Change
2.1.3
Categorize Change
2.1.3.1
Required?
2.1.3.2
Elective?
2.2
Assess Potential Impacts
2.2.1
Cost Effects
2.2.2
Schedule Effects
2.2.3
Organizational Effects
2.2.4
Secondary Effects
2.3
Post Potential Change to Log
Go to 3.0


Level 2: Management Processes
3.0 Evaluate Change
3.1
Timeliness of Decision
3.1.1
Immediate or High Priority?
Y
3.1.2
Determine Funding Source for Interim Approval
Go to 4.1
N
3.2
From 4.1.1.1
Collect Data
3.2.1
Analysis of Cost, Schedule, Quality, etc.
3.3
Identify Impacts
3.3.1
Primary
3.3.2
Secondary
3.3.3
Route to Organizations
3.4
Determining Final Funding Source?
3.5
Immediate or High Priority?
N
Y
3.5.1
Change Category?
Elective
Required
Stop Project
Stop/Deny Change
3.6
Authorize Change?
N
Y
Go to 4.0


Level 2: Management Processes
4.0 Implement Change
4.1
Implement Change
4.1.1
Interim Approval?
N
Y
From 3.1.1
4.1.1.1
Communicate Change Design
Go to 3.2
4.1.2
Stop
N
Final Approval?
Y
4.2
Communicate Final Change Decision
4.3
Document Authorization
4.3.1
Final Classification/ Categorization
4.4
Monitor Implementation
4.3.2
Update Agreement/ Contract and Baseline Document
4.4.1
Go to 2.1
N
Change Proceeding per Plan?
Y
Go to 5.0


Level 2: Management Processes
5.0 Lessons Learned and Update
5.1
Perform Root Cause Evaluation
5.2
Prepare Lessons Learned Throughout Project Life Cycle
5.2.1
Take Corrective Action on Project
5.3
UpdateDatabases Project and Corporate
5.3.1
Costs
5.3.2
Scope
5.3.3
Schedule
5.3.4
Timing
5.4
Compare Results to Initial Objectives
5.5
Incorporate Lessons Learned Project and Corporate
5.5.1
Add Significant Items to Project Risk Checklist
5.5.2
Add Significant Measurements To Standard Reporting System
5.5.3
Update CMS Procedures
End

Appendix C Risk Identification Checklist

Appendix C provides a risk identification checklist, modified from a risk checklist developed by CII ("Management…", 1989), to help an owner identify potential risks and areas of uncertainty.

Project Size
- Physical area – urban or rural
- Population – total and individual craft

Project Execution Strategy Employed

Contract Type
- Lump Sum, Unit Price, Guaranteed Maximum, Reimbursable

Contract Clauses
- Differing site conditions clauses
- Delay clauses - No damage for delay
- Consequential damages clauses
- Indemnity clauses
- Payment clauses

Area Factors
- Geography/geology/altitude
- Area economic conditions
- Government stability and sophistication
- Police, fire, and medical support
- Local population attitude and stability
- Transportation network
- Communications
- Other support infrastructure

Site Factors
- Topography and drainage
- Access and egress
- Congestion
- Adjacent operations
- Hazards – safety and health
- Location and adequacy of construction support facilities
- Availability of utilities
- Security

Weather
- Normal weather patterns
- Potential for extreme weather

Monetary
- Contract prices
- Escalation
- Exchange rates
- Area cost indices
- Cost overruns

Payment - Retention
Overhead costs
Contractual incentives and penalties
Regulatory penalties

Ability to Perform
- Familiarity with type of work
- Contractor familiarity with type of work
- Availability and qualifications of key personnel
- Knowledge of area
- Differing or unforeseen site conditions
- Quality of design
- Timeliness of design
- Complexity, constructibility of design
- New technology
- Scope changes
- Availability of and access to work areas

Time Factors
- Deadlines and milestones
- Scheduled work days
- Schedule overruns - potential for delays
- Potential for third party delays

Regulatory Factors
- Permits and Environmental Impact

Contractor/Subcontractor/Vendor Factors
- Technical qualifications
- Financial stability
- Timeliness/reliability
- Bondability

Contractor Performance Factors
- Availability of labor
- Labor skill level
- Availability of resources
- Work ethic/productivity
- Wage rates
- Substance abuse

Appendix D CA/T Project Timelines

Political Timeline for Massachusetts and CA/T Project

1952	DPW Commissioner William Callahan
1952	Turnpike Authority Established - William Callahan-Head
1959 to 1967	John Collins Mayor of Boston
1966	John Volpe Governor of Massachusetts
1968	Richard Nixon Elected President of the United States
1968	Nixon Appoints John Volpe U.S. Secretary of Transportation
1968 End of	Frank Sargent Governor of Massachusetts
1970 End of	Frank Sargent Governor of Massachusetts
1970 End of	Sargent Appoints Alan Altshuler Mass. 1st Secretary of Transportation
1974 End of	Michael Dukakis Governor of Massachusetts
1974 End of	Dukakis Appoints Fred Salvucci Mass. Secretary of Transportation
1978 End of	Edward King Governor of Massachusetts
1978 End of	King Appoints Barry Locke Mass. Secretary of Transportation
1981 May	Locke Arrested for Bribe - Replaced by James Carlin
1982 End of	Michael Dukakis Governor of Massachusetts
1982 End of	Dukakis Appoints Fred Salvucci Mass. Secretary of Transportation
1986 End of	Michael Dukakis Governor of Massachusetts
1986 End of	Dukakis Appoints Fred Salvucci Mass. Secretary of Transportation
1990 End of	William Weld Governor of Massachusetts
1990 End of	Salvucci Leaves Massachusetts Secretary of Transportation Office

Development Timeline CA/T Project

1934		Sumner Tunnel Completed
1950's		Elevated Artery Construction
1950's	Mid	City Recognized Elevated Artery's Blighting Influence
1957		DPW projects need for a THT
1959		Elevated Artery/Depressed Dewey Square Completed
1961		Callahan Tunnel Completed
1960's	Late	Brookline State Rep. Michael Dukakis opposes any THT proposal
1968		MTA Preliminary Feasibility Study: Third Crossing Boston Harbor
1968	Sept.	Sargent establishes taskforce to review highway plans for Eastern Massachusetts
1969	Jan.	Study revealed transportation is controlled more by politics than need
1970	Early	Boston Transportation Planning Review (BTPR) to study Inner Belt, Route 2 ext., Southeast Expressway, I-95, THT, and No-Build Alternatives
1970		Gov. Sargent supports 2-lane special purpose THT, linking the North and South railroad stations, and later the possible depression of the CA
1971		Bill Reynolds suggests depressing the Central Artery
1972		Sargent adopts pro-transit / no-build highway strategy
1972	Oct.	BTPR releases a study on the CA – 2 options: 1) Depressions and widening 2) Selective relocation and removal of ramps
1970's	Mid	Sargent supports special purpose tunnel and Central Artery depression
1973		State secures enactment of Federal legislation to allow the transfer of money from interstate highways in urban areas to mass transit
1973		U.S. Congress authorizes funds to build a special purpose THT
1974		Mass. Port Authority endorses the THT

1974		Micheal Dukakis elected Governor – no interest in tunnel, opposes highway construction inside Rte 128 except possible artery depression
1975		Boston Redevelopment Authority (BRA) conducts a feasibility study of depressing the CA
1975	Early	BRA issues final report for CA project – technically feasible and justifiable if Federal government funds it
1975	Early	FHWA rejected the state's request to include $326 million for the Artery depression in the ICE
1975	Late	New Extensive Artery Depression Plan 1) Central Section Depression 2) Dewey Square tunnel upgrade or new parallel tunnel 3) New Charles River crossing 4) Reconfiguration of Rte 93/Rte 1 interchange
1975	Late	Salvucci obtains congressional support of Thomas O'Neil Jr. for CA proj.
1976	Jan.	FHWA & Congress agree to allocate $360 million for CA in the ICE Project divided into 3 parts – FHWA supported northern & southern sec. Northern Sec. – I-93/Rte 1 work in Charlestown & Charles River Crossing Central Sec. – Depressing the existing elevated viaduct in Boston Southern Sec. – At Dewey Sq. new Fort Point Channel Tunnel and Potential THT
1976		Mass. DPW prepares Central Artery Corridor: north area planning study
1977	Early	Salvucci attempts to gain public support for depressing the CA
1977		FHWA & Congress agree to allocate $484 million for CA in the 1977 ICE
1977		FHWA accepts Draft EIS, U.S. Rte I-93, U.S. Rte 1, Central Artery
1978		Central Transportation Planning Staff (CTPS) prepares Central Artery/ I-93 corridor: central area planning study
1978		CTPS prepares Central Artery/I-93 corridor: south area planning study
1978	Mid	3 Section Artery Plan moves ahead Northern section gained FHWA approval, secured permits, and hired an engineering design consortium Central and Southern sections began design work by another consortium
1978		Gov. Ed King supports a general purpose THT and the Leverett Connector and rejects plans for depressing the CA
1979		FHWA & Congress agree to allocate $456 million for the CA in the 1979 ICE
1979	April	State initiates study to re-examine THT & its financing
1979	Mid	King Administration stops planning studies for the Central and Southern sections
1979	Fall	Locke convenes a task force to guide the development of the tunnel proj.
1979	End	State halts planning for the Northern section for at least 2 years to re-examine the Leverett Connector Option
1980	Nov.	CTPS Draft Artery/THT Corridor Planning Study – Many Options/No Recommendations
1981		FHWA & Congress agree to allocate $544 million for the Artery and $404 million for a 2-lane tunnel in the 1981 ICE
1981	Early	Revised Corridor Planning Study 4 Options 1) No-Build 2 & 3) General Purpose Tunnel 4) Combination tunnel-depressed artery
1981	July	FHWA rejects state's request to fund a draft EIS for the THT
1981	Late	FHWA agrees to fund EIS for the THT and the Turnpike Authority is to manage the EIS process

1982	Jan.	DPW files ENF for the THT starting the environmental review process
1982	June	FHWA announces it would not fund the depression of elevated ramps in City Square – Northern Section
1982	Late	A provision of the 1982 Surface Transportation Act reinstates Federal funding for the Northern Section
1982	Dec.	State issues DEIS for the THT
1983		FHWA & Congress agree to allocate $170 million for the Artery and $339 million for the tunnel in the 1983 ICE
1983	Mar.	FHWA allows the CA depression to be added to the THT EIS
1983	April	Salvucci announces the state was moving ahead with studies to widen and depress the artery, build a seaport access road, and build a tunnel from South Boston piers to Logan Airport
1983	Spring	Salvucci creates team to organize public support for the CA project
1983	June	DPW issues Supplemental Draft EIS for Third Harbor Tunnel, Interstate 90/Central Artery, Interstate 93
1983	July	Salvucci publicly supports THT approval
1983	Mid	State officials estimate the combined CA/T project would cost $2.2 Billion
1983	Sept.	State estimates the Central Artery depression will cost $1.3 billion
1983	Sept.	Dukakis publicly supports THT approval and the CA/T project
1983	Sept.	DPW issues the Final EIS portion for the CA/T Project
1983	Fall	FHWA rejects Final EIS for the Artery Depression
1983	Fall	FHWA opposes Federal funding of the CA/T project
1983		Design Changes 1) Expansion of Artery from 6 to 8 lanes 2) Removal of the rail connection between North & South Station 3) From partially covered self-ventilating to fully depressed mechanical-ventilated facility 4) Gillette relocation of the Fort Point Channel Tunnel
1983	Late	Regional support for the CA/T project
1983	Late	The need and the project were sufficiently identified
1983 – 1985		Initial environmental review of CA/T Project
1983 – 1987		Political maneuvering to obtain FHWA and Congressional approval
1985		FHWA & Congress agree to allocate $2.5 billion for the CA/T project in the 1985 ICE
1985	July	State estimates CA/T Project cost at $2.56 billion
1985	Aug.	DPW publishes Final EIS, Third Harbor Tunnel, Interstate 90/Central Artery, Interstate 93
1986	Jan.	Mass. EOEA and FHWA approve FEIS for CA/T Project
1987	April	Congress overrides President Reagan's Veto to pass legislation that includes Federal funding of the CA/T project
1987		FHWA & Congress agree to allocate $3.3 billion for the CA/T project in the 1987 ICE
1988		Mass. DPW Central Artery THT: section design, consultant briefing
1988	Mid	State supports Scheme Z for Charles River Crossing
1988	Sept.	Boston Society of Architects issues a Plan for the Central Artery – Central Artery Task Force
1989	Mid	State estimates CA/T Project cost at $4.4 billion
1989	Aug.	Public opposition to Scheme Z
1990	May	DPW issues Draft Supplemental EIS Central Artery (I-93)/THT (I-90) Project
1990	Nov.	DPW issues Final Supplemental EIS Central Artery (I-93)/THT (I-90) Project
1991	Jan.	DPW issues Resolution of Comments to Final Supplemental EIS Central Artery

		(I-93)/THT (I-90) Project
1991	Jan.	Mass. EOEA approves the FSEIS for the CA/T Project
1991	May	FHWA approves FSEIS and issues ROD for the CA/T Project
1993	July	DPW issues Draft EIS, Charles River Crossing
1993	Nov.	Revised design for Charles River Crossing completed
1993	Dec.	DPW issues Final EIS, Charles River Crossing
1994	June	FHWA issues Record of Decision: Central Artery (I-93)/Tunnel (I-90), Charles River Crossing
1995		State estimates CA/T project cost at $7.7 billion
1995		CA/T project completion date forecasted at 2004

Appendix E Tren Urbano Timeline

1964		San Juan Urban Transportation Planning
1967	Nov.	Wilbur Smith & Associates, Inc. Transportation Plan for the San Juan Metropolitan Area – Recommended: 1) Expanded Highway Links 2) High Capacity Public Transport Link from Old San Juan to Rio Piedras
1967		Regional Rail Transit System Proposed
1979		Feasibility Analysis of Transit Alternatives
1980		Rail Concept added to the SJMA Regional Transportation Plan
1989		DTPW proposes Tren Urbano
1989		DTPW hires Parsons DeLeuw, Inc. to develop conceptual design
1991-1992		Tren Urbano emerges in the Regional Transportation Plan Intermodal elements include expanded bus and publico service
1992		Barton Aschman Associates, Inc. San Juan Regional Transportation Study Recommends: High Capacity Public Transit System
1992	Mar.	*Capital Investment Analysis: Fixed Guideway Program for Greater San* **Juan**
1992	Dec.	*Financing Tren Urbano – An Extended Range Investment Outlook for Puerto Rico's Transportation Infrastructure*
1992	Dec.	*A Cost/Benefit Analysis of Tren Urbano, Basic Elements*
1993	Jan.	Governor Pedro Rossello through the DTPW/HTA reviews and revises rail concept to initiate Tren Urbano
1993	Feb.	DTPW submits Request for Participation in FTA Turnkey Demonstration Program
1993	Feb.	FTA selected Tren Urbano as one of the Turnkey Demonstration Projects
1993	Nov.	Barton Aschman Associates, Inc. publishes *San Juan Regional Transportation Plan*
1993		Tren Urbano review concluded the project was one of the most cost effective in the country
1993	Sept.	DTPW/HTA publishes Request for Letters of Interest for GMC services
1993	Sept.	10 firms submit Letters of Interest
1993	Dec.	DTPW/HTA issues RFPs to six teams
1994	Jan.	Tren Urbano requests and receives Federal funding assistance
1994	Jan.	4 firms submit proposals
1994	Feb.	HTA selects 2 finalists for GMC services
1994	March	Finalists respond to revised scope of work
1994	April	HTA selects GMAEC as the GMC

1994		FTA rated Tren Urbano one of the most cost-effective projects in the U.S.
1994		Alignment developed to 10% preliminary engineering
1994		FTA grants HTA $10 million for planning and preliminary engineering costs
1994		HTA develops 1994-1998 Capital Improvements Program, assigns $160 million for Tren Urbano from tolls, gasoline taxes, and vehicle registration fees
1994	Aug.	HTA signs contract with GMAEC
1994	Dec.	GMAEC issues *Procurement Strategy Paper*
1995	March	HTA/GMAEC finalizes hybrid Turnkey approach
1995	March	HTA/GMAEC issues DEIS
1995	Spring	HTA begins ST^3 Turnkey contractor procurement
1995	July	HTA/GMAEC issues ST^3 Request for Qualifications
1995	Aug.	HTA/GMAEC evaluates potential firms' qualifications
1995	Aug.	HTA/GMAEC issues ST^3 Request for Proposals
1995	Nov.	HTA/GMAEC receives firms' proposals
1995	Nov.	GMAEC completes 30% preliminary engineering
1995	Nov.	HTA/GMAEC issues FEIS
1996	Jan.	HTA/GMAEC reviews potential proposals
1996	Feb.	FTA approves FEIS and issues ROD
1996	March	DTPW signs Full Funding Grant Agreement with FTA
1996	March	HTA/GMAEC receives firms' Final Proposals
1996	July	HTA awards Turnkey contract to Siemens' Consortium
1996	July	Final Design and Construction Phase begins
1997	June	All construction contracts awarded
1997	Dec.	Final design completed
2001	Oct.	Expected start of operations

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