SAUDCONSULT

SAUDI CONSULTING SERVICES

سعودكونسلت
SAUDCONSULT

Construction Project Management (CPM)

Procedures Manual

Volume 1 of 3

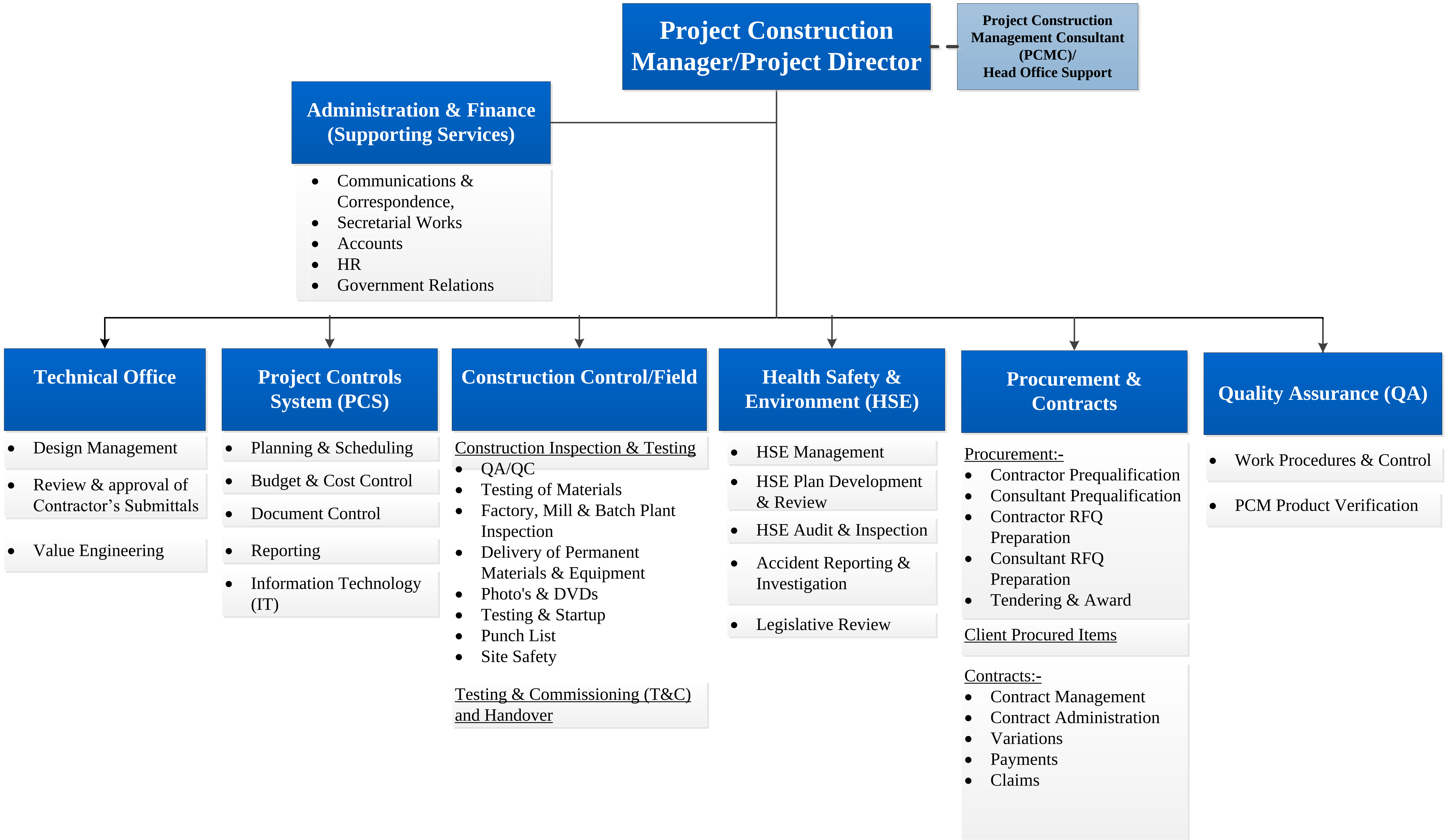
The Manual

Version 00

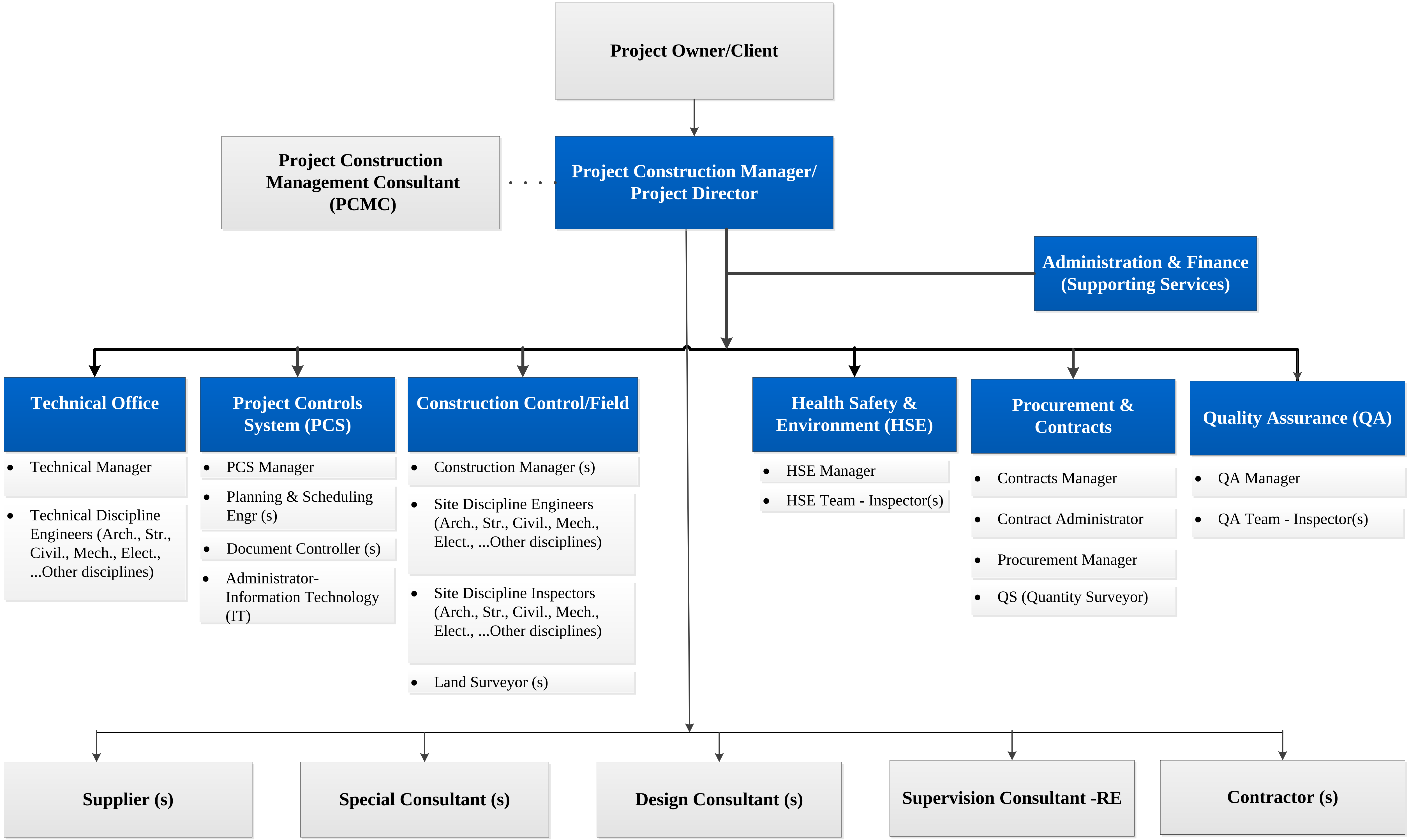
**PROJECT MANAGEMENT OFFICE-
CONSTRUCTION PROJECT MANAGEMENT
(PMO-CPM)**

Version Date: 2015

Typical Organization Chart - Functional
for
Construction Project Management (CPM) Projects



Typical Organization Chart - Operational
for
Construction Project Management (CPM) Projects



CM Manual Navigating Procedure in the electronic copy:

1. Open the file. Cover Page (page 1) is the default page to display on your screen.
2. Click or scroll down to next page (Page 2) Table of Content.
3. All text in the Table of Content in Light Blue Color have dynamic link to:-

- The page of the Chapter or subject within the same document.
- The file of the subject outside the document (Separate files)

Using the hand tool *(the curser will change shape to Hand when pointing on the underlined text in Light Blue Color*), click on the subject that you are concerned and it will jump to the page of the subject within the manual or to the file of the subject in another file.

4. If you are at the end of any Chapter page of the Manual and you wish to go back to **table of contents** of this document, click on the Back to the Table of Contents Footer and it will lead you back to table of contents.
   Every footer note Back to the Table of Contents marks the end of each Chapter & has a dynamic link going back to Table of Content.

   Other means of navigating within the manual is thru the bookmark. Click on each bookmark and it will jump to the page of the subject. Bookmark tab located at the left hand side of your screen to display the contents.

5. Texts in blue colors in the bookmarks are the cover page of each Chapter showing its content. Titles in the cover page also have dynamic links to the page of the subject.

INTRODUCTION TO MANUAL

The Procedures Manual describes the project construction management team members and their responsibilities in construction projects. This manual will be managed by the ENTERPRISE PROJECT MANAGEMENT OFFICE (EPMO). The duties, work responsibilities, and procedures are laid out in detail. This Manual concentrates on the **"WHAT, WHY, WHEN, WHO, AND HOW"** processes used in Construction Management (CM).

For purposes of this manual, the person in charge of the project site is called the Project Construction Manager (PCM) ; the Client or his representative is called the Project Owner.

This manual (VOLUME 1 OF 3) is comprised of twelve (12) chapters:

- CHAPTER 1 - The Owners' Perspective
- CHAPTER 2 – Organizing for Project Construction Management
- CHAPTER 3 – The Design and Construction Process
- CHAPTER 4 – Labor, Material and Equipment
- CHAPTER 5 – Cost Estimation
- CHAPTER 6- Economic Evaluation of Facility Investments
- CHAPTER 7- Construction Pricing and Contracting
- CHAPTER 8- Construction Planning
- CHAPTER 9-Fundamental Scheduling Procedures
- CHAPTER 10- Cost Control, Monitoring and Accounting
- CHAPTER 11-Quality Control and Safety During Construction
- CHAPTER 12-Organization and Use of Construction Project Information
- ATTACHMENT :-
  VOLUME 2 OF 3 Project Construction Management (PCM) Procedures Manual
  VOLUME 3 OF 3 Construction Management Staff Standard Job Description

It is understood that no single project will use every procedure detailed in this manual. The intent was to create a comprehensive resource that Construction Management team can use to ensure effective and consistent Project Construction Management. Think of it as a master mechanic with a full toolbox; he will only use the specific tools necessary for each job and some jobs will require more tools.

As you read this manual on-line, you will find the hyperlinks in each section for ease in navigating through the manual.

TABLE OF CONTENTS

What is Construction Management?

Introduction,

What is construction management?

Construction management or **Project Construction Management** is the overall planning, coordination, and control of a project from inception to completion. CM is aimed at meeting a client's requirement in order to produce a functionally and financially viable project. CM is Project Construction Management that applies to the construction sector.

It is the process of overseeing projects for residential, commercial and industrial construction. Construction managers direct and coordinate projects to maximize efficiency in the building process. Depending on their level of experience, they may supervise an entire project, or a portion of one.

Who are the Construction managers?

> “Construction managers supervise the construction process from initial design to the final walk-through”

Construction managers schedule and coordinate construction processes including licensing, material supply chains, safety code compliance and both budget and timeline projections. *Typically they do not perform actual construction tasks*. Depending on the company, this position may also be referred to as a project manager, construction superintendent, project supervisor or general contractor.

These managers supervise the construction process from initial design to the final walk-through, making sure each stage gets completed on time and on budget. They often coordinate with many different stakeholders: owners, engineers, architects and craftspeople. Construction managers also find, contract with and supervise tradespeople for specific tasks such as painting, plumbing and carpeting. In a very large project there may also be multiple Project construction managers who work together towards the final goal. For example, in the construction of a large industrial complex there may be a site manager, landscaping manager, building systems manager and structural manager.

Other qualifications for a career in construction management include problem-solving skills, flexibility and the ability to multitask under pressure. As the construction industry becomes more advanced, experience in the field is no longer the only requirement for managers. A bachelor's degree in construction science, construction management or civil engineering in addition to work experience is becoming the norm for construction management positions.

Overview

- Functions
- Terminology
- Business model
  - Design, bid, build contracts
  - Design and build contracts
  - Planning and scheduling
  - Architecture–Engineer
  - Agency CM
  - CM at-risk

Functions

The functions of Construction Management typically include the following:

1. Specifying project objectives and plans including delineation of scope, budgeting, scheduling, setting performance requirements, and selecting project participants.
2. Maximize the resource efficiency through procurement of labor, materials and equipment.
3. Implementing various operations through proper coordination and control of planning, design, estimating, contracting and construction in the entire process.
4. Developing effective communications and mechanisms for resolving conflicts.

Most common responsibilities of a Construction Manager fall into the following 7 categories:

1- Project Construction Management Planning,
2- Cost Management,
3- Time Management,
4- Quality Management,
5- Contract Administration,
6- Safety Management,
7- And CM Professional Practice. CM professional practice includes specific activities, such as defining the responsibilities and management structure of the Project Construction Management team, organizing and leading by implementing project controls, defining roles and responsibilities, developing communication protocols, and

identifying elements of project design and construction likely to give rise to disputes and claims.

➢ Terminology

The following abbreviations are commonly used in Construction Project Management:

Programme management (ProgM):

- UK:
  1- Programme management is concerned with managing time in a project and is thereby part of the PCM function.
  2- Management of a client's portfolio (client's programme in this sense is equivalent to a client's brief).
- USA: management of a client's portfolio.

Project control (PC):

The gathering of data on the progress of a project: - producing progress reports, monitoring time, cost, and quality. The PC function can be characterized as passive, whereas construction Project Construction Management (PCM) is active.

Project leader (PL):

The PL is responsible for achieving the project's objectives. He is the manager "in line".

Project director (PD):

The PD is the leader of a big project that can be broken down in sub-projects (e.g. Channel tunnel). A PD can also be the head of a PM organization.

Owner representative (OR):

The OR is the representative of the owner. This function can be provided either internally or externally.

Document Control (DC):

DC is a key function of a Project Manager.

Finance build operate transfer (FBOT)

Build operate transfer (BOT)

Design build operate transfer (DBOT)

Build own operate (BOO)

Engineering procurement construction (EPC)

Private finance initiative (PFI)

General contract (GC)

Joint Venture (JV)

Guaranteed maximum price (GMP)

Multiple prime contracts (MPC)

- UK: one contractor takes responsibility for the development (package deal).
- USA: a client may have 5 or 6 prime contractors.

➢ Business model

Typically the construction industry includes three parties:

- An owner,
- A designer (architect or engineer), and
- A builder (usually called the general contractor).

Traditionally, there are two contracts between these parties as they work together to plan, design, and construct the project. The first contract is the owner-designer contract, which involves planning, design, and construction administration. The second contract is the owner-contractor contract, which involves construction. An indirect, third-party relationship exists between the designer and the contractor due to these two contracts.

An owner may also contract with a construction Project Construction Management Company as an advisor, creating a third contract relationship in the construction project. The construction manager's role is to provide construction advice to the designer, on the owner's behalf, design advice to the constructor, again on the owner's behalf, and other advice as necessary.

- **Design, bid, build contracts**

  The phrase design, bid, build describes the prevailing model of construction management in which the general contractor is engaged through a tender process after the designs have been completed by the architect or engineer.

- **Design and build contracts**

  Many owners – particularly government agencies – let out contracts which are known as **design-build contracts.** In this type of contract, the construction team (known as the design-builder) is responsible for taking the owner's concept and completing a detailed design before, following the owner's approval of the design, proceeding with construction. Virtual Design and Construction technology may be used by contractors to maintain a tight construction time.

- **Planning and scheduling**

  Project Construction Management methodology:

  - Work breakdown structure
  - Project network of activities
    - Critical path method (CPM)
    - Resource management
    - Resource leveling

- **Architecture–Engineer**

  - Work inspection
  - Change orders
  - Review payments
  - Materials and samples
  - Shop drawings
  - 3d image

- **Agency CM**

  Construction Cost Management is a fee-based service in which the Construction Manager (C.M) is responsible exclusively to the owner and acts in the owner's interests at every stage of the project. The construction manager offers advice, uncolored by any conflicting interest, on matters such as:

- Optimum use of available funds;
- Control of the scope of the work;
- Project scheduling;
- Optimum use of design and construction firms' skills and talents;
- Avoidance of delays, changes and disputes;
- Enhancing project design and construction quality;
- Optimum flexibility in contracting and procurement.
- Cash flow Management.

- **CM at-risk**

CM at-risk is a delivery method which entails a commitment by the construction manager to deliver the project within a Guaranteed Maximum Price (GMP), in most cases. The construction manager acts as consultant to the owner in the development and design phases, (often referred to as "Preconstruction Services"), but as the equivalent of a general contractor during the construction phase. When a construction manager is bound to a GMP, the most fundamental character of the relationship is changed. In addition to acting in the owner's interest, the construction manager must manage and control construction costs to not exceed the GMP, which would be a financial hit to the CM Company.

Back to the Table of Contents

Fundamental Concepts for Owners, Engineers, Architects and Builders.

1. The Owners' Perspective
2. Organizing For Project Construction Management
3. The Design And Construction Process
4. Labor Material, And Equipment Utilization
5. Cost Estimation
6. Economic Evaluation of Facility Investments
7. Construction Pricing and Contracting
8. Construction Planning
9. Fundamental Scheduling Procedures
10. Cost Control Monitoring, and Accounting
11. Quality Control and Safety During Construction
12. Organization and Use of Project Information

Preface

The following develops a specific viewpoint in discussing the participants, the processes and the techniques of Project Construction Management for construction. This viewpoint is that of owners who desire completion of projects in a timely, cost effective fashion. Some profound implications for the objectives and methods of Project Construction Management result from this perspective:

- The "life cycle" of costs and benefits from initial planning through operation and disposal of a facility are relevant to decision making. An owner is concerned with a project from the cradle to the grave. Construction costs represent only one portion of the overall life cycle costs.
- Optimizing performance at one stage of the process may not be beneficial overall if additional costs or delays occur elsewhere. For example, saving money on the design process will be a false economy if the result is excess construction costs.
- Fragmentation of Project Construction Management among different specialists may be necessary, but good communication and coordination among the participants is essential to accomplish the overall goals of the project. New information technologies can be instrumental in this process, especially the Internet and specialized Extranets.
- Productivity improvements are always of importance and value. As a result, introducing new materials and automated construction processes is always desirable as long as they are less expensive and are consistent with desired performance.
- Quality of work and performance are critically important to the success of a project since it is the owner who will have to live with the results.

Back to the Table of Contents

CHAPTER 1

THE OWNERS' PERSPECTIVE

1.1 Introduction

Each of the numerous participants in the process of planning, designing, financing, constructing and operating physical facilities has a different perspective on Project Construction Management for construction. Specialized knowledge can be very beneficial, particularly in large and complicated projects, since experts in various specialties can provide valuable services. However, it is advantageous to understand how the different parts of the process fit together. Waste, excessive cost and delays can result from poor coordination and communication among specialists. It is particularly in the interest of owners to insure that such problems do not occur. And it behooves all participants in the process to heed the interests of owners because, in the end, it is the owners who provide the resources and call the shots.

By adopting the viewpoint of the owners, we can focus our attention on the complete process of *Project Construction Management* for constructed facilities rather than the historical roles of various specialists such as planners, architects, engineering designers, constructors, fabricators, material suppliers, financial analysts and others. To be sure, each specialty has made important advances in developing new techniques and tools for efficient implementation of construction projects. However, it is through the understanding of the entire process of Project Construction Management that these specialists can respond more effectively to the owner's desires for their services, in marketing their specialties, and in improving the productivity and quality of their work.

The introduction of innovative and more effective Project Construction Management for construction is not an academic exercise.

Improvement of Project Construction Management not only can aid the construction industry, but may also be the engine for the national and world economy. However, if we are to make meaningful improvements, we must first understand the construction industry, its operating environment and the institutional constraints affecting its activities as well as the nature of Project Construction Management.

1.2 The Project Life Cycle

The acquisition of a constructed facility usually represents a major capital investment, whether its owner happens to be an individual, a private corporation or a public agency. Since the commitment of resources for such an investment is motivated by market demands or perceived needs, the facility is expected to satisfy certain objectives within the constraints specified by the owner and relevant regulations. With the exception of the speculative housing market, where the residential units may be sold as built by the real estate developer, most constructed facilities are custom made in consultation with the owners. A real estate developer may be regarded as the sponsor of building projects, as much as a government agency may be the sponsor of a public project and turns it over to another government unit upon its completion. From the viewpoint of Project Construction Management, the terms "owner" and "sponsor" are synonymous because both have the ultimate authority to make all important decisions. Since an owner is essentially acquiring a facility on a promise in some form of agreement, it will be wise for any owner to have a clear understanding of the acquisition process in order to maintain firm control of the quality, timeliness and cost of the completed facility.

From the perspective of an owner, the project life cycle for a constructed facility may be illustrated schematically in Figure 1-1. Essentially, a project is conceived to meet market demands or needs in a timely fashion. Various possibilities may be considered in the conceptual planning stage, and the technological and economic feasibility of each alternative will be assessed and compared in order to select the best possible project. The financing schemes for the proposed alternatives must also be examined, and the project will be programmed with respect to the timing for its completion and for available cash flows.

After the scope of the project is clearly defined,

- Detailed engineering design will provide the blueprint for construction, and
- The definitive cost estimate will serve as the baseline for cost control.
- In the procurement and construction stage, the delivery of materials and the erection of the project on site must be carefully planned and controlled.
- After the construction is completed, there is usually a brief period of start-up or shake-down of the constructed facility when it is first occupied.
- Finally, the management of the facility is turned over to the owner for full occupancy until the facility lives out its useful life and is designated for demolition or conversion.

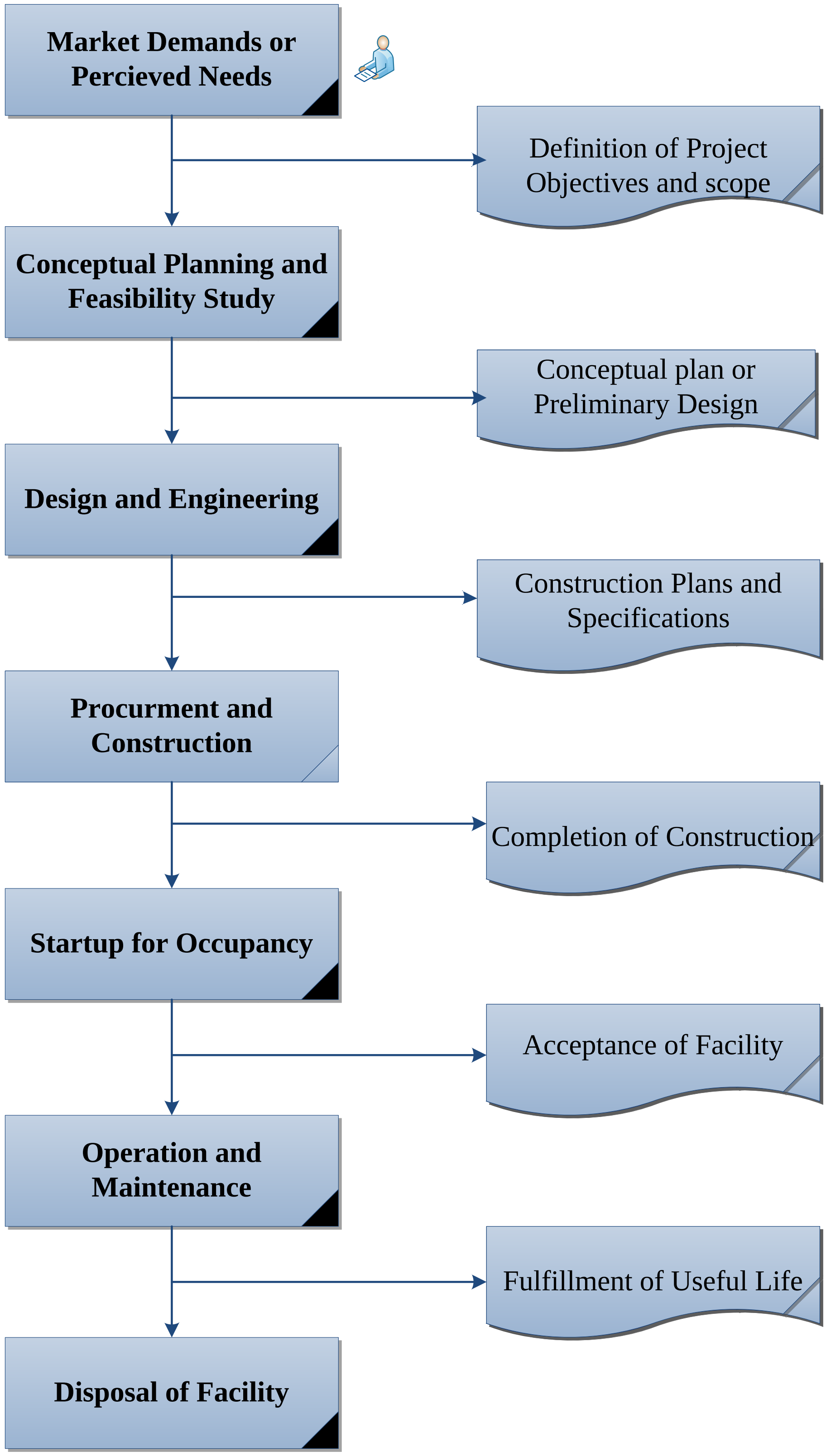


Figure 1-1: The Project Life Cycle of a Constructed Facility

Of course, the stages of development in Figure 1-1 may not be strictly sequential. Some of the stages require iteration, and others may be carried out in parallel or with overlapping time frames, depending on the nature, size and urgency of the project. Furthermore, an owner may have in-house capacities to handle the work in every stage of the entire process, or it may seek professional advice and services for the work in all stages. Understandably, most owners choose to handle some of the work in-house and to contract outside professional services for other components of the work as needed. By examining the project life cycle from an owner's perspective we can focus on the proper roles of various activities and participants in all stages regardless of the contractual arrangements for different types of work.

The project life cycle may be viewed as a process through which a project is implemented from cradle to grave. This process is often very complex; however, it can be decomposed into several stages as indicated by the general outline in Figure 1-1. The solutions at various stages are then integrated to obtain the final outcome. Although each stage requires different expertise, it usually includes both technical and managerial activities in the *knowledge domain* of the specialist. The owner may choose to decompose the entire process into more or less stages based on the size and nature of the project, and thus obtain the most efficient result in implementation. Very often, the owner retains direct control of work in the planning and programming stages, but increasingly outside planners and financial experts are used as consultants because of the complexities of projects. Since operation and maintenance of a facility will go on long after the completion and acceptance of a project, it is usually treated as a separate problem except in the consideration of the life cycle cost of a facility. All stages from conceptual planning and feasibility studies to the acceptance of a facility for occupancy may be broadly lumped together and referred to as the Design/Construct process, while the procurement and construction alone are traditionally regarded as the province of the construction industry.

Owners must recognize that there is no single best approach in organizing Project Construction Management throughout a project's life cycle. All organizational approaches have advantages and disadvantages, depending on the knowledge of the owner in construction management as well as the type, size and location of the project. It is important for the owner to be aware of the approach which is most appropriate and beneficial for a particular project. In making choices, owners should be concerned with the life cycle costs of constructed facilities rather than simply the initial construction costs. Saving small amounts of money during construction may not be worthwhile if the result is much larger operating costs or not meeting the functional requirements for the new facility satisfactorily. Thus, owners must be very concerned with the quality of the finished product as well as the cost of construction itself. Since facility operation and maintenance is a part of the project life cycle, the owners' expectation to satisfy investment objectives during the project life cycle will require consideration of the cost of operation and maintenance. Therefore, the facility's operating management should also be considered as early as possible, just as the construction process should be kept in mind at the early stages of planning and programming.

1.3 Major Types of Construction

The broad spectrum of constructed facilities may be classified into four major categories, each with its own characteristics.

Residential Housing Construction

Residential housing construction includes single-family houses, multi-family dwellings, and high-rise apartments. During the development and construction of such projects, the developers or sponsors who are familiar with the construction industry usually serve as surrogate owners and take charge, making necessary contractual agreements for design and construction, and arranging the financing and sale of the completed structures. Residential housing designs are usually performed by architects and engineers, and the construction executed by builders who hire subcontractors for the structural, mechanical, electrical and other specialty work. An exception to this pattern is for single-family houses which may be designed by the builders as well.

The residential housing market is heavily affected by general economic conditions, tax laws, and the monetary and fiscal policies of the government. Often, a slight increase in total demand will cause a substantial investment in construction, since many housing projects can be started at different locations by different individuals and developers at the same time. Because of the relative ease of entry, at least at the lower end of the market, many new builders are attracted to the residential housing construction. Hence, this market is highly competitive, with potentially high risks as well as high rewards.

Figure 1-2: Residential Housing Construction

Institutional and Commercial Building Construction

Institutional and commercial building construction encompasses a great variety of project types and sizes, such as schools and universities, medical clinics and hospitals, recreational facilities and sports stadiums, retail chain stores and large shopping centers, warehouses and light manufacturing plants, and skyscrapers for offices and hotels. The owners of such buildings may or may not be familiar with construction industry practices, but they usually are able to select competent professional consultants and arrange the financing of the constructed facilities themselves. Specialty architects and engineers are often engaged for designing a specific type of building, while the builders or general contractors undertaking such projects may also be specialized in only that type of building.

Figure 1-3: Construction of Commercial Buildings in Hong Kong

Specialized Industrial Construction

Specialized industrial construction usually involves very large scale projects with a high degree of technological complexity, such as oil refineries, cement Factory, steel mills, chemical processing plants and coal-fired or nuclear power plants. The owners usually are deeply involved in the development of a project, and prefer to work with designers-builders such that the total time for the completion of the project can be shortened. They also want to pick a team of designers and builders with whom the owner has developed good working relations over the years.

Figure 1-4: Construction of a Cement factory

Infrastructure and Heavy Construction

Infrastructure and heavy construction includes projects such as highways, mass transit systems, tunnels, bridges, pipelines, drainage systems and sewage treatment plants. Most of these projects are publicly owned and therefore financed either through bonds or taxes. This category of construction is characterized by a high degree of mechanization, which has gradually replaced some labor intensive operations.

The engineers and builders engaged in infrastructure construction are usually highly specialized since each segment of the market requires different types of skills.

Figure 1-5: Construction of highways

1.4 Selection of Professional Services

When an owner decides to seek professional services for the design and construction of a facility, he is confronted with a broad variety of choices. The type of services selected depends to a large degree on the type of construction and the experience of the owner in dealing with various professionals in the previous projects undertaken by the firm. Generally, several common types of professional services may be engaged either separately or in some combination by the owners.

Financial Planning Consultants

At the early stage of strategic planning for a capital project, an owner often seeks the services of financial planning consultants such as certified public accounting (CPA) firms to evaluate the economic and financial feasibility of the constructed facility, particularly with respect to various provisions of government and local tax laws which may affect the investment decision. Investment banks may also be consulted on various options for financing the facility in order to analyze their long-term effects on the financial health of the owner organization.

Architectural and Engineering Firms

Traditionally, the owner engages an architectural and engineering (A/E) firm or consortium as technical consultant in developing a preliminary design. After the engineering design and financing arrangements for the project are completed, the owner will enter into a construction contract with a general contractor either through competitive bidding or negotiation. The general contractor will act as a constructor and/or a coordinator of a large number of subcontractors who perform various specialties for the completion of the project. The A/E firm completes the design and may also provide on-site quality inspection during construction. Thus, the A/E firm acts as the prime professional on behalf of the owner and supervises the construction to insure satisfactory results. This practice is most common in building construction.

In the past two decades, this traditional approach has become less popular for a number of reasons, particularly for large scale projects. The A/E firms, which are engaged by the owner as the prime professionals for design and inspection, have become more isolated from the construction process. This has occurred because of pressures to reduce fees to A/E firms, the threat of litigation regarding construction defects, and lack of knowledge of new construction techniques on the part of architect and engineering professionals. Instead of preparing a construction plan along with the design, many A/E firms are no longer responsible for the details of construction nor do they provide periodic field inspection in many cases. As a matter of fact, such firms will place a prominent disclaimer of responsibilities on any shop drawings they may check, and they will often regard their representatives in the field as observers instead of inspectors. Thus, the A/E firm and the general contractor on a project often become antagonists who are looking after their own competing interests. As a result, even the constructability of some engineering designs may become an issue of contention. To carry this protective attitude to the extreme, the specifications prepared by an A/E firm for the general contractor often protects the interest of the A/E firm at the expense of the interests of the owner and the contractor.

In order to reduce the cost of construction, some owners introduce value engineering, which seeks to reduce the cost of construction by soliciting a second design that might cost less than the original design produced by the A/E firm. In practice, the second design is submitted by the contractor after receiving a construction contract at a stipulated sum, and the saving in cost resulting from the redesign is shared by the contractor and the owner. The contractor is able to absorb the cost of redesign from the profit in construction or to reduce the construction cost as a result of the re-design. If the owner had been willing to pay a higher fee to the A/E firm or to better direct the design process, the A/E firm might have produced an improved design which would cost less in the first place. Regardless of the merit of value engineering, this practice has undermined the role of the A/E firm as the prime professional acting on behalf of the owner to supervise the contractor.

Design/Construct Firms

A common trend in industrial construction, particularly for large projects, is to engage the services of a design/construct firm. By integrating design and construction management in a single organization, many of the conflicts between designers and constructors might be avoided. In particular, designs will be closely scrutinized for their constructability. However, an owner engaging a design/construct firm must insure that the quality of the constructed facility is not sacrificed by the desire to reduce the time or the cost for completing the project. Also, it is difficult to make use of competitive bidding in this type of design/construct process. As a result, owners must be relatively sophisticated in negotiating realistic and cost-effective construction contracts.

One of the most obvious advantages of the integrated design/construct process is the use of phased construction for a large project. In this process, the project is divided up into several phases, each of which can be designed and constructed in a staggered manner. After the completion of the design of the first phase, construction can begin without waiting for the completion of the design of the second phase, etc. If proper coordination is exercised, the total project duration can be greatly reduced. Another advantage is to exploit the possibility of using the turnkey approach whereby an owner can delegate all responsibility to the design/construct firm which will deliver to the owner a completed facility that meets the performance specifications at the specified price.

Professional Construction Managers

A construction manager (CM) offers professional services from the inception to the completion of a construction project. These construction managers mostly come from the ranks of A/E firms or general contractors who may or may not retain dual roles in the service of the owners. In any case, the owner can rely on the service of a single prime professional to manage the entire process of a construction project. However, like the A/E firms of several decades ago, the construction managers are appreciated by some owners but not by others. Before long, some owners find that the construction managers too may try to protect their own interest instead of that of the owners when the stakes are high.

It should be obvious to all involved in the construction process that the party which is required to take higher risk demands larger rewards. If an owner wants to engage an A/E firm on the basis of low fees instead of established qualifications, it often gets what it deserves; or if the owner wants the general contractor to bear the cost of uncertainties in construction such as foundation conditions, the contract price will be higher even if competitive bidding is used in reaching a contractual agreement. Without mutual respect and trust, an owner cannot expect that construction managers can produce better results than other professionals. Hence, an owner must understand its own responsibility and the risk it wishes to assign to itself and to other participants in the process.

Operation and Maintenance Managers

Although many owners keep a permanent staff for the operation and maintenance of constructed facilities, others may prefer to contract such tasks to professional managers. Understandably, it is common to find in-house staff for operation and maintenance in specialized industrial plants and infrastructure facilities, and the use of outside managers under contracts for the operation and maintenance of rental properties such as apartments and office buildings. However, there are exceptions to these common practices. For example, maintenance of public roadways can be contracted to private firms. In any case, managers can provide a spectrum of operation and maintenance services for a specified time period in accordance to the terms of contractual agreements. Thus, the owners can be spared the provision of in-house expertise to operate and maintain the facilities.

Facilities Management

As a logical extension for obtaining the best services throughout the project life cycle of a constructed facility, some owners and developers are receptive to adding strategic planning at the beginning and facility maintenance as a follow-up to reduce space-related costs in their real estate holdings. Consequently, some architectural/engineering firms and construction management firms with computer-based expertise, together with interior design firms, are offering such front-end and follow-up services in addition to the more traditional services in design and construction.

Facilities management is the discipline of planning, designing, constructing and managing space -- in every type of structure from office buildings to process plants. It involves developing corporate facilities policy, long-range forecasts, real estate, space inventories, projects (through design, construction and renovation), building operation and maintenance plans and furniture and equipment inventories.

A common denominator of all firms entering into these new services is that they all have strong computer capabilities and heavy computer investments. In addition to the use of computers for aiding design and monitoring construction, the service includes the compilation of a computer record of building plans that can be turned over at the end of construction to the facilities management group of the owner. A computer data base of facilities information makes it possible for planners in the owner's organization to obtain overview information for long range space forecasts, while the line managers can use as-built information such as lease/tenant records, utility costs, etc. for day-to-day operations.

1.5 Construction Contractors

Builders who supervise the execution of construction projects are traditionally referred to as contractors, or more appropriately called constructors. The general contractor coordinates various tasks for a project while the specialty contractors such as mechanical or electrical contractors perform the work in their specialties. Material and equipment suppliers often act as installation contractors; they play a significant role in a construction project since the conditions of delivery of materials and equipment affect the quality, cost, and timely completion of the project. It is essential to understand the operation of these contractors in order to deal with them effectively.

General Contractors

The function of a general contractor is to coordinate all tasks in a construction project. Unless the owner performs this function or engages a professional construction manager to do so, a good general contractor who has worked with a team of superintendents, specialty contractors or subcontractors together for a number of projects in the past can be most effective in inspiring loyalty and cooperation. The general contractor is also knowledgeable about the labor force employed in construction.

Specialty Contractors

Specialty contractors include mechanical, electrical, foundation, excavation, and demolition contractors among others. They usually serve as subcontractors to the general contractor of a project. In some cases, legal statutes may require an owner to deal with various specialty contractors directly. In some projects, specialty contractors, such as mechanical and electrical contractors, are not subjected to the supervision of the general contractor of a construction project and must be given separate prime contracts on public works. With the exception of such special cases, an owner will hold the general contractor responsible for negotiating and fulfilling the contractual agreements with the subcontractors.

Material and Equipment Suppliers

Major material suppliers include specialty contractors in structural steel fabrication and erection, sheet metal, ready mixed concrete delivery, reinforcing steel bar detailers, roofing, glazing etc. Major equipment suppliers for industrial construction include manufacturers of generators, boilers and piping and other equipment. Many suppliers handle on-site installation to insure that the requirements and contractual specifications are met. As more and larger structural units are prefabricated off-site, the distribution between specialty contractors and material suppliers becomes even less obvious.

1.6 Financing of Constructed Facilities

A major construction project requires an enormous amount of capital that is often supplied by lenders who want to be assured that the project will offer a fair return on the investment. The direct costs associated with a major construction project may be broadly classified into two categories: (1) the construction expenses paid to the general contractor for erecting the facility on site and (2) the expenses for land acquisition, legal fees, architect/engineer fees, construction management fees, interest on construction loans and the opportunity cost of carrying empty space in the facility until it is fully occupied. The direct construction costs in the first category represent approximately 60 to 80 percent of the total costs in most construction projects. Since the costs of construction are ultimately borne by the owner, careful financial planning for the facility must be made prior to construction.

Construction Financing

Construction loans to contractors are usually provided by banks or savings and loan associations for construction financing. Upon the completion of the facility, construction loans will be terminated and the post-construction facility financing will be arranged by the owner.

Construction loans provided for different types of construction vary. In the case of residential housing, construction loans and long-term mortgages can be obtained from savings and loans associations or commercial banks. For institutional and commercial buildings, construction loans are usually obtained from commercial banks. Since the value of specialized industrial buildings as collateral for loans is limited, construction loans in this domain are rare, and construction financing can be done from the pool of general corporate funds. For infrastructure construction owned by government, the property cannot be used as security for a private loan, but there are many possible ways to finance the construction, such as general appropriation from taxation or special bonds issued for the project.

Traditionally, banks serve as construction lenders in a three-party agreement among the contractor, the owner and the bank. The stipulated loan will be paid to the contractor on an agreed schedule upon the verification of completion of various portions of the project. Generally, a payment request together with a standard progress report will be submitted each month by the contractor to the owner which in turn submits a draw request to the bank. Provided that the work to date has been performed satisfactorily, the disbursement is made on that basis during the construction period. Under such circumstances, the bank has been primarily concerned with the completion of the facility on time and within the budget. The economic life of the facility after its completion is not a concern because of the transfer of risk to the owner or an institutional lender.

Facility Financing

Many private corporations maintain a pool of general funds resulting from retained earnings and long-term borrowing on the strength of corporate assets, which can be used for facility financing. Similarly, for public agencies, the long-term funding may be obtained from the commitment of general tax revenues from the federal, state and/or local governments. Both private corporations and public agencies may issue special bonds for the constructed facilities which may obtain lower interest rates than other forms of borrowing. Short-term borrowing may also be used for bridging the gaps in long-term financing. Some corporate bonds are convertible to stocks under circumstances specified in the bond agreement. For public facilities, the assessment of user fees to repay the bond funds merits consideration for certain types of facilities such as toll roads and sewage treatment plants. The use of mortgages is primarily confined to rental properties such as apartments and office buildings.

1.7 Legal and Regulatory Requirements

The owners of facilities naturally want legal protection for all the activities involved in the construction. It is equally obvious that they should seek competent legal advice. However, there are certain principles that should be recognized by owners in order to avoid unnecessary pitfalls.

Legal Responsibilities

Activities in construction often involve risks, both physical and financial. An owner generally tries to shift the risks to other parties to the degree possible when entering into contractual agreements with them. However, such action is not without cost or risk. For example, a contractor who is assigned the risks may either ask for a higher contract price to compensate for the higher risks, or end up in non-performance or bankruptcy as an act of desperation. Such consequences can be avoided if the owner is reasonable in risk allocation. When risks are allocated to different parties, the owner must understand the implications and spell them out clearly. Sometimes there are statutory limitations on the allocation of liabilities among various groups, such as prohibition against the allocation of negligence in design to the contractor. An owner must realize its superior power in bargaining and hence the responsibilities associated with this power in making contractual agreements.

Mitigation of Conflicts

It is important for the owner to use legal counselors as advisors to mitigate conflicts before they happen rather than to wield conflicts as weapons against other parties. There are enough problems in design and construction due to uncertainty rather than bad intentions. The owner should recognize the more enlightened approaches for mitigating conflicts, such as using owner-controlled wrap-up insurance which will provide protection for all parties involved in the construction process for unforeseen risks, or using arbitration, mediation and other extra-judicial solutions for disputes among various parties. However, these compromise solutions are not without pitfalls and should be adopted only on the merit of individual cases.

Government Regulation

To protect public safety and welfare, legislatures and various government agencies periodically issue regulations which influence the construction process, the operation of constructed facilities, and their ultimate disposal. For example, building codes promulgated by local authorities have provided guidelines for design and construction practices for a very long time.

Owners must be aware of the impacts of these regulations on the costs and durations of various types of construction projects as well as possibilities of litigation due to various contentions. For example, owners acquiring sites for new construction may be strictly liable for any hazardous wastes already on the site or removed from the site. For large scale projects involving new technologies, the construction costs often escalate with the uncertainty associated with such restrictions.

1.8 The Changing Environment of the Construction Industry

The construction industry is a conglomeration of diverse fields and participants that have been loosely lumped together as a sector of the economy. The construction industry plays a central role in national welfare, including the development of residential housing, office buildings and industrial plants, and the restoration of the nation's infrastructure and other public facilities. The importance of the construction industry lies in the function of its products which provide the foundation for industrial production, and its impacts on the national economy cannot be measured by the value of its output or the number of persons employed in its activities alone.

To be more specific, construction refers to all types of activities usually associated with the erection and repair of immobile facilities. Contract construction consists of a large number of firms that perform construction work for others, and is estimated to be approximately 85% of all construction activities. The remaining 15% of construction is performed by owners of the facilities, and is referred to as force-account construction.

Construction is a significant factor in the Gross National Product although its importance has been declining in recent years. Not to be ignored is the fact that as the nation's constructed facilities become older, the total expenditure on rehabilitation and maintenance may increase relative to the value of new construction.

Owners who pay close attention to the peculiar characteristics of the construction industry and its changing operating environment will be able to take advantage of the favorable conditions and to avoid the pitfalls. Several factors are particularly noteworthy because of their significant impacts on the quality, cost and time of construction.

New Technologies

In recent years, technological innovation in design, materials and construction methods have resulted in significant changes in construction costs. Computer-aids have improved capabilities for generating quality designs as well as reducing the time required to produce alternative designs. New materials not only have enhanced the quality of construction but also have shortened the time for shop fabrication and field erection. Construction methods have gone through various stages of mechanization and automation, including the latest development of construction robotics.

The most dramatic new technology applied to construction has been the Internet and its private, corporate Intranet versions. The Internet is widely used as a means to foster collaboration among professionals on a project, to communicate for bids and results, and to procure necessary goods and services. Real time video from specific construction sites is widely used to illustrate construction progress to interested parties. The result has been more effective collaboration, communication and procurement.

The effects of many new technologies on construction costs have been mixed because of the high development costs for new technologies. However, it is unmistakable that design professionals and construction contractors who have not adapted to changing technologies have been forced out of the mainstream of design and construction activities. Ultimately, construction quality and cost can be improved with the adoption of new technologies which are proved to be efficient from both the viewpoints of performance and economy.

Labor Productivity

The term productivity is generally defined as a ratio of the production output volume to the input volume of resources. Since both output and input can be quantified in a number of ways, there is no single measure of productivity that is universally applicable, particularly in the construction industry where the products are often unique and there is no standard for specifying the levels for aggregation of data. However, since labor constitutes a large part of the cost of construction, labor productivity in terms of output volume (constant money value or functional units) per person-hour is a useful measure. Labor productivity measured in this way does not necessarily indicate the efficiency of labor alone but rather measures the combined effects of labor, equipment and other factors contributing to the output.

While aggregate construction industry productivity is important as a measure of national economy, owners are more concerned about the labor productivity of basic units of work produced by various crafts on site. Thus, an owner can compare the labor performance at different geographic locations, under different working conditions, and for different types and sizes of projects.

Construction costs usually run parallel to material prices and labor wages. Actually, over the years, labor productivity has increased in some traditional types of construction and thus provides a leveling or compensating effect when hourly rates for labor increase faster than other costs in construction. However, labor productivity has been stagnant or even declined in unconventional or large scale projects.

1.9 The Role of Project Construction Managers

In the project life cycle, the most influential factors affecting the outcome of the project often reside at the early stages. At this point, decisions should be based on competent economic evaluation with due consideration for adequate financing, the prevalent social and regulatory environment, and technological considerations. Architects and engineers might specialize in planning, in construction field management, or in operation, but as project Construction managers, they must have some familiarity with all such aspects in order to understand properly their role and be able to make competent decisions.

Many large-scale projects have run into serious problems of management, such as cost overruns and long schedule delays. Actually, the management of *megaprojects* or *super projects* is not a practice peculiar to our time. The problems are organizational rather than technical.

It is customary to think of engineering as a part of a trilogy, pure science, applied science and engineering. It needs emphasis that this trilogy is only one of a triad of trilogies into which engineering fits. This first is pure science, applied science and engineering; the second is economic theory, finance and engineering; and the third is social relations, industrial relations and engineering. Many engineering problems are as closely allied to social problems as they are to pure science.

The greatest stumbling block to effective management in construction is the inertia and historic divisions among planners, designers and constructors. While technical competence in design and innovation remains the foundation of engineering practice, the social, economic and organizational factors that are pervasive in influencing the success and failure of construction projects must also be dealt with effectively by design and construction organizations. Of course, engineers are not expected to know every detail of management techniques, but they must be knowledgeable enough to anticipate the problems of management so that they can work harmoniously with professionals in related fields to overcome the inertia and historic divisions.

Paradoxically, engineers who are creative in engineering design are often innovative in planning and management since both types of activities involve problem solving. In fact, they can reinforce each other if both are included in the education process, provided that creativity and innovation instead of routine practice are emphasized. A project Construction manager who is well educated in the *fundamental principles* of engineering design and management can usefully apply such principles once he has acquired basic understanding of a new *application area*. A project Construction manager who has been trained by rote learning for a specific type of project may merely gain one year of experience repeated twenty times even if he has been in the field for twenty years. A broadly educated project Construction manager can reasonably hope to become a leader in the profession; a narrowly trained project Construction manager is often relegated to the role of his first job level permanently.

The owners have much at stake in selecting a competent project Construction manager and in providing him with the authority to assume responsibility at various stages of the project regardless of the types of contractual agreements for implementing the project. Of course, the project Construction manager must also possess the leadership quality and the ability to handle effectively intricate interpersonal relationships within an organization. The ultimate test of the education and experience of a project Construction manager for construction lies in his ability to apply fundamental principles to solving problems in the new and unfamiliar situations which have become the hallmarks of the changing environment in the construction industry.

Back to the Table of Contents

CHAPTER-2

Organizing for Project Construction Management

2.1 What is Project Construction Management?

Generally, project Construction management is distinguished from the general management of corporations by the mission-oriented nature of a project. A project organization will generally be terminated when the mission is accomplished. According to the Project Management Institute, the discipline of project Construction management can be defined as follows:

Project management is the art of directing and coordinating human and material resources throughout the life of a project by using modern management techniques to achieve predetermined objectives of scope, cost, time, quality and participation satisfaction.

The functions of project Construction management for construction generally include the following:

1. Specification of project objectives and plans including delineation of scope, budgeting, scheduling, setting performance requirements, and selecting project participants.
2. Maximization of efficient resource utilization through procurement of labor, materials and equipment according to the prescribed schedule and plan.
3. Implementation of various operations through proper coordination and control of planning, design, estimating, contracting and construction in the entire process.
4. Development of effective communications and mechanisms for resolving conflicts among the various participants.

2.2 Trends in Modern Management

In recent years, the management process approach emphasizes the systematic study of management by identifying management functions in an organization and then examining each in detail. There is general agreement regarding the functions of planning, organizing and controlling.

Project Construction managers should be aware of the strategic position of their own organization and the other organizations involved in the project. The project Construction manager faces the difficult task of trying to align the goals and strategies of these various organizations to accomplish the project goals.

2.3 Strategic Planning and Project Programming

In order to gain time, some owners are willing to forego thorough planning and feasibility study so as to proceed on a project with inadequate definition of the project scope. Invariably, subsequent changes in project scope will increase construction costs; however, profits derived from earlier facility operation often justify the increase in construction costs. The owner or facility sponsor holds the key to influence the construction costs of a project because any decision made at the beginning stage of a project life cycle has far greater influence than those made at later stages.

2.4 Effects of Project Risks on Organization

The uncertainty in undertaking a construction project comes from many sources and often involves many participants in the project. Since each participant tries to minimize its own risk, the conflicts among various participants can be detrimental to the project. Only the owner has the power to moderate such conflicts as it alone holds the key to risk assignment through proper contractual relations with other participants.

Risks in construction projects may be classified in a number of ways. One form of classification is as follows:

1. Socioeconomic factors
    - Environmental protection
    - Public safety regulation
    - Economic instability
    - Exchange rate fluctuation
2. Organizational relationships
    - Contractual relations
    - Attitudes of participants
    - Communication
3. Technological problems
    - Design assumptions
    - Site conditions
    - Construction procedures
    - Construction occupational safety

2.5 Organization of Project Participants

In general, there are many ways to decompose a project into stages. The most typical ways are:

- Sequential processing whereby the project is divided into separate stages and each stage is carried out successively in sequence.
- Parallel processing whereby the project is divided into independent parts such that all stages are carried out simultaneously.
- Staggered processing whereby the stages may be overlapping, such as the use of phased design-construct procedures for fast track operation.

2.6 Traditional Designer-Constructor Sequence

For ordinary projects of moderate size and complexity, the owner often employs a designer (an architectural/engineering firm) which prepares the detailed plans and specifications for the constructor (a general contractor). The designer also acts on behalf of the owner to oversee the project implementation during construction. The general contractor is responsible for the construction itself even though the work may actually be undertaken by a number of specialty subcontractors.

2.7 Professional Construction Management

Professional construction management refers to a project Construction management team consisting of a professional construction manager and other participants who will carry out the tasks of project planning, design and construction in an integrated manner. Contractual relationships among members of the team are intended to minimize adversarial relationships and contribute to greater response within the management group. A professional construction manager is a firm specialized in the practice of professional construction management which includes:

- Work with owner and the A/E firms from the beginning and make recommendations on design improvements, construction technology, schedules and construction economy.
- Propose design and construction alternatives if appropriate, and analyze the effects of the alternatives on the project cost and schedule.
- Monitor subsequent development of the project in order that these targets are not exceeded without the knowledge of the owner.

- Coordinate procurement of material and equipment and the work of all construction contractors, and monthly payments to contractors, changes, claims and inspection for conforming design requirements.
- Perform other project related services as required by owners.

Professional construction management is usually used when a project is very large or complex.

2.8 Owner-Builder Operation

In this approach an owner must have a steady flow of on-going projects in order to maintain a large work force for in-house operation. However, the owner may choose to subcontract a substantial portion of the project to outside consultants and contractors for both design and construction, even though it retains centralized decision making to integrate all efforts in project implementation.

2.9 Turnkey Operation

Some owners wish to delegate all responsibilities of design and construction to outside consultants in a turnkey project arrangement. A contractor agrees to provide the completed facility on the basis of performance specifications set forth by the owner. The contractor may even assume the responsibility of operating the project if the owner so desires. In order for a turnkey operation to succeed, the owner must be able to provide a set of unambiguous performance specifications to the contractor and must have complete confidence in the capability of the contractor to carry out the mission.

Back to the Table of Contents

CHAPTER-3

The Design and Construction Process

3.1 Design and Construction as an Integrated System

In the planning of facilities, it is important to recognize the close relationship between design and construction. These processes can best be viewed as an integrated system. Broadly speaking, design is a process of creating the description of a new facility, usually represented by detailed plans and specifications; construction planning is a process of identifying activities and resources required to make the design a physical reality. Hence, construction is the implementation of a design envisioned by architects and engineers.

3.2 Construction Site Environment

While the general information about the construction site is usually available at the planning stage of a project, it is important for the design professionals and construction manager as well as the contractor to visit the site. Each group will be benefited by first-hand knowledge acquired in the field.

3.3 Value Engineering

Value engineering may be broadly defined as an organized approach in identifying unnecessary costs in design and construction and in soliciting or proposing alternative design or construction technology to reduce costs without sacrificing quality or performance requirements.

3.4 Construction Planning

There are some recommendations or issues that can be addressed to describe the characteristics of good plans, but this does not necessarily tell a planner how to discover a good plan. However, as in the design process, strategies of decomposition in which planning is divided into sub problems and hierarchical planning in which general activities are repeatedly subdivided into more specific tasks can be readily adopted in many cases.

From the standpoint of construction contractors or the construction divisions of large firms, the planning process for construction projects consists of three stages that take place between the moments in which a planner starts the plan for the construction of a facility to the moment in which the evaluation of the final output of the construction process is finished.

1) The *estimate* stage involves the development of a cost and duration estimate for the construction of a facility as part of the proposal of a contractor to an owner.

2) In the *monitoring and control stage* of the construction process, the construction manager has to keep constant track of both activities' durations and ongoing costs.
3) The *evaluation stage* is the one in which results of the construction process are matched against the estimate.

3.5 Computer-Aided Engineering

The computer is often used as only an incidental tool in the design, construction and project management processes. However, new capabilities, systems and application programs are rapidly being adopted. These are motivated in part by the remarkable improvement in computer hardware capability, the introduction of the Internet, and an extraordinary decline in cost.

3.6 Pre-Project Planning

Even before design and construction processes begin, there is a stage of "pre-project planning" that can be critical for project success. In this process, the project scope is established. Since construction and design professionals are often not involved in this project scope stage, the terminology of describing this as a "pre-project" process has arisen. From the owner's perspective, defining the project scope is just another phase in the process of acquiring a constructed facility.

Back to the Table of Contents

CHAPTER-4

Labor, Material and Equipment

4.1 Labor Productivity

Productivity in construction is often broadly defined as output per labor hour. Construction output may be expressed in terms of functional units or constant currency units. In the former case, labor productivity is associated with units of product per labor hour, such as cubic yards of concrete placed per hour or miles of highway paved per hour. In the latter case, labor productivity is identified with value of construction (in constant currency units) per labor hour.

4.2 Materials Management

Materials management is an important element in project planning and control. Materials represent a major expense in construction, so minimizing procurement or purchase costs presents important opportunities for reducing costs.

4.3 Material Procurement and Delivery

The main sources of information for feedback and control of material procurement are requisitions, bids and quotations, purchase orders and subcontracts, shipping and receiving documents, and invoices..

The process of delivery, including transportation, field storage and installation will be different for these materials. The equipment needed to handle and haul of materials will also be different.

4.4 Inventory Control

Once goods are purchased, they represent an inventory used during the construction process. The general objective of inventory control is to minimize the total cost of keeping the inventory

4.5 Construction Equipment

The selection of the appropriate type and size of construction equipment often affects the required amount of time and effort and thus the job-site productivity of a project. It is therefore important for site managers and construction planners to be familiar with the characteristics of the major types of equipment most commonly used in construction.

Back to the Table of Contents

CHAPTER-5 Cost Estimation

5.1 Costs Associated with Constructed Facilities

The costs of a constructed facility to the owner include both the initial capital cost and the subsequent operation and maintenance costs. Each of these major cost categories consists of a number of cost components.
The capital cost for a construction project includes the expenses related to the inital establishment of the facility:

- Land acquisition, including assembly, holding and improvement
- Planning and feasibility studies
- Architectural and engineering design
- Construction, including materials, equipment and labor
- Field supervision of construction
- Construction financing
- Insurance and taxes during construction
- Owner's general office overhead
- Equipment and furnishings not included in construction
- Inspection and testing

The operation and maintenance cost in subsequent years over the project life cycle includes the following expenses:

- Land rent, if applicable
- Operating staff
- Labor and material for maintenance and repairs
- Periodic renovations
- Insurance and taxes
- Financing costs
- Utilities
- Owner's other expenses

In most construction budgets, there is an allowance for contingencies or unexpected costs occurring during construction. This contingency amount may be included within each cost item or be included in a single category of construction contingency. The amount of contingency is based on historical experience and the expected difficulty of a particular construction project. For example, one construction firm makes estimates of the expected cost in five different areas:

- Design development changes,
- Schedule adjustments,
- General administration changes (such as wage rates),
- Differing site conditions for those expected, and
- Third party requirements imposed during construction, such as new permits.

5.2 Approaches to Cost Estimation

Cost estimating is one of the most important steps in project Construction management. A cost estimate establishes the base line of the project cost at different stages of development of the project. A cost estimate at a given stage of project development represents a prediction provided by the cost engineer or estimator on the basis of available data.

5.3 Types of Construction Cost Estimates

Construction cost constitutes only a fraction, though a substantial fraction, of the total project cost.
For establishing the financing of a project, either a design estimate or a bid estimate is used.

1. **Design Estimates.** For the owner or its designated design professionals, the types of cost estimates encountered run parallel with the planning and design as follows:
    - Screening estimates (or order of magnitude estimates)
    - Preliminary estimates (or conceptual estimates)
    - Detailed estimates (or definitive estimates)
    - Engineer's estimates based on plans and specifications

For each of these different estimates, the amount of design information available typically increases.

2. **Bid Estimates.** For the contractor, a bid estimate submitted to the owner either for competitive bidding or negotiation consists of direct construction cost including field supervision, plus a markup to cover general overhead and profits. The direct cost of construction for bid estimates is usually derived from a combination of the following approaches.
    - Subcontractor quotations
    - Quantity takeoffs
    - Construction procedures.
3. **Control Estimates.** For monitoring the project during construction, a control estimate is derived from available information to establish:
    - Budget estimate for financing
    - Budgeted cost after contracting but prior to construction
    - Estimated cost to completion during the progress of construction.

5.4 Historical Cost Data

Preparing cost estimates normally requires the use of historical data on construction costs. Historical cost data will be useful for cost estimation only if they are collected and organized in a way that is compatible with future applications. Organizations which are engaged in cost estimation continually should keep a file for their own use. The information must be updated with respect to changes that will inevitably occur. The format of cost data, such as unit costs for various items, should be organized according to the current standard of usage in the organization.

5.5 Estimate Based on Engineer's List of Quantities

The engineer's estimate is based on a list of items and the associated quantities from which the total construction cost is derived. This same list is also made available to the bidders if unit prices of the items on the list are also solicited from the bidders. Thus, the itemized costs submitted by the winning contractor may be used as the starting point for budget control.
In general, the progress payments to the contractor are based on the units of work completed and the corresponding unit prices of the work items on the list. Hence, the estimate based on the engineers' list of quantities for various work items essentially defines the level of detail to which subsequent measures of progress for the project will be made.

5.6 Allocation of Construction Costs Over Time

Since construction costs are incurred over the entire construction phase of a project, it is often necessary to determine the amounts to be spent in various periods to derive the cash flow profile, especially for large projects with long durations. Consequently, it is important to examine the percentage of work expected to be completed at various time periods to which the costs would be charged. More accurate estimates may be accomplished once the project is scheduled as described in Chapter 10, but some rough estimate of the cash flow may be required prior to this time.

Back to the Table of Contents

CHAPTER-6

Economic Evaluation of Facility Investments

6.1 Project Life Cycle and Economic Feasibility

This chapter will present an overview of the decision process for economic evaluation of facilities with regard to the project life cycle. The cycle begins with the initial conception of the project and continues through planning, design, procurement, construction, start-up, operation and maintenance.

6.2 Basic Concepts of Economic Evaluation

A systematic approach for economic evaluation of facilities consists of the following major steps:

1. Generate a set of projects or purchases for investment consideration.
2. Establish the planning horizon for economic analysis.
3. Estimate the cash flow profile for each project.
4. Specify the minimum attractive rate of return (MARR).
5. Establish the criterion for accepting or rejecting a proposal, or for selecting the best among a group of mutually exclusive proposals, on the basis of the objective of the investment.
6. Perform sensitivity or uncertainty analysis.
7. Accept or reject a proposal on the basis of the established criterion.

6.3 Costs and Benefits of a Constructed Facility

To obtain an accurate estimate of costs in the cash flow profile for the acquisition and operation of a project, it is necessary to specify the resources required to construct and operate the proposed physical facility, given the available technology and operating policy.

In the private sector, the benefits derived from a facility investment are often measured by the revenues generated from the operation of the facility. In the public sector, income may also be accrued to a public agency from the operation of the facility.

6.4 Interest Rates and the Costs of Capital

The cost of capital or MARR depends on the real interest rate (i.e., market interest rate less the inflation rate) over the period of investment. As the cost of capital rises, it becomes less and less attractive to invest in a large facility because of the opportunities foregone over a long period of time.

6.5 Uncertainty and Risk

Since future events are always uncertain, all estimates of costs and benefits used in economic evaluation involve a degree of uncertainty. Probabilistic methods are often used in decision analysis to determine expected costs and benefits as well as to assess the degree of risk in particular projects.

Back to the Table of Contents

CHAPTER-7

Construction Pricing and Contracting

7.1 Pricing for Constructed Facilities

The construction contract price includes the direct project cost including field supervision expenses plus the markup imposed by contractors for general overhead expenses and profit. The most common types of pricing arrangements can be described broadly to illustrate the basic principles.

Competitive Bidding

The basic structure of the bidding process consists of the formulation of detailed plans and specifications of a facility based on the objectives and requirements of the owner, and the invitation of qualified contractors to bid for the right to execute the project. Detailed plans and specifications are usually prepared by an architectural/engineering firm which oversees the bidding process on behalf of the owner. The final bids are normally submitted on either a lump sum or unit price basis, as stipulated by the owner.

- A lump sum bid represents the total price for which a contractor offers to complete a facility according to the detailed plans and specifications.
- Unit price bidding is used in projects for which the quantity of materials or the amount of labor involved in some key tasks is particularly uncertain. In such cases, the contractor is permitted to submit a list of unit prices for those tasks, and the final price used to determine the lowest bidder is based on the lump sum price computed by multiplying the quoted unit price for each specified task by the corresponding quantity in the owner's estimates for quantities. However, the total payment to the winning contractor will be based on the actual quantities multiplied by the respective quoted unit prices.

Negotiated Contracts

Instead of inviting competitive bidding, private owners often choose to award construction contracts with one or more selected contractors. A major reason for using negotiated contracts is the flexibility of this type of pricing arrangement, particularly for projects of large size and great complexity or for projects which substantially duplicate previous facilities sponsored by the owner. An owner may value the expertise and integrity of a particular contractor who has a good reputation or has worked successfully for the owner in the past. If it becomes necessary to meet a deadline for completion of the project, the construction of a project may proceed without waiting for the completion of the detailed plans and specifications (Fast Track) with a contractor that the owner can trust. However, the owner's staff must be highly knowledgeable and competent in evaluating contractor proposals and monitoring subsequent performance.

Generally, negotiated contracts require the reimbursement of direct project cost plus the contractor's fee as determined by one of the following methods:

1. *Cost plus fixed percentage* (The fixed percentage is determined at the outset of the project)
2. *Cost plus fixed fee* (The fixed fee is determined at the outset of the project)
3. *Cost plus variable fee* (used as an incentive to reduce costs by sharing any cost savings)
4. *Target estimate* (used as an incentive to reduce costs by sharing any cost savings)
5. *Guaranteed maximum price or cost* (imposes a penalty on a contractor for cost overruns and failure to complete the project on time. With a guaranteed maximum price contract, amounts below the maximum are typically shared between the owner and the contractor, while the contractor is responsible for costs above the maximum)

Speculative Residential Construction

In residential construction, developers often build houses and condominiums in anticipation of the demand of home buyers. Because the basic needs of home buyers are very similar and home designs can be standardized to some degree, the probability of finding buyers of good housing units within a relatively short time is quite high. Consequently, developers are willing to undertake speculative building and lending institutions are also willing to finance such construction. The developer essentially set the price for each housing unit as the market will bear, and can adjust the prices of remaining units at any given time according to the market trend.

Force-Account Construction

Some owners use in-house labor forces to perform a substantial amount of construction, particularly for addition, renovation and repair work. Then, the total of the force-account charges including in-house overhead expenses will be the pricing arrangement for the construction.

7.2 Contract Provisions for Risk Allocation

Provisions for the allocation of risk among parties to a contract can appear in numerous areas in addition to the total construction price. Typically, these provisions assign responsibility for covering the costs of possible or unforeseen occurrences. A partial list of responsibilities with concomitant risk that can be assigned to different parties would include:

- Force majeure (i.e., this provision absolves an owner or a contractor for payment for costs due to "Acts of God" and other external events such as war or labor strikes)
- Indemnification (i.e., this provision absolves the indemnified party from any payment for losses and damages incurred by a third party such as adjacent property owners.)
- Liens (i.e., assurances that third party claims are settled such as "mechanics liens" for worker wages),
- Labor laws (i.e., payments for any violation of labor laws and regulations on the job site),
- Differing site conditions (i.e., responsibility for extra costs due to unexpected site conditions),
- Delays and extensions of time,
- Liquidated damages (i.e., payments for any facility defects with payment amounts agreed to in advance)
- Consequential damages (i.e., payments for actual damage costs assessed upon impact of facility defects),
- Occupational safety and health of workers,
- Permits, licenses, laws, and regulations,
- Equal employment opportunity regulations,
- Termination for default by contractor,
- Suspension of work,
- Warranties and guarantees.

Standard forms for contracts can be obtained from numerous sources. These standard forms may include risk and responsibility allocations which are unacceptable to one or more of the contracting parties. In particular, standard forms may be biased to reduce the risk and responsibility of the originating organization or group. Parties to a contract should read and review all contract documents carefully.

The three examples appearing below illustrate contract language resulting in different risk assignments between a contractor (CONTRACTOR) and an owner (COMPANY). Each contract provision allocates different levels of indemnification risk to the contractor.

7.3 Types of Construction Contracts

While construction contracts serve as a means of pricing construction, they also structure the allocation of risk to the various parties involved. The owner has the sole power to decide what type of contract should be used for a specific facility to be constructed and to set forth the terms in a contractual agreement. It is important to understand the risks of the contractors associated with different types of construction contracts.

Lump Sum Contract

In a lump sum contract, the owner has essentially assigned all the risk to the contractor, who in turn can be expected to ask for a higher markup in order to take care of unforeseen contingencies. Beside the fixed lump sum price, other commitments are often made by the contractor in the form of submittals such as a specific schedule, the management reporting system or a quality control program. If the actual cost of the project is underestimated, the underestimated cost will reduce the contractor's profit by that amount. An overestimate has an opposite effect, but may reduce the chance of being a low bidder for the project.

Unit Price Contract

In a unit price contract, the risk of inaccurate estimation of uncertain quantities for some key tasks has been removed from the contractor. However, some contractors may submit an "unbalanced bid" when it discovers large discrepancies between its estimates and the owner's estimates of these quantities. Depending on the confidence of the contractor on its own estimates and its propensity on risk, a contractor can slightly raise the unit prices on the underestimated tasks while lowering the unit prices on other tasks. If the contractor is correct in its assessment, it can increase its profit substantially since the payment is made on the actual quantities of tasks; and if the reverse is true, it can lose on this basis. Furthermore, the owner may disqualify a contractor if the bid appears to be heavily unbalanced. To the extent that an underestimate or overestimate is caused by changes in the quantities of work, neither error will affect the contractor's profit beyond the markup in the unit prices.

Cost Plus Fixed Percentage Contract

For certain types of construction involving new technology or extremely pressing needs, the owner is sometimes forced to assume all risks of cost overruns. The contractor will receive the actual direct job cost plus a fixed percentage, and have little incentive to reduce job cost. Furthermore, if there are pressing needs to complete the project, overtime payments to workers are common and will further increase the job cost. Unless there are compelling reasons, such as the urgency in the construction of military installations, the owner should not use this type of contract.

Cost Plus Fixed Fee Contract

Under this type of contract, the contractor will receive the actual direct job cost plus a fixed fee, and will have some incentive to complete the job quickly since its fee is fixed regardless of the duration of the project. However, the owner still assumes the risks of direct job cost overrun while the contractor may risk the erosion of its profits if the project is dragged on beyond the expected time.

Cost plus Variable Percentage Contract

For this type of contract, the contractor agrees to a penalty if the actual cost exceeds the estimated job cost, or a reward if the actual cost is below the estimated job cost. In return for taking the risk on its own estimate, the contractor is allowed a variable percentage of the direct job-cost for its fee. Furthermore, the project duration is usually specified and the contractor must abide by the deadline for completion. This type of contract allocates considerable risk for cost overruns to the owner, but also provides incentives to contractors to reduce costs as much as possible.

Target Estimate Contract

This is another form of contract which specifies a penalty or reward to a contractor, depending on whether the actual cost is greater than or less than the contractor's estimated direct job cost. Usually, the percentages of savings or overrun to be shared by the owner and the contractor are predetermined and the project duration is specified in the contract. Bonuses or penalties may be stipulated for different project completion dates.

Guaranteed Maximum Cost Contract

When the project scope is well defined, an owner may choose to ask the contractor to take all the risks, both in terms of actual project cost and project time. Any work change orders from the owner must be extremely minor if at all, since performance specifications are provided to the owner at the outset of construction. The owner and the contractor agree to a project cost guaranteed by the contractor as maximum. There may be or may not be additional provisions to share any savings if any in the contract. This type of contract is particularly suitable for turnkey operation.

7.4 Principles of Contract Negotiation

Negotiation is another important mechanism for arranging construction contracts. Project Construction managers often find themselves as participants in negotiations, either as principal negotiators or as expert advisors. These negotiations can be complex and often present important opportunities and risks for the various parties involved. For example, negotiation on work contracts can involve issues such as completion date, arbitration procedures, special work item compensation, contingency allowances as well as the overall price. As a general rule, exogenous factors such as the history of a contractor and the general economic climate in the construction industry will determine the results of negotiations. However, the skill of a negotiator can affect the possibility of reaching an agreement, the profitability of the project, the scope of any eventual disputes, and the possibility for additional work among the participants. Thus, negotiations are an important task for many project Construction managers. Even after a contract is awarded on the basis of competitive bidding, there are many occasions in which subsequent negotiations are required as conditions change over time.

Poor negotiating strategies adopted by one or the other party may preclude an agreement even with the existence of a feasible agreement range. For example, one party may be so demanding that the other party simply breaks off negotiations. In effect, negotiations are not a well behaved solution methodology for the resolution of disputes.

Back to the Table of Contents

CHAPTER-8

Construction Planning

8.1 Basic Concepts in the Development of Construction Plans

Construction planning is a fundamental and challenging activity in the management and execution of construction projects. It involves the choice of technology, the definition of work tasks, the estimation of the required resources and durations for individual tasks, and the identification of any interactions among the different work tasks. A good construction plan is the basis for developing the budget and the schedule for work. Developing the construction plan is a critical task in the management of construction, even if the plan is not written or otherwise formally recorded. In addition to these technical aspects of construction planning, it may also be necessary to make organizational decisions about the relationships between project participants and even which organizations to include in a project. For example, the extent to which sub-contractors will be used on a project is often determined during construction planning.

In developing a construction plan, it is common to adopt a primary emphasis on either cost control or on schedule control as illustrated in Fig. 8-1. Some projects are primarily divided into expense categories with associated costs. In these cases, construction planning is cost or expense oriented. Within the categories of expenditure, a distinction is made between costs incurred directly in the performance of an activity and indirectly for the accomplishment of the project. For example, borrowing expenses for project financing and overhead items are commonly treated as indirect costs. For other projects, scheduling of work activities over time is critical and is emphasized in the planning process. In this case, the planner insures that the proper precedencies among activities are maintained and that efficient scheduling of the available resources prevails. Traditional scheduling procedures emphasize the maintenance of task precedencies (resulting in *critical path scheduling* procedures) or efficient use of resources over time (resulting in *job shop scheduling* procedures). Finally, most complex projects require consideration of cost and scheduling over time, so that planning, monitoring and record keeping must consider both dimensions. In these cases, the integration of schedule and budget information is a major concern.

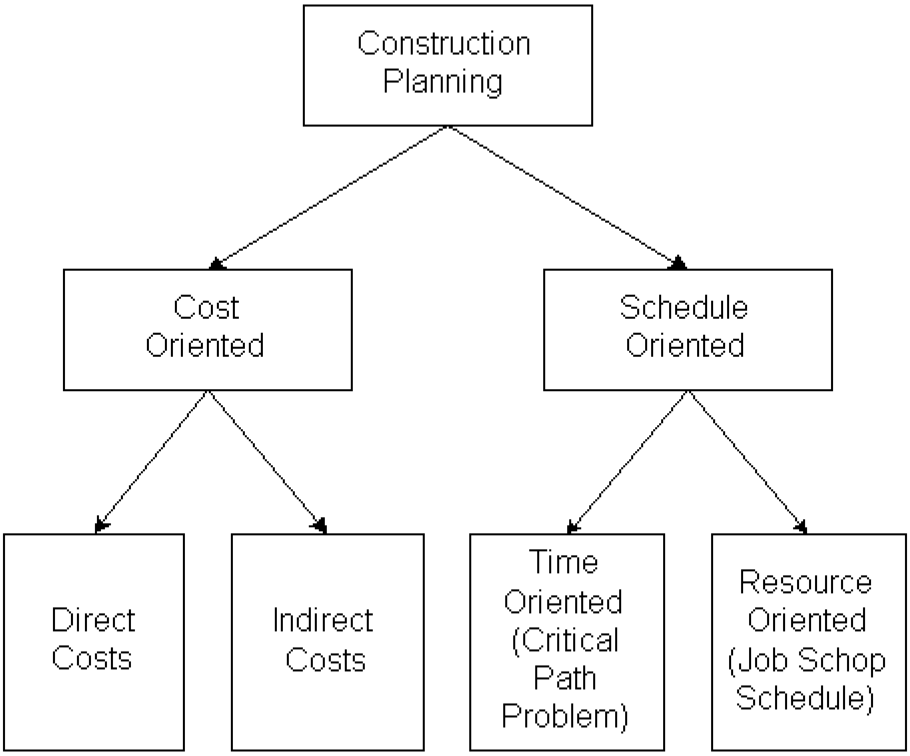


Figure 8-1 Alternative Emphases in Construction Planning

In this chapter, we shall consider the functional requirements for construction planning such as technology choice, work breakdown, and budgeting. Construction planning is not an activity which is restricted to the period after the award of a contract for construction. It should be an essential activity during the facility design. Also, if problems arise during construction, re-planning is required.

8.2 Defining Work Tasks

To define the various work tasks that must be accomplished. These work tasks represent the necessary framework to permit scheduling of construction activities, along with estimating the resources required by the individual work tasks, and any necessary precedencies or required sequence among the tasks. The terms work "tasks" or "activities" are often used interchangeably in construction plans to refer to specific, defined items of work. In job shop or manufacturing terminology, a project would be called a "job" and an activity called an "operation", but the sense of the terms is equivalent. The scheduling problem is to determine an appropriate set of activity start time, resource allocations and completion times that will result in completion of the project in a timely and efficient fashion.

Construction planning is the necessary fore-runner to scheduling. In this planning, defining work tasks, technology and construction method is typically done either simultaneously or in a series of iterations.

The definition of appropriate work tasks can be a laborious and tedious process, yet it represents the necessary information for application of formal scheduling procedures.

For the scheduling process itself, numerous computer programs are available. But for the important task of defining activities, reliance on the skill, judgment and experience of the construction planner is likely to continue.

More formally, an activity is any subdivision of project tasks. The set of activities defined for a project should be comprehensive or completely exhaustive so that all necessary work tasks are included in one or more activities. Typically, each design element in the planned facility will have one or more associated project activities. Execution of an activity requires time and resources, including manpower and equipment, as described in the next section. The time required to perform an activity is called the duration of the activity. The beginning and the end of activities are signposts or milestones, indicating the progress of the project. Occasionally, it is useful to define activities which have no duration to mark important events. For example, receipt of equipment on the construction site may be defined as an activity since other activities would depend upon the equipment availability and the project Construction manager might appreciate formal notice of the arrival. Similarly, receipt of regulatory approvals would also be specially marked in the project plan.

The extent of work involved in any one activity can vary tremendously in construction project plans. Indeed, it is common to begin with fairly coarse definitions of activities and then to further sub-divide tasks as the plan becomes better defined. As a result, the definition of activities evolves during the preparation of the plan. A result of this process is a natural hierarchy of activities with large, abstract functional activities repeatedly sub-divided into more and more specific sub-tasks. For example, the problem of placing concrete on site would have sub-activities associated with placing forms, installing reinforcing steel, pouring concrete, finishing the concrete, removing forms and others. Even more specifically, sub-tasks such as removal and cleaning of forms after concrete placement can be defined. Even further, the sub-task "clean concrete forms" could be subdivided into the various operations:

- Transport forms from on-site storage and unload onto the cleaning station.
- Position forms on the cleaning station.
- Wash forms with water.
- Clean concrete debris from the form's surface.

- Coat the form surface with an oil release agent for the next use.
- Unload the form from the cleaning station and transport to the storage location.

More formally, a hierarchical approach to work task definition decomposes the work activity into component parts in the form of a tree. Higher levels in the tree represent decision nodes or summary activities, while branches in the tree lead to smaller components and work activities. A variety of constraints among the various nodes may be defined or imposed, including precedence relationships among different tasks as defined below.

The number and detail of the activities in a construction plan is a matter of judgment or convention. Construction plans can easily range between less than a hundred to many thousand defined tasks, depending on the planner's decisions and the scope of the project. If subdivided activities are too refined, the size of the network becomes unwieldy and the cost of planning excessive. Sub-division yields no benefit if reasonably accurate estimates of activity durations and the required resources cannot be made at the detailed work breakdown level. On the other hand, if the specified activities are too coarse, it is impossible to develop realistic schedules and details of resource requirements during the project. More detailed task definitions permit better control and more realistic scheduling. It is useful to define separate work tasks for:

- Those activities which involve different resources, or
- Those activities which do not require continuous performance.

8.3 Estimating Activity Durations

In most scheduling procedures, each work activity has associated time duration. These durations are used extensively in preparing a schedule.

All formal scheduling procedures rely upon estimates of the durations of the various project activities as well as the definitions of the predecessor relationships among tasks. The variability of an activity's duration may also be considered. Formally, the *probability distribution* of an activity's duration as well as the expected or most likely duration may be used in scheduling. A probability distribution indicates the chance that particular activity duration will occur. In advance of actually doing a particular task, we cannot be certain exactly how long the task will require.

In addition, productivity rates may vary in both systematic and random fashions from the average. An example of systematic variation is the effect of *learning* on productivity. As a crew becomes familiar with an activity and the work habits of the crew, their productivity will typically improve.. A common construction example is that the assembly of floors in a building might go faster at higher levels due to improved productivity even though the transportation time up to the active construction area is longer. Again, historical records or subjective adjustments might be made to represent learning curve variations in average productivity.

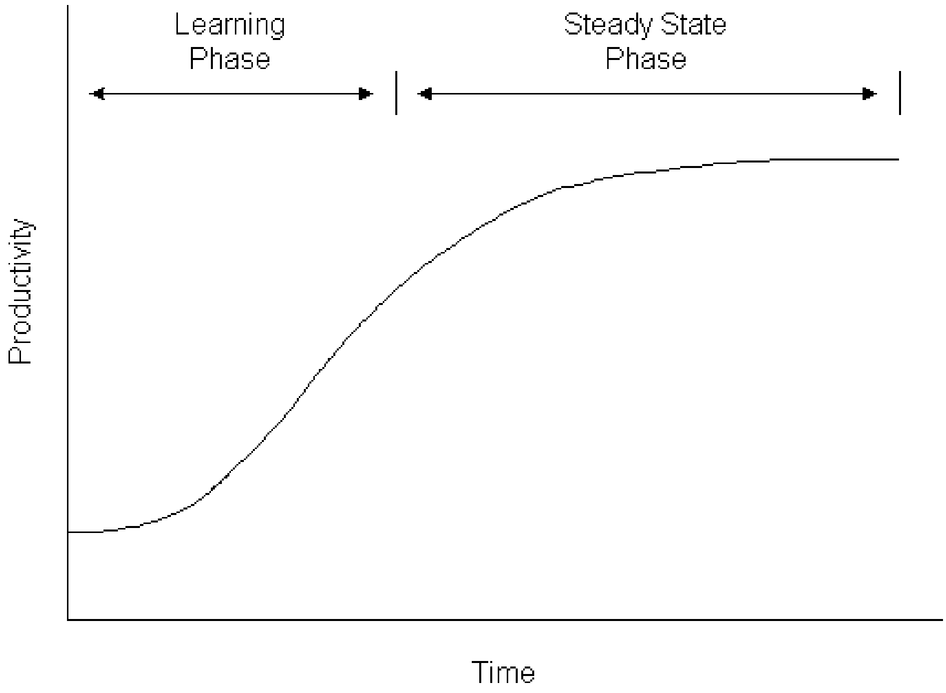


Figure 8-3 Illustration of Productivity Changes Due to Learning

Weather effects are often very important and thus deserve particular attention in estimating durations. Weather has both systematic and random influences on activity durations. As a simple example, an activity might require ten days in perfect weather, but the activity could not proceed in the rain. Furthermore, suppose that rain is expected ten percent of the days in a particular month. In this case, the expected activity duration is eleven days including one expected rain day.

8.4 Estimating Resource Requirements for Work Activities

In addition to precedence relationships and time durations, *resource requirements* are usually estimated for each activity. Since the work activities defined for a project are comprehensive, the total resources required for the project are the sum of the resources required for the various activities. By making resource requirement estimates for each activity, the requirements for particular resources during the course of the project can be identified. Potential bottlenecks can thus be identified, and schedule, resource allocation or technology changes made to avoid problems.

The initial problem in estimating resource requirements is to decide the extent and number of resources that might be defined. At a very aggregate level, resources categories might be limited to the amount of labor (measured in man-hours or in dollars), the amount of materials required for an activity, and the total cost of the activity. At this aggregate level, the resource estimates may be useful for purposes of project monitoring and cash flow planning..

8.5 Coding Systems

One objective in many construction planning efforts is to define the plan within the constraints of a universal *coding system* for identifying activities. Each activity defined for a project would be identified by a pre-defined code specific to that activity. The use of a common nomenclature or identification system is basically motivated by the desire for better integration of organizational efforts and improved information flow. In particular, coding systems are adopted to provide a numbering system to replace verbal descriptions of items. These codes reduce the length or complexity of the information to be recorded. A common coding system within an organization also aids consistency in definitions and categories between projects and among the various parties involved in a project. Common coding systems also aid in the retrieval of historical records of cost, productivity and duration on particular activities. Finally, electronic data storage and retrieval operations are much more efficient with standard coding systems.

The most widely used standard coding system for constructed facilities is the MASTERFORMAT system developed by the Construction Specifications Institute (CSI) of the United States and Construction Specifications of Canada. After development of separate systems, this combined system was originally introduced as the Uniform Construction Index (UCI) in 1972 and was subsequently adopted for use by numerous firms, information providers, professional societies and trade organizations. The term MASTERFORMAT was introduced with the 1978 revision of the UCI codes. MASTERFORMAT provides a standard identification code for nearly all the elements associated with building construction.

Back to the Table of Contents

CHAPTER-9

Fundamental Scheduling Procedures

9.1 Relevance of Construction Schedules

In addition to assigning dates to project activities, project scheduling is intended to match the resources of equipment, materials and labor with project work tasks over time. Good scheduling can eliminate problems due to production bottlenecks, facilitate the timely procurement of necessary materials, and otherwise insure the completion of a project as soon as possible. In contrast, poor scheduling can result in considerable waste as laborers and equipment wait for the availability of needed resources or the completion of preceding tasks. Delays in the completion of an entire project due to poor scheduling can also create havoc for owners who are eager to start using the constructed facilities.

Attitudes toward the formal scheduling of projects are often extreme. Many owners require detailed construction schedules to be submitted by contractors as a means of monitoring the work progress. The actual work performed is commonly compared to the schedule to determine if construction is proceeding satisfactorily. After the completion of construction, similar comparisons between the planned schedule and the actual accomplishments may be performed to allocate the liability for project delays due to changes requested by the owner, worker strikes or other unforeseen circumstances.

Formal scheduling procedures have become much more common with the advent of personal computers on construction sites and easy-to-use software programs. Sharing schedule information via the Internet has also provided a greater incentive to use formal scheduling methods.

A basic distinction exists between *resource oriented* and *time oriented* scheduling techniques. For resource oriented scheduling, the focus is on using and scheduling particular resources in an effective fashion. For example, the project Construction manager's main concern on a high-rise building site might be to insure that cranes are used effectively for moving materials; without effective scheduling in this case, delivery trucks might queue on the ground and workers wait for deliveries on upper floors. For time oriented scheduling, the emphasis is on determining the completion time of the project given the necessary precedence relationships among activities. Hybrid techniques for resource leveling or resource constrained scheduling in the presence of precedence relationships also exist. Most scheduling software is time-oriented, although virtually all of the programs have the capability to introduce resource constraints.

9.2 The Critical Path Method

The most widely used scheduling technique is the critical path method (CPM) for scheduling, often referred to as *critical path scheduling*. This method calculates the minimum completion time for a project along with the possible start and finish times for the project activities. Indeed, many texts and managers regard critical path scheduling as the only usable and practical scheduling procedure. Computer programs and algorithms for critical path scheduling are widely available and can efficiently handle projects with thousands of activities.

The *critical path* itself represents the set or sequence of predecessor/successor activities which will take the longest time to complete. The duration of the critical path is the sum of the activities' durations along the path. Thus, the critical path can be defined as the longest possible path through the "network" of project activities. The duration of the critical path represents the minimum time required to complete a project. Any delays along the critical path would imply that additional time would be required to complete the project.

There may be more than one critical path among all the project activities, so completion of the entire project could be delayed by delaying activities along any one of the critical paths. For example, a project consisting of two activities performed in parallel that each requires three days would have each activity critical for a completion in three days.

9.3 Activity Float and Schedules

Float is a very valuable concept since it represents the scheduling flexibility or "maneuvering room" available to complete particular tasks. Activities on the critical path do not provide any flexibility for scheduling nor leeway in case of problems. For activities with some float, the actual starting time might be chosen to balance workloads over time, to correspond with material deliveries, or to improve the project's cash flow.

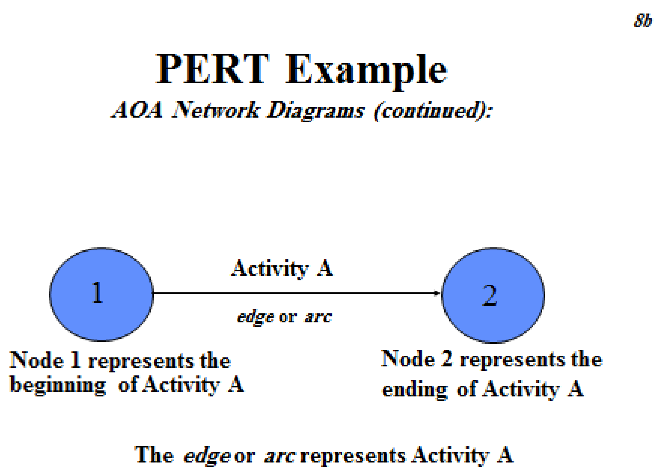
Of course, if one activity is allowed to float or change in the schedule, then the amount of float available for other activities may decrease. Three separate categories of float are defined in critical path scheduling:

1. *Free float* is the amount of delay which can be assigned to any one activity without delaying subsequent activities.
2. *Independent float* is the amount of delay which can be assigned to any one activity without delaying subsequent activities or restricting the scheduling of preceding activities.
3. *Total float* is the maximum amount of delay which can be assigned to any activity without delaying the entire project.

9.4 Presenting Project Schedules

Communicating the project schedule is a vital ingredient in successful project Construction management. A good presentation will greatly ease the manager's problem of understanding the multitude of activities and their inter-relationships. Moreover, numerous individuals and parties are involved in any project, and they have to understand their assignments. *Graphical* presentations of project schedules are particularly useful since it is much easier to comprehend a graphical display of numerous pieces of information than to sift through a large table of numbers.

Network diagrams for projects have already been introduced. These diagrams provide a powerful visualization of the precedencies and relationships among the various project activities. They are a basic means of communicating a project plan among the participating planners and project monitors.



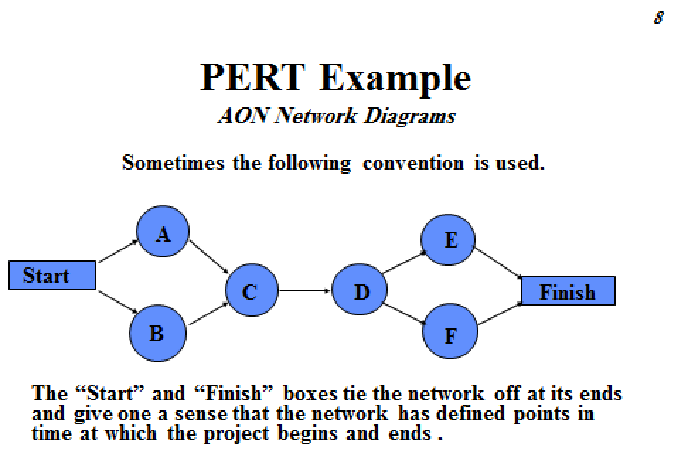


Figure 9.4a an Example Network Diagram

Another useful graphical representation tool is a bar or Gantt chart illustrating the scheduled time for each activity. The bar chart lists activities and shows their scheduled start, finish and duration. Activities are listed in the vertical axis, while time since project commencement is shown along the horizontal axis. During the course of *monitoring* a project, useful additions to the basic bar chart include a vertical line to indicate the current time plus small marks to indicate the current state of work on each activity.

Figure 9.4b an Example Bar Chart

SAUDCONSULT

Resident Engineering Manual SCHEDULE (Revised to 1st Base line Schedule)

Base Line Schedule (Planned)
Actual Progress
Behind Schedule

30thJan. 2013 Cut Off Date

ACTIVITY DESCRIPTION	Start Date	Finish Date	% Actual Completed	Nov. 2012	Dec. 2012	Jan. 2013	Feb. 2013	Mar. 2013	Apr-13	May-13
				w1 w2 w3 w4	w1 w2 w3 w4	w1 w2 w3 w4	w1 w2 w3 w4	w1 w2 w3 w4	w1 w2 w3 w4	w1 w2 w3 w4
Original Base Line Schedule	01st Nov. 2012	14th apr. 2013								
Revised 1st Base Line Schedule	01st Nov. 2012	21st Qpr. 2013								
Data Collection, Evaluation & Assesment										
Available ISO Manuals										
Company Organization Chart										
Available Manulas (Supervision & P. Management)										
List of current on going Projects(Oct. 2012 update)										
Annual review of QC Committee-2011	1-Nov-2012	7-Mar-2013								
Executive Summary Report (3rd Quarterly Report Sept. 2012)			65%							
Example Report (no. 22) from "SCInformation center fo Supervision Projects "										
…… Etc.										
Resident Engineering Manual										
Preparation/ Finalization of of Manual Table of contents (M-TOC)	1-Dec-2012	15-Dec-2012	100%							
Complete Procedures details (narrative)	22-Dec-2012	7-Feb-2013	100%	85.71% Scheduled						
			14.30%	Ahead of Schedule						
Complete Procedures (Flow Charts)	7-Feb-2013	21-Feb-2013								
Complete Procedures (Generic Forms)	21-Feb-2013	14-Mar-2013								
Complete Supervision Staff, Organization, Job Description/Duties & Responsibilities	14-Mar-2013	28-Mar-2013								
Loading the Manual on line with proper links	28-Mar-2013	22-Apr-2013								

Sr.	CORE TEAM	No.	Yrs Exp.		2012	2013
	Jehad Bakeer	1				
	Sherief (Sec .)- Joined 8th Dec. 2012	1				
	IT Dept.	?				

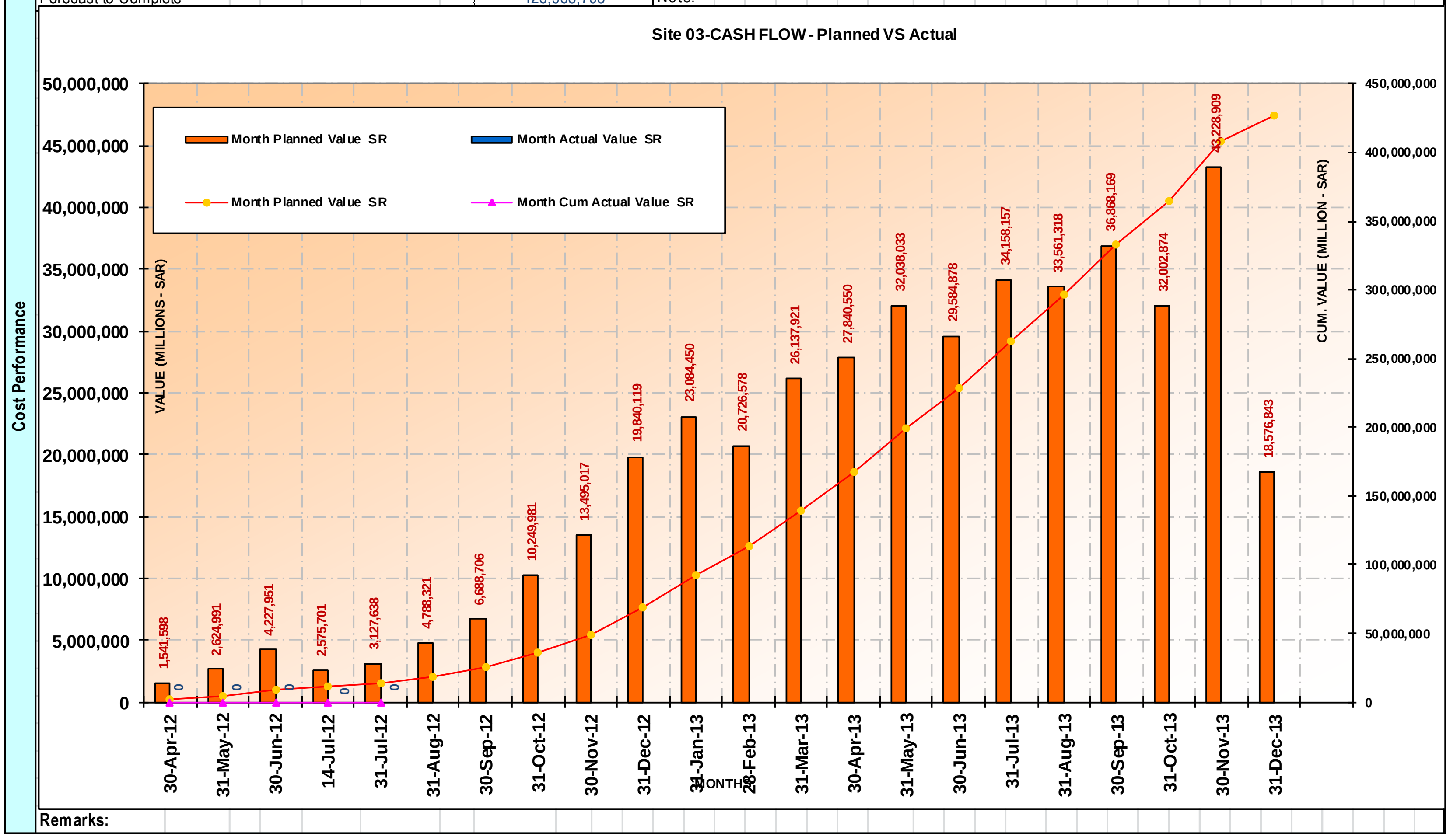
NOTE:- Review Periods ARE NOT Included

30thJan. 2013 Cut Off Date

Bar charts are particularly helpful for communicating the current state and schedule of activities on a project. As such, they have found wide acceptance as a project representation tool in the field. For planning purposes, bar charts are not as useful since they do not indicate the precedence relationships among activities. Thus, a planner must remember or record separately that a change in one activity's schedule may require changes to successor activities. There have been various schemes for mechanically linking activity bars to represent precedencies, but it is now easier to use computer based tools to represent such relationships.

Other graphical representations are also useful in project monitoring. Time and activity graphs are extremely useful in portraying the current status of a project. Times versus completion curves are also useful in project monitoring. Not only the history of the project can be indicated, but the future possibilities for earliest and latest start times

Original Contract Value	426,968,703	Approved Variations	0	0	Nos	Planned Cost	10,970,241
Current Contract Value	426,968,703	Pending Variations	0	0	Nos	Actual Cost	0
Forecast at Completion	426,968,703	Potential Variations	0	0	Nos	Earned Value Cost	-2.57%
Forecast to Complete	426,968,703	Note:					



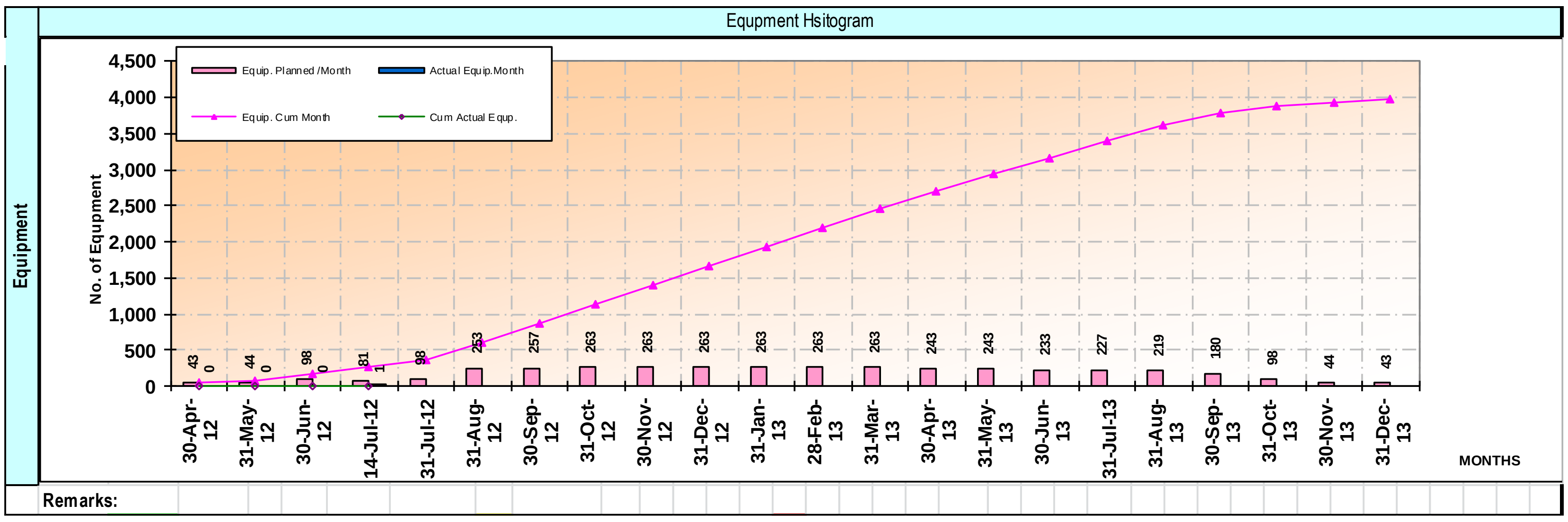


Figure 9.4C Example of Time and activity graphs

The use of graphical project representations is an important and extremely useful aid to planners and managers. Of course, detailed numerical reports may also be required to check the peculiarities of particular activities. But graphs and diagrams provide an invaluable means of rapidly communicating or understanding a project schedule. With computer based storage of basic project data, graphical output is readily obtainable and should be used whenever possible.

Back to the Table of Contents

CHAPTER-10

Cost Control, Monitoring and Accounting

10.1 The Cost Control Problem

During the execution of a project, procedures for project control and record keeping become indispensable tools to managers and other participants in the construction process. These tools serve the dual purpose of recording the financial transactions that occur as well as giving managers an indication of the progress and problems associated with a project. The problems of project control are aptly summed up in an old definition of a project as "any collection of vaguely related activities that are ninety percent complete, over budget and late''. The task of project control systems is to give a fair indication of the existence and the extent of such problems.

Project control procedures are primarily intended to identify deviations from the project plan rather than to suggest possible areas for cost savings. This characteristic reflects the advanced stage at which project control becomes important. The time at which major cost savings can be achieved is during planning and design for the project. During the actual construction, changes are likely to delay the project and lead to inordinate cost increases. As a result, the focus of project control is on fulfilling the original design plans or indicating deviations from these plans, rather than on searching for significant improvements and cost savings. It is only when a rescue operation is required that major changes will normally occur in the construction plan.

10.2 The Project Budget

For cost control on a project, the construction plan and the associated cash flow estimates can provide the baseline reference for subsequent project monitoring and control. For schedules, progress on individual activities and the achievement of milestone completions can be compared with the project schedule to monitor the progress of activities. Contract and job specifications provide the criteria by which to assess and assure the required quality of construction. The final or detailed cost estimate provides a baseline for the assessment of financial performance during the project. To the extent that costs are within the detailed cost estimate, then the project is thought to be under financial control. Overruns in particular cost categories signal the possibility of problems and give an indication of exactly what problems are being encountered. Expense oriented construction planning and control focuses upon the categories included in the final cost estimation. This focus is particular relevant for projects with few activities and considerable repetition such as grading and paving roadways.

For control and monitoring purposes, the original detailed cost estimate is typically converted to a project budget, and the project budget is used subsequently as a guide for management. Specific items in the detailed cost estimate become job cost elements. Expenses incurred during the course of a project are recorded in specific job cost accounts to be compared with the original cost estimates in each category. Thus, individual job cost accounts generally represent the basic unit for cost control. Alternatively, job cost accounts may be disaggregated or divided into work elements which are related both to particular scheduled activities and to particular cost accounts.

In addition to cost amounts, information on material quantities and labor inputs within each job account is also typically retained in the project budget. With this information, actual materials usage and labor employed can be compared to the expected requirements. As a result, cost overruns or savings on particular items can be identified as due to changes in unit prices, labor productivity or in the amount of material consumed.

Converting a final cost estimate into a project budget compatible with an organization's cost accounts is not always a straightforward task. As described in Chapter 5, cost estimates are generally disaggregated into appropriate functional or resource based project categories. For example, labor and material quantities might be included for each of several physical components of a project. For cost accounting purposes, labor and material quantities are aggregated by type no matter for which physical component they are employed.

10.3Forecasting for Activity Cost Control

For the purpose of project Construction management and control, it is not sufficient to consider only the past record of costs and revenues incurred in a project. Good managers should focus upon future revenues, future costs and technical problems. For this purpose, traditional financial accounting schemes are not adequate to reflect the dynamic nature of a project. Accounts typically focus on recording routine costs and past expenditures associated with activities. Generally, past expenditures represent *sunk costs* that cannot be altered in the future and may or may not be relevant in the future. For example, after the completion of some activity, it may be discovered that some quality flaw renders the work useless. Unfortunately, the resources expended on the flawed construction will generally be *sunk* and cannot be recovered for re-construction (although it may be possible to change the burden of who pays for these resources by financial withholding or charges; owners will typically attempt to have constructors or designers pay for changes due to quality flaws). Since financial accounts are historical in nature, some means of forecasting or projecting the future course of a project is essential for management control. In this section, some methods for cost control and simple forecasts are described.

Forecasting is used to assess the project status, costs are reported in five categories, representing the sum of all the various cost accounts associated with each category:

- **Budgeted Cost**
  The budgeted cost is derived from the detailed cost estimate prepared at the start of the project. The factors of cost would be referenced by cost account and by a prose description.

  Estimated-total cost

  The estimated or forecast total cost in each category is the current best estimate of costs based on progress and any changes since the budget was formed. Estimated total costs are the sum of cost to date, commitments and exposure.

  Methods for estimating total costs are described below.

- **Cost Committed and Cost Exposure**!! Estimated cost to completion in each category is divided into firm commitments and estimated additional cost or *exposure.* Commitments may represent material orders or subcontracts for which firm dollar amounts have been committed.
- **Cost to Date**
  The actual cost incurred to date is recorded and can be derived from the financial record keeping accounts.
- **Over or (Under)**
  The amount over or under the budget for each category. This becomes an indicator of the extent of variance from the project budget; items with unusually large overruns would represent a particular managerial concern. Note that *variance* is used in the terminology of project control to indicate a difference between budgeted and actual expenditures.
- The current status of the project is a forecast budget overrun/under percent of the budgeted project costs incurred to date.

For project control, managers would focus particular attention on items indicating substantial deviation from budgeted amounts. In particular, the cost overruns in the labor and in the “other expense categories” would be worthy of attention by a project Construction manager. A next step would be to look in greater detail at the various components of these categories. Overruns in cost might be due to lower than expected productivity, higher than expected wage rates, higher than expected material costs, or other factors. Even further, low productivity might be caused by inadequate training, lack of required resources such as equipment or tools, or inordinate amounts of re-work to correct quality problems. Review of a job status report is only the first step in project control.

In addition to changes in productivities, other components of the estimating formula can be adjusted or more detailed estimates substituted. For example, the change in unit prices due to new labor contracts or material supplier's prices might be reflected in estimating future expenditures. In essence, the same problems encountered in preparing the detailed cost estimate are faced in the process of preparing exposure estimates, although the number and extent of uncertainties in the project environment decline as work progresses. The only exception to this rule is the danger of quality problems in completed work which would require re-construction.

10.4 Financial Accounting Systems and Cost Accounts

The cost accounts described in the previous sections provide only one of the various components in a financial accounting system. Before further discussing the use of cost accounts in project control, the relationship of project and financial accounting deserves mention. Accounting information is generally used for three distinct purposes:

- Internal reporting to project Construction managers for day-to-day planning, monitoring and control.
- Internal reporting to managers for aiding strategic planning.
- External reporting to owners, government, regulators and other outside parties.

External reports are constrained to particular forms and procedures by contractual reporting requirements or by generally accepted accounting practices. Preparation of such external reports is referred to as *financial accounting*. In contrast, *cost* or *managerial* accounting is intended to aid internal managers in their responsibilities of planning, monitoring and control.

Project costs are always included in the system of financial accounts associated with an organization. At the heart of this system, all expense transactions are recorded in a general ledger. The general ledger of accounts forms the basis for management reports on particular projects as well as the financial accounts for an entire organization. Other components of a financial accounting system include:

- The **accounts payable** journal is intended to provide records of bills received from vendors, material suppliers, subcontractors and other outside parties. Invoices of charges are recorded in this system as are checks issued in payment. Charges to individual cost accounts are relayed or *posted* to the General Ledger.
- **Accounts receivable journals** provide the opposite function to that of accounts payable. In this journal, billings to clients are recorded as well as receipts. Revenues received are relayed to the general ledger.
- **Job cost ledgers** summarize the charges associated with particular projects, arranged in the various cost accounts used for the project budget.
- **Inventory** records are maintained to identify the amount of materials available at any time.

In traditional bookkeeping systems, day to day transactions are first recorded in journals. With double-entry bookkeeping, each transaction is recorded as both a debit and a credit to particular accounts in the ledger. For example, payment of a supplier's bill represents a debit or increase to a project cost account and a credit or reduction to the company's cash account. Periodically, the transaction information is summarized and transferred to ledger accounts. This process is called *posting*, and may be done instantaneously or daily in computerized systems.

In reviewing accounting information, the concepts of *flows* and *stocks* should be kept in mind. Daily transactions typically reflect flows of value amounts entering or leaving the organization. Similarly, use or receipt of particular materials represents flows from or to inventory. An account balance represents the *stock* or cumulative amount of funds resulting from these daily flows. Information on both flows and stocks are needed to give an accurate view of an organization's state. In addition, forecasts of future changes are needed for effective management.

Information from the general ledger is assembled for the organization's financial reports, including balance sheets and income statements for each period. These reports are the basic products of the financial accounting process and are often used to assess the performance of an organization. The balance sheet reflects the effects of income flows during the year on the overall worth of the organization.

Today's management accounting information, driven by the procedures and cycle of the organization's financial reporting system, is too late, too aggregated and too distorted to be relevant for managers' planning and control decisions.

Management accounting reports are of little help to operating managers as they attempt to reduce costs and improve productivity. Frequently, the reports decrease productivity because they require operating managers to spend time attempting to understand and explain reported variances that have little to do with the economic and technological reality of their operations...

The management accounting system also fails to provide accurate product costs. Cost are distributed to products by simplistic and arbitrary measures, usually direct labor based, that do not represent the demands made by each product on the firm's resources.

As a result, complementary procedures to those used in traditional financial accounting are required to accomplish effective project control, as described in the preceding and following sections. While financial statements provide consistent and essential information on the condition of an entire organization, they need considerable interpretation and supplementation to be useful for project Construction management.

10.5 Control of Project Cash Flows

Project Construction managers are involved with assessment of the overall status of the project, including the status of activities, financing, payments and receipts. These various items comprise the project and financing cash flows described in earlier chapters. These components include costs incurred (as described above), billings and receipts for billings to owners (for contractors), payable amounts to suppliers and contractors, financing plan cash flows (for bonds or other financial instruments), etc.

A summary of the project status as viewed from different components of the accounting system should include:

- **Costs**
  A summary of charges as reflected by the job cost accounts, including expenditures and estimated costs. This provides an aggregate summary of the detailed activity cost information The estimate should reflect the actual percentage of work completed as well as other effects such as changes in unit prices for labor or materials..
- **Billings**
  Summarizes the state of cash flows with respect to the owner of the facility.

- **Payables**
  The Payables summarizes the amount owed by the contractor to material suppliers, labor or sub-contractors.
- **Receivables**
  Summarizes the cash flow of receipts from the owner. Note that sometimes the actual receipts from the owner may differ from the amounts billed due to delayed payments or retainage on the part of the owner.
- **Cash Position**
  summarizes the cash position of the project as if all expenses and receipts for the project were combined in a single account.

10.6 Schedule Control

In addition to cost control, project Construction managers must also give considerable attention to monitoring schedules. Construction typically involves a deadline for work completion, so contractual agreements will force attention to schedules. More generally, delays in construction represent additional costs due to late facility occupancy or other factors. Just as costs incurred are compared to budgeted costs, actual activity durations may be compared to expected durations. In this process, forecasting the time to complete particular activities may be required.

Schedule adherence and the current status of a project can also be represented on geometric models of a facility. For example, an animation of the construction sequence can be shown on a computer screen, with different colors or other coding scheme indicating the type of activity underway on each component of the facility. Deviations from the planned schedule can also be portrayed by color coding. The result is a mechanism to both indicate work in progress and schedule adherence specific to individual components in the facility.

In evaluating schedule progress, it is important to bear in mind that some activities possess float or scheduling leeway, whereas delays in activities on the critical path will cause project delays. In particular, the delay in planned progress at time t may be soaked up in activities' float (thereby causing no overall delay in the project completion) or may cause a project delay. As a result of this ambiguity, it is preferable to update the project schedule to devise an accurate portrayal of the schedule adherence. After applying a scheduling algorithm, a new project schedule can be obtained. For cash flow planning purposes, a graph or report can be constructed to compare actual expenditures to planned expenditures at any time. This process of re-scheduling to indicate the schedule adherence is only one of many instances in which schedule and budget updating may be appropriate.

10.7 Schedule and Budget Updates

Scheduling and project planning is an activity that continues throughout the lifetime of a project. As changes or discrepancies between the plan and the realization occur, the project schedule and cost estimates should be modified and new schedules devised. Too often, the schedule is devised once by a planner in the central office, and then revisions or modifications are done incompletely or only sporadically. The result is the lack of effective project monitoring and the possibility of eventual chaos on the project site.

On "fast track" projects, initial construction activities are begun even before the facility design is finalized. In this case, special attention must be placed on the coordinated scheduling of design and construction activities. Even in projects for which the design is finalized before construction begins, *change orders* representing changes in the "final" design are often issued to incorporate changes desired by the owner.

Periodic updating of future activity durations and budgets is especially important to avoid excessive optimism in projects experiencing problems. If one type of activity experiences delays on a project, then related activities are also likely to be delayed unless managerial changes are made. Construction projects normally involve numerous activities which are closely related due to the use of similar materials, equipment, workers or site characteristics. Expected cost changes should also be propagated throughout a project plan. In essence, duration and cost estimates for future activities should be revised in light of the actual experience on the job. Without this updating, project schedules slip more and more as time progresses. To perform this type of updating, project Construction managers need access to original estimates and estimating assumptions.

Unfortunately, most project cost control and scheduling systems do not provide many aids for such updating. What is required is a means of identifying discrepancies, diagnosing the cause, forecasting the effect, and propagating this effect to all related activities. While these steps can be undertaken manually, computers aids to support interactive updating or even automatic updating would be helpful.

Beyond the direct updating of activity durations and cost estimates, project managers should have mechanisms available for evaluating any type of schedule change. Updating activity duration estimations, changing scheduled start times, modifying the estimates of resources required for each activity, and even changing the project network logic (by inserting new activities or other changes) should all be easily accomplished. In effect, scheduling aids should be directly available to project Construction managers. Fortunately, local computers are commonly available on site for this purpose.

10.8 Relating Cost and Schedule Information

The previous sections focused upon the identification of the budgetary and schedule status of projects. Actual projects involve a complex inter-relationship between time and cost. As projects proceed, delays influence costs and budgetary problems may in turn require adjustments to activity schedules. Trade-offs between time and costs in which additional resources applied to a project activity might result in a shorter duration but higher costs. Unanticipated events might result in increases in both time and cost to complete an activity. For example, excavation problems may easily lead to much lower than anticipated productivity on activities requiring digging.

While project managers implicitly recognize the inter-play between time and cost on projects, it is rare to find effective project control systems which include both elements. Usually, project costs and schedules are recorded and reported by separate application programs. Project Construction managers must then perform the tedious task of relating the two sets of information.

The difficulty of integrating schedule and cost information stems primarily from the level of detail required for effective integration. Usually, a single project activity will involve numerous cost account categories. For example, an activity for the preparation of a foundation would involve laborers, cement workers, concrete forms, concrete, reinforcement, transportation of materials and other resources. Even a more disaggregated activity definition such as erection of foundation forms would involve numerous resources such as forms, nails, carpenters, laborers, and material transportation. Again, different cost accounts would normally be used to record these various resources. Similarly, numerous activities might involve expenses associated with particular cost accounts. For example, a particular material such as standard piping might be used in numerous different schedule activities. To integrate cost and schedule information, the disaggregated charges for specific activities and specific cost accounts must be the basis of analysis.

A straightforward means of relating time and cost information is to define individual *work elements* representing the resources in a particular cost category associated with a particular project activity. Work elements would represent an element in a two-dimensional matrix of activities and cost accounts. A numbering or identifying system for work elements would include both the relevant cost account and the associated activity. In some cases, it might also be desirable to identify work elements by the responsible organization or individual. In this case, a three dimensional representation of work elements is required, with the third dimension corresponding to responsible individuals. More generally, modern computerized databases can accommodate a flexible structure of data representation to support aggregation with respect to numerous different perspectives.

With this organization of information, a number of management reports or views could be generated. These costs could be used to evaluate alternate technologies to accomplish particular activities or to derive the expected project cash flow over time as the schedule changes. From a management perspective, problems developing from particular activities could be rapidly identified since costs would be accumulated at such a disaggregated level. As a result, project control becomes at once more precise and detailed.

Until data collection is better automated, the use of work elements to control activities in large projects is likely to be difficult to implement. However, certain segments of project activities can profit tremendously from this type of organization. In particular, material requirements can be tracked in this fashion. Materials involve only a subset of all cost accounts and project activities, so the burden of data collection and control is much smaller than for an entire system. Moreover, the benefits from integration of schedule and cost information are particularly noticeable in materials control since delivery schedules are directly affected and bulk order discounts might be identified. Consequently, materials control systems can reasonably encompass a "work element" accounting system.
In the absence of a work element accounting system, costs associated with particular activities are usually estimated by summing expenses in all cost accounts directly related to an activity plus a proportion of expenses in cost accounts used jointly by two or more activities. The basis of cost allocation would typically be the level of effort or resource required by the different activities. For example, costs associated with supervision might be allocated to different concreting activities on the basis of the amount of work (measured in cubic meters of concrete) in the different activities. With these allocations, cost estimates for particular work activities can be obtained.

Back to the Table of Contents

CHAPTER-11

Quality Control and Safety During Construction

11.1 Quality and Safety Concerns in Construction

Quality control and safety represent increasingly important concerns for project Construction managers. Defects or failures in constructed facilities can result in very large costs. Even with minor defects, re-construction may be required and facility operations impaired. Increased costs and delays are the result. In the worst case, failures may cause personal injuries or fatalities. Accidents during the construction process can similarly result in personal injuries and large costs. Indirect costs of insurance, inspection and regulation are increasing rapidly due to these increased direct costs. Good project Construction managers try to ensure that the job is done right the first time and that no major accidents occur on the project.

As with cost control, the most important decisions regarding the quality of a completed facility are made during the design and planning stages rather than during construction. It is during these preliminary stages that component configurations, material specifications and functional performance are decided. Quality control during construction consists largely of insuring *conformance* to these original design and planning decisions.

While conformance to existing design decisions is the primary focus of quality control, there are exceptions to this rule. First, unforeseen circumstances, incorrect design decisions or changes desired by an owner in the facility function may require re-evaluation of design decisions during the course of construction. While these changes may be motivated by the concern for quality, they represent occasions for re-design with all the attendant objectives and constraints. As a second case, some designs rely upon informed and appropriate decision making during the construction process itself. For example, some tunneling methods make decisions about the amount of shoring required at different locations based upon observation of soil conditions during the tunneling process. Since such decisions are based on better information concerning actual site conditions, the facility design may be more cost effective as a result.

With the attention to conformance as the measure of quality during the construction process, the specification of quality requirements in the design and contract documentation becomes extremely important. Quality requirements should be clear and verifiable, so that all parties in the project can understand the requirements for conformance. Much of the discussion in this chapter relates to the development and the implications of different quality requirements for construction as well as the issues associated with insuring conformance.

Safety during the construction project is also influenced in large part by decisions made during the planning and design process. Some designs or construction plans are inherently difficult and dangerous to implement, whereas other, comparable plans may considerably reduce the possibility of accidents. For example, clear separation of traffic from construction zones during roadway rehabilitation can greatly reduce the possibility of accidental collisions. Beyond these design decisions, safety largely depends upon education, vigilance and cooperation during the construction process. Workers should be constantly alert to the possibilities of accidents and avoid taken unnecessary risks.

11.2 Organizing for Quality and Safety

A variety of different organizations are possible for quality and safety control during construction. One common model is to have a group responsible for quality assurance and another group primarily responsible for safety within an organization. In large organizations, departments dedicated to quality assurance and to safety might assign specific individuals to assume responsibility for these functions on particular projects. For smaller projects, the project Construction manager or an assistant might assume these and other responsibilities. In either case, insuring safe and quality construction is a concern of the project Construction manager in overall charge of the project in addition to the concerns of personnel, cost, time and other management issues.

Inspectors and quality assurance personnel will be involved in a project to represent a variety of different organizations. Each of the parties directly concerned with the project may have their own quality and safety inspectors, including the owner, the engineer/architect, and the various constructor firms. These inspectors may be contractors from specialized quality assurance organizations. In addition to on-site inspections, samples of materials will commonly be tested by specialized laboratories to insure compliance. Inspectors to insure compliance with regulatory requirements will also be involved. Common examples are inspectors for the local government's building department, for environmental agencies, and for occupational health and safety agencies.

While the multitude of participants involved in the construction process require the services of inspectors, it cannot be emphasized too strongly that inspectors are only a formal check on quality control. Quality control should be a primary objective for all the members of a project team. Managers should take responsibility for maintaining and improving quality control. Employee participation in quality control should be sought and rewarded, including the introduction of new ideas. Most important of all, quality improvement can serve as a catalyst for improved productivity. By suggesting new work methods, by avoiding rework, and by avoiding long term problems, good quality control can pay for itself. Owners should promote good quality control and seek out contractors who maintain such standards.

In addition to the various organizational bodies involved in quality control, issues of quality control arise in virtually all the functional areas of construction activities. For example, insuring accurate and useful information is an important part of maintaining quality performance. Other aspects of quality control include document control (including changes during the construction process), procurement, field inspection and testing, and final checkout of the facility.

11.3 Work and Material Specifications

Specifications of work quality are an important feature of facility designs. Specifications of required quality and components represent part of the necessary documentation to describe a facility. Typically, this documentation includes any special provisions of the facility design as well as references to generally accepted specifications to be used during construction.

General specifications of work quality are available in numerous fields and are issued in publications of organizations such as the American Society for Testing and Materials (ASTM), the American National Standards Institute (ANSI), or the Construction Specifications Institute (CSI). Distinct specifications are formalized for particular types of construction activities, such as welding standards issued by the American Welding Society, or for particular facility types, such as the *Standard Specifications for Highway Bridges* issued by the American Association of State Highway and Transportation Officials. These general specifications must be modified to reflect local conditions, policies, available materials, local regulations and other special circumstances.

Construction specifications normally consist of a series of instructions or prohibitions for specific operations. For example, the following passage illustrates a typical specification, in this case for excavation for structures:

Conform to elevations and dimensions shown on plan within a tolerance of plus or minus 2.54 millimeters, and extending a sufficient distance from footings and foundations to permit placing and removal of concrete formwork, installation of services, other construction, and for inspection. In excavating for footings and foundations, take care not to disturb bottom of excavation. Excavate by hand to *final grade just before concrete reinforcement is placed. Trim bottoms to required lines and grades to leave solid base to receive concrete.*

This set of specifications requires judgment in application since some items are not precisely specified. For example, excavation must extend a "sufficient" distance to permit inspection and other activities. Obviously, the term "sufficient" in this case may be subject to varying interpretations. In contrast, a specification that tolerances are within plus or minus *2.54 millimeters* is subject to direct measurement. However, specific requirements of the facility or characteristics of the site may make the standard tolerance of *2.54 millimeters* inappropriate. Writing specifications typically requires a trade-off between assuming reasonable behavior on the part of all the parties concerned in interpreting words such as "sufficient" versus the effort and possible inaccuracy in pre-specifying all operations.

In recent years, *performance specifications* have been developed for many construction operations. Rather than specifying the required construction *process,* these specifications refer to the required performance or quality of the finished facility. The exact method by which this performance is obtained is left to the construction contractor. For example, *traditional specifications for asphalt pavement specified the composition of the asphalt material, the asphalt temperature during paving, and compacting procedures*. In contrast, *a performance specification for asphalt would detail the desired performance of the pavement with respect to impermeability, strength, etc*. How the desired performance level was attained would be up to the paving contractor. In some cases, the payment for asphalt paving might increase with better quality of asphalt beyond some minimum level of performance.

11.4 Total Quality Control

Quality control in construction typically involves insuring compliance with minimum standards of material and workmanship in order to insure the performance of the facility according to the design. For the purpose of insuring compliance, *random samples and statistical methods are commonly used as the basis for accepting or rejecting work completed and batches of materials*. Rejection of a batch is based on *non-conformance or violation of the relevant design specifications*. Procedures for this quality control practice are described in the following sections.

An implicit assumption in these traditional quality control practices is the notion of an *acceptable quality level* which is an allowable fraction of defective items. Materials obtained from suppliers or work performed by an organization is inspected and passed as acceptable if the estimated defective percentage is within the acceptable quality level. Problems with materials or goods are corrected after delivery of the product.

In contrast to this traditional approach of quality control is the goal of *total quality control*. In this system, no defective items are allowed anywhere in the construction process. While the zero defects goal can never be permanently obtained, it provides a goal so that an organization is never satisfied with its quality control program even if defects are reduced by substantial amounts year after year. This concept and approach to quality control was first developed in manufacturing firms in Japan and Europe, but has since spread to many construction companies. The best known formal certification for quality improvement is the International Organization for Standardization's ISO 9000 standard. ISO 9000 emphasizes good documentation, quality goals and a series of cycles of planning, implementation and review.

Total quality control is a commitment to quality expressed in all parts of an organization and typically involves many elements. Design reviews to insure safe and effective construction procedures are a major element. Other elements include extensive training for personnel, shifting the responsibility for detecting defects from quality control inspectors to workers, and continually maintaining equipment. Worker involvement in improved quality control is often formalized in *quality circles* in which groups of workers meet regularly to make suggestions for quality improvement. Material suppliers are also required to insure zero defects in delivered goods. Initially, all materials from a supplier are inspected and batches of goods with any defective items are returned. Suppliers with good records can be certified and not subject to complete inspection subsequently.

The traditional microeconomic view of quality control is that there is an "optimum" proportion of defective items. Trying to achieve greater quality than this optimum would substantially increase costs of inspection and reduce worker productivity. However, many companies have found that commitment to total quality control has substantial economic benefits that had been unappreciated in traditional approaches. Expenses associated with inventory, rework, scrap and warranties were reduced. Worker enthusiasm and commitment improved. Customers often appreciated higher quality work and would pay a premium for good quality. As a result, improved quality control became a competitive advantage.

Of course, total quality control is difficult to apply, particular in construction. The unique nature of each facility, the variability in the workforce, the multitude of subcontractors and the cost of making necessary investments in education and procedures make programs of total quality control in construction difficult.

Nevertheless, a commitment to improved quality even without endorsing the goal of zero defects can pay real dividends to organizations.

11.5 Quality Control by Statistical Methods

An ideal quality control program might test all materials and work on a particular facility. For example, non-destructive techniques such as x-ray inspection of welds can be used throughout a facility. An on-site inspector can witness the appropriateness and adequacy of construction methods at all times. Even better, individual craftsmen can perform continuing inspection of materials and their own work. Exhaustive or 100% testing of all materials and work by inspectors can be exceedingly expensive, however. In many instances, testing requires the destruction of a material sample, so exhaustive testing is not even possible. As a result, small samples are used to establish the basis of accepting or rejecting a particular work item or shipment of materials. Statistical methods are used to interpret the results of test on a small sample to reach a conclusion concerning the acceptability of an entire *lot* or batch of materials or work products.

The use of statistics is essential in interpreting the results of testing on a small sample. Without adequate interpretation, small sample testing results can be quite misleading. As an example, suppose that there are ten defective pieces of material in a lot of one hundred. In taking a sample of five pieces, the inspector might not find *any* defective pieces or might have *all* sample pieces defective. Drawing a direct inference that none or all pieces in the population are defective on the basis of these samples would be incorrect. Due to this random nature of the sample selection process, testing results can vary substantially. It is only with statistical methods that issues such as the chance of different levels of defective items in the full lot can be fully analyzed from a small sample test.

There are two types of statistical sampling which are commonly used for the purpose of quality control in batches of work or materials:

1. The acceptance or rejection of a lot is based on the number of defective (bad) or non-defective (good) items in the sample. This is referred to as *sampling by attributes*.
2. Instead of using defective and non-defective classifications for an item, a quantitative quality measure or the value of a measured variable is used as a quality indicator. This testing procedure is referred to as *sampling by variables*.

Whatever sampling plan is used in testing, it is always assumed that the samples are representative of the entire population under consideration. Samples are expected to be chosen randomly so that each member of the population is equally likely to be chosen. Convenient sampling plans such as sampling every twentieth piece, choosing a sample every two hours, or picking the top piece on a delivery truck may be adequate to insure a random sample if pieces are randomly mixed in a stack or in use. However, some convenient sampling plans can be inappropriate. For example, checking only easily accessible joints in a building component is inappropriate since joints that are hard to reach may be more likely to have erection or fabrication problems.

Another assumption implicit in statistical quality control procedures is that the quality of materials or work is expected to vary from one piece to another. This is certainly true in the field of construction. While a designer may assume that all concrete is exactly the same in a building, the variations in material properties, manufacturing, handling, pouring, and temperature during setting insure that concrete is actually heterogeneous in quality. Reducing such variations to a minimum is one aspect of quality construction. Insuring that the materials actually placed achieve some minimum quality level with respect to average properties or fraction of defectives is the task of quality control.

11.6 Statistical Quality Control with Sampling by Attributes

Sampling by attributes is a widely applied quality control method. The procedure is intended to determine whether or not a particular group of materials or work products is acceptable. In the literature of statistical quality control, a group of materials or work items to be tested is called a lot or batch. An assumption in the procedure is that each item in a batch can be tested and classified as either acceptable or deficient based upon mutually acceptable testing procedures and acceptance criteria. Each lot is tested to determine if it satisfies a minimum acceptable quality level (AQL) expressed as the maximum percentage of defective items in a lot or process.

In its basic form, sampling by attributes is applied by testing a pre-defined number of sample items from a lot. If the number of defective items is greater than a trigger level, then the lot is rejected as being likely to be of unacceptable quality. Otherwise, the lot is accepted. Developing this type of sampling plan requires consideration of probability, statistics and acceptable risk levels on the part of the supplier and consumer of the lot. Refinements to this basic application procedure are also possible. For example, if the number of defectives is greater than some pre-defined number, then additional sampling may be started rather than immediate rejection of the lot. In many cases, the trigger level is a single defective item in the sample. In the remainder of this section, the mathematical basis for interpreting this type of sampling plan is developed.

11.7 Statistical Quality Control with Sampling by Variables

As described in the previous section, sampling by attributes is based on a classification of items as good or defective. Many work and material attributes possess continuous properties, such as strength, density or length. With the sampling by attributes procedure, a particular level of a variable quantity must be defined as acceptable quality. More generally, two items classified as good might have quite different strengths or other attributes. Intuitively, it seems reasonable that some "credit" should be provided for exceptionally good items in a sample. Sampling by variables was developed for application to continuously measurable quantities of this type. The procedure uses measured values of an attribute in a sample to determine the overall acceptability of a batch or lot. Sampling by variables has the advantage of using more information from tests since it is based on actual measured values rather than a simple classification. As a result, acceptance sampling by variables can be more efficient than sampling by attributes in the sense that fewer samples are required to obtain a desired level of quality control.

To summarize, the application of sampling by variables requires the specification of a sample size, the relevant upper or limits, and either (1) the allowable fraction of items falling outside the designated limits or (2) the allowable probability that the population average falls outside the designated limit. Random samples are drawn from a pre-defined population and tested to obtained measured values of a variable attribute. From these measurements, the sample mean, standard deviation, and quality control test statistic are calculated. Finally, the test statistic is compared to the allowable trigger level and the lot is either accepted or rejected. It is also possible to apply sequential sampling in this procedure, so that a batch may be subjected to additional sampling and testing to further refine the test statistic values.

With sampling by variables, it is notable that a producer of material or work can adopt two general strategies for meeting the required specifications. First, a producer may insure that the average quality level is quite high, even if the variability among items is high. Second, a producer may meet a desired quality target by reducing the variability within each batch. In either case, a producer should maintain high.

11.8 Safety

Construction is a relatively hazardous undertaking. There are significantly more injuries and lost workdays due to injuries or illnesses in construction than in virtually any other industry. Work related injuries and illnesses cost Include direct costs (medical costs, premiums for workers' compensation benefits, liability and property losses) as well as indirect costs (reduced worker productivity, delays in projects, administrative time, and damage to equipment and the facility). In contrast to most industrial accidents, innocent bystanders may also be injured by construction accidents. Several crane collapses from high rise buildings under construction have resulted in fatalities to passerby's. Prudent project Construction managers and owners would like to reduce accidents, injuries and illnesses as much as possible.

As with all the other costs of construction, it is a mistake for owners to ignore a significant category of costs such as injury and illnesses. While contractors may pay insurance premiums directly, these costs are reflected in bid prices or contract amounts. Delays caused by injuries and illnesses can present significant opportunity costs to owners. In the long run, the owners of constructed facilities must pay all the costs of construction. For the case of injuries and illnesses, this general principle might be slightly qualified since significant costs are borne by workers themselves or society at large. However, court judgments and insurance payments compensate for individual losses and are ultimately borne by the owners.

The causes of injuries in construction are numerous. The largest single category for both injuries and fatalities are individual falls. Handling goods and transportation are also a significant cause of injuries. From a management perspective, however, these reported causes do not really provide a useful prescription for safety policies. An individual fall may be caused by a series of coincidences: a railing might not be secure, a worker might be inattentive, the footing may be slippery, etc. Removing any one of these compound causes might serve to prevent any particular accident. However, it is clear that conditions such as unsecured railings will normally increase the risk of accidents.

Various measures are available to improve jobsite safety in construction. Several of the most important occur before construction is undertaken. These include design, choice of technology and education. By altering facility designs, particular structures can be safer or more hazardous to construct. For example, parapets can be designed to appropriate heights for construction worker safety, rather than the minimum height required by building codes.

Choice of technology can also be critical in determining the safety of a jobsite. Safeguards built into machinery can notify operators of problems or prevent injuries. For example, simple switches can prevent equipment from being operating when protective shields are not in place. With the availability of on-board electronics (including computer chips) and sensors, the possibilities for sophisticated machine controllers and monitors has greatly expanded for construction equipment and tools. Materials and work process choices also influence the safety of construction. For example, substitution of alternative materials for asbestos can reduce or eliminate the prospects of long term illnesses such as *asbestosis*.

Educating workers and managers in proper procedures and hazards can have a direct impact on jobsite safety. The realization of the large costs involved in construction injuries and illnesses provides a considerable motivation for awareness and education. Regular safety inspections and safety meetings have become standard practices on most job sites.

Pre-qualification of contractors and sub-contractors with regard to safety is another important avenue for safety improvement. If contractors are only invited to bid or enter negotiations if they have an acceptable record of safety (as well as quality performance), then a direct incentive is provided to insure adequate safety on the part of contractors.

During the construction process itself, the most important safety related measures are to insure vigilance and cooperation on the part of managers, inspectors and workers. Vigilance involves considering the risks of different working practices. In also involves maintaining temporary physical safeguards such as barricades, braces, guy lines, railings, toe boards and the like. Sets of standard practices are also important, such as:

- Requiring hard hats on site.
- Requiring eye protection on site.
- Requiring hearing protection near loud equipment.
- Insuring safety shoes for workers.
- providing first-aid supplies and trained personnel on site

While eliminating accidents and work related illnesses is a worthwhile goal, it will never be attained. Construction has a number of characteristics making it inherently hazardous. Large forces are involved in many operations. The jobsite is continually changing as construction proceeds. Workers do not have fixed worksites and must move around a structure under construction. The tenure of a worker on a site is short, so the worker's familiarity and the employer-employee relationship are less settled than in manufacturing settings. Despite these peculiarities and as a result of exactly these special problems, improving worksite safety is a very important project Construction management concern.

Back to the Table of Contents

CHAPTER-12

Organization and Use of Project Information

12.1 Types of Project Information

Construction projects inevitably generate enormous and complex sets of information. Effectively managing this bulk of information to insure its availability and accuracy is an important managerial task. Poor or missing information can readily lead to project delays, uneconomical decisions, or even the complete failure of the desired facility. Pity the owner and project Construction manager who suddenly discover on the expected delivery date that important facility components have not yet been fabricated and cannot be delivered for six months! With better information, the problem could have been identified earlier, so that alternative suppliers might have been located or schedules arranged. Both project design and control are crucially dependent upon accurate and timely information, as well as the ability to use this information effectively. At the same time, too much unorganized information presented to managers can result in confusion and paralysis of decision making.

As a project proceeds, the types and extent of the information used by the various organizations involved will change. A listing of the most important information sets would include:

- cash flow and procurement accounts for each organization,
- intermediate analysis results during planning and design,
- design documents, including drawings and specifications,
- construction schedules and cost estimates,
- quality control and assurance records,
- chronological files of project correspondence and memorandum,
- construction field activity and inspection logs,
- Legal contracts and regulatory documents.

Some of these sets of information evolve as the project proceeds. The financial accounts of payments over the entire course of the project are an example of overall growth. The passage of time results in steady additions in these accounts, whereas the addition of a new actor such as a contractor leads to a sudden jump in the number of accounts. Some information sets are important at one stage of the process but may then be ignored. Common examples include planning or structural analysis databases which are not ordinarily used during construction or operation. However, it may be necessary at later stages in the project to re-do analyses to consider desired changes. In this case, archival information storage and retrieval become important. Even after the completion of construction, an historical record may be important for use during operation, to assess responsibilities in case of facility failures or for planning similar projects elsewhere.

The control and flow of information is also important for collaborative work environments, where many professionals are working on different aspects of a project and sharing information. Collaborative work environments provide facilities for sharing data files, tracing decisions, and communication via electronic mail or video conferencing. The data stores in these collaborative work environments may become very large.

While there may be substantial costs due to inaccurate or missing information, there are also significant costs associated with the generation, storage, transfer, retrieval and other manipulation of information. In addition to the costs of clerical work and providing aids such as computers, the organization and review of information command an inordinate amount of the attention of project Construction managers, which may be the scarcest resource on any construction project. It is useful, therefore, to understand the scope and alternatives for organizing project information.

12.2 Accuracy and Use of Information

Numerous sources of error are expected for project information. While numerical values are often reported to the nearest cent or values of equivalent precision, it is rare that the actual values are so accurately known. Living with some uncertainty is an inescapable situation, and a prudent manager should have an understanding of the uncertainty in different types of information and the possibility of drawing misleading conclusions.

We have already discussed the uncertainty inherent in making forecasts of project costs and durations sometime in the future. Forecast uncertainty also exists in the short term. For example, consider estimates of work completed.

Every project Construction manager is familiar with situations in which the final few bits of work for a task take an inordinate amount of time. Unforeseen problems, inadequate quality on already completed work, lack of attention, accidents, or postponing the most difficult work problems to the end can all contribute to making the final portion of an activity actually require far more time and effort than expected. The net result is that estimates of the actual proportion of work completed are often inaccurate.

Some inaccuracy in reports and estimates can arise from conscious choices made by workers, foremen or managers. If the value of insuring accuracy is thought to be low or nonexistent, then a rational worker will not expend effort or time to gather or to report information accurately. Many project scheduling systems flounder on exactly this type of non-reporting or miss-reporting. The original schedule can quickly become extremely misleading without accurate updating! Only if all parties concerned have specific mandates or incentives to report accurately will the data be reliable.

Another source of inaccuracy comes from transcription errors of various sorts. Typographical errors, incorrect measurements from reading equipment, or other recording and calculation errors may creep into the sets of information which are used in project Construction management. Despite intensive efforts to check and eliminate such errors, their complete eradication is virtually impossible.

More generally, even information which is gathered and reported correctly may be interpreted incorrectly. While the actual information might be correct within the terms of the data gathering and recording system, it may be quite misleading for managerial purposes. A few examples can illustrate the problems which may arise in naively interpreting recorded information without involving any conceptual understanding of how the information is actually gathered, stored and recorded or how work on the project actually proceeds.

12.3 Computerized Organization & Organizing Information in Databases

Numerous formal methods and possible organizations exist for the information required for project Construction management.

Given the bulk of information associated with construction projects, formal organization of the information is essential so as to avoid chaos. Virtually all major firms in the arena of project Construction management have computer based organization of cost accounts and other data. With the advent of micro-computer database managers, it is possible to develop formal, computerized databases for even small organizations and projects. Equivalent organization of information for *manual* manipulation is possible but tedious. Computer based information systems also have the significant advantage of rapid retrieval for immediate use and, in most instances, lower overall costs. For example, computerized specifications writing systems have resulted in well documented savings. These systems have records of common specification phrases or paragraphs which can be tailored to specific project applications.

Formally, a database is a collection of stored operational information used by the management and application systems of some particular enterprise. This stored information has explicit associations or relationships depending upon the content and definition of the stored data, and these associations may themselves be considered to be part of the database.

Back to the Table of Contents