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SIXTH
EDITION

CONSTRUCTION PROJECT MANAGEMENT

A PRACTICAL GUIDE TO FIELD
CONSTRUCTION MANAGEMENT

S. KEOKI SEARS · GLENN A. SEARS · RICHARD H. CLOUGH

JERALD L. ROUNDS · ROBERT O. SEGNER, JR.

WILEY

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Construction Management**

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Preface

This sixth edition of the well-respected text on construction project management represents a significant revision. The intent is to retain the flavor and quality of the classic book while eliminating some of the detail and updating the content. The content is enhanced by the addition of new material introducing some rapidly evolving topics in construction project management. New instructional materials have also been added to each chapter to increase its value in the classroom. A new example project, selected from the building sector, has been incorporated. Finally, this book takes advantage of advances in technology by employing a companion website that contains material that was appended at the end of the book or inserted as oversized figures in previous editions.



Some detail (such as the detailed cost estimate) and some older content, such as that describing the Arrow Diagramming Method for Critical Path representation have been greatly reduced or eliminated. The coverage of other topics has been increased, and new topics have been added. Reference to line-of-balance scheduling, which provides a valuable representation of repetitive projects, has been expanded. An introduction to Building Information Modeling (BIM) and its associated contract basis founded on Integrated Project Delivery (IPD) has been added. Also a section and various references throughout the book have been added to introduce the basics of lean construction.

To support the use of the book in a learning environment, an introductory section for each chapter has been added that includes a bulleted list of learning objectives. At the end of each chapter, a list of key points from the chapter has been provided, together with review questions and problems. To support live delivery of classes, a set of PowerPoint slides has been prepared for each chapter. It is anticipated that these instructional enhancements will enrich the learning experience provided by the book.

To broaden the scope of the sixth edition, a new example project in the form of a commercial building has been added. The bridge example is retained and in many instances is the single example of reference where topics are addressed that represent the building sector as well as the heavy civil sector.

The building example is an actual project, in the form of a single-story office building constructed in 2006–2007 for a technology company engaged in computer programming and consulting. The design and construction information for the building project was graciously provided to the authors for inclusion in this book by the project design team, the contractor, and the owner. A picture of the building, shown on the book cover, was also provided.

A building, by nature, is far more complex than a bridge. Whereas the bridge is primarily composed of structure and earthwork, and can be fully described in a few drawings, a building contains structure and earthwork, but it also contains an envelope to keep the elements out and to enable control of the interior environment. All surfaces in the building, including floors, walls, and ceilings, require finishes. Buildings have openings requiring doors and windows and the associated hardware. They typically have architectural features such as millwork and signage. Moreover, a building contains a number of systems, such as mechanical, plumbing, fire safety, electrical, and low-voltage systems for security and communication. Each of these building elements must be fully designed and represented in graphical models (the drawings). As a result, though the building is relatively small and uncomplicated, the design of our commercial building example project encompasses some 40 pages of drawings. The inclusion of this complete set of drawings is made possible only by linking a companion website to the book. The companion website is accessed through the following URL: www.wiley.com/go/cpm6e.



In addition to the commercial building drawings, a number of other useful items will be found on the companion website. On the website will be found the figures that were large enough in previous editions to require cumbersome fold-out pages. These are referred to as charts in this edition to distinguish them from figures embedded in the text. Providing them in digital format on the companion website is consistent with the industry trend away from paper documentation. Relevant appendix material from previous editions has also been retained on the companion website. Finally, an instructor-only, password accessible location on the website holds an answer key for the end-of-chapter review questions and problems, as well as the PowerPoint presentations.



A new team of authors has taken on the responsibility to develop this sixth edition of *Construction Project Management*. Jerald L. Rounds and Robert O. Segner, Jr. are honored to have been chosen to continue the excellence of *Construction Project Management* initiated by Richard H. Clough and continued through many revisions by Glenn A. Sears and more recently by S. Keoki Sears.

Jerald L. Rounds and Robert O. Segner, Jr.

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Additional resources for students and instructors are available on the book's companion website at www.wiley.com/go/cpm6e.

The following icon is used throughout the text to indicate content for which a related resource is available on the site:



1 Construction Practices

1.1 Introduction

The objective of this book is to present and discuss the management of field construction projects. These projects involve a great deal of time and expense, so close management control is required if they are to be completed within the established time and cost constraints. The text also develops and discusses management techniques directed toward the control of cost, time, resources, and project finance during the construction process. Emphasis is placed on practical and applied procedures of proven efficacy. Examples relate to field construction practices.

Effective management of a project also requires a considerable background of general knowledge about the construction industry. The purpose of this chapter is to familiarize the reader with certain fundamentals of construction practice that will be useful for a complete understanding of the discussions presented in later chapters. Learning objectives for this chapter include:

- ☐ Recognize the size and impact of the construction industry.
- ☐ Understand how a construction project moves from concept to reality.
- ☐ Identify entities involved in a construction project and various project delivery systems that link the participating entities.
- ☐ Introduce the role of the project manager.

1.2 The Construction Industry

In terms of the dollar value of output produced, the construction industry is one of the largest single production activities of the US economy. As of December of 2013, the seasonally adjusted value of construction put in place for 2013 was estimated to be \$0.930 trillion. This figure is updated monthly by the US Census Bureau. The current value can be found on the US Census Bureau website under Construction Spending, www.census.gov/construction/c30/c30index.html. The current dollar gross domestic product (GDP) in the fourth quarter of 2013 was \$17.103 trillion. This figure is regularly updated by the US Department of Commerce, Bureau of Economic Analysis, and can be found at www.bea.gov/newsreleases/national/gdp/gdpnewsrelease.htm.

Though construction was severely impacted by the economic downturn at the end of the first decade of this century, the annual expenditure for construction still accounts for almost 5.44 percent of the GDP. More than 1 of every 20 dollars spent for goods and services in the United States is spent on construction. The construction industry is also one of the nation's largest employers, so its impact in terms of both dollars and jobs remains considerable.

Not only does the construction industry touch the lives of virtually every human being on a daily basis; it also occupies a fundamental position in many national economies. This large and pervasive industry is regarded as the bellwether of economic growth in the United States. Periods of national prosperity usually are associated with high levels of construction activity. One is the natural result of the other.

The construction industry is heterogeneous and enormously complex. There are several major classifications of construction that differ markedly from one another: housing, nonresidential building, heavy civil, utility, and industrial. In addition, these construction types are further divided into many specialties, such as electrical, concrete, excavation, piping, and roofing.

Construction work is accomplished by contractors who vary widely in terms of size and specialty. Some contractors choose to concentrate on a particular task or aspect of the construction project and are therefore referred to as specialty contractors. Others assume broader responsibility for a comprehensive work package and are referred to as general contractors. Commonly, general contractors will subcontract specific aspects of a project to specialty contractors, forming a contractual web of general contractors and specialty contractors. Within the industry, very large contractors handle annual volumes in excess of \$15 billion; their annual budgets rival the gross national products of many small countries. However, the construction industry is typified by small businesses.

1.3 The Construction Project

Construction projects are intricate, time-consuming undertakings. The total development of a project normally consists of several phases requiring a diverse range of specialized services. In progressing from initial planning to project completion, the typical job passes through successive and distinct stages that demand input from such disparate areas as financial organizations, governmental agencies, engineers, architects, lawyers, insurance and surety companies, contractors, material and equipment manufacturers and suppliers, and construction craft workers.

During the construction process itself, even a project of modest proportions involves many skills, materials, and literally hundreds of different operations. The assembly process must follow a natural order of events that constitutes a complicated pattern of individual time requirements and restrictive sequential relationships among the project's many segments.

To a great extent, each construction project is unique—no two jobs are ever exactly the same. In its specifics, each structure is tailored to suit its environment, arranged to perform its own particular function, and designed to reflect personal tastes and preferences. The vagaries of the construction site and the possibilities for creative and utilitarian variation of even the most standardized building product combine to make each construction project a new and different experience. The contractor sets up its “factory” on the site and, to a large extent, custom builds each structure.

Construction is subject to the influence of highly variable and sometimes unpredictable factors. The construction team, which includes architects, engineers, craft workers, specialty contractors, material suppliers, and others, changes from one job to the next. All the complexities inherent in different construction sites—such as subsoil conditions, surface topography, weather, transportation, material supply, utilities and services, local specialty contractors, labor conditions, and available technologies—are an innate part of construction.

However, though construction projects are subject to infinite variety, construction processes tend to be consistent from job to job. Each job goes through mobilization and closeout processes. All materials and installed equipment are subject to a procurement process that includes submittals, approvals, purchase, and shipment to the job site. Contracts are negotiated. Costs are estimated and billed out when a component is completed. Changes happen regularly, but even changes are handled through a consistent change order process. Hence, much of the current focus in construction management is on understanding and managing construction processes more effectively.

The character of construction projects, typified by their complexity and diversity and by the nonstandardized nature of their production, is a result of variable inputs operated on by standard processes yielding a unique

product. The use of prefabricated modular units is somewhat limiting this variability, but it is unlikely that field construction will ever be able to adapt completely to the standardized methods and product uniformity of assembly-line production. To the contrary, many manufacturing processes are moving toward mass customization, or “one-off” production and adopting many of the project management tools originating in the construction industry.

1.4 Project Stages

A construction project proceeds in a rather definite order; the stages of development that follow are typical.

A. Planning and Definition

Once an owner has identified the need for a new facility, he or she must define the requirements and delineate the budgetary constraints. Project definition involves establishing broad project characteristics, such as location, performance criteria, size, configuration, layout, equipment, services, and other owner requirements needed to establish the general aspects of the project. Conceptual planning stops short of detailed design, although a considerable amount of preliminary architectural or engineering work may be required. The definition of the work is basically the responsibility of the owner, although a design professional may be called in to provide technical assistance and advice.

B. Design

The design phase involves the architectural and engineering design of the entire project. It culminates in the preparation of final working drawings and specifications for the total construction program. In practice, design, procurement, and construction often overlap, with procurement and construction beginning on certain segments as soon as the design is completed and drawings and specifications become available for those segments.

With the advent of high-speed computing and massive data management capabilities, the various design components can now be incorporated into a single database producing integrated design in a digital format. Production information is being added to the database, resulting in a Building Information Modeling (BIM) model of the project that contains all information on the project in a unique digital format. The use of BIM is still in the early stages, but its use is evolving rapidly throughout the construction industry.

C. Procurement and Construction

Procurement refers to the ordering, expediting, and delivering of key project equipment and materials, especially those that may involve long delivery periods. This function may or may not be handled separately from the construction process itself. *Construction* is, of course, the process of physically erecting the project and putting the materials and equipment into place, and this involves providing the manpower, construction equipment, materials, supplies, supervision, and management necessary to accomplish the work.

This stage moves toward conclusion with substantial completion of the project when the owner gains beneficial use of the facility. The conclusion of the project occurs when the terms of all contracts are fulfilled and the contracts are closed out. This closeout cycle is often part of a commissioning process that accomplishes many things, including bringing the facility on line, facilitating owner occupancy and turnover of facility operations to the owner, and closing out of all construction contracts. Many contractors follow the final closeout of the project with an internal postproject review from which the contractor gleans a great deal of information that helps to improve company processes and hence to mold the evolution of the company.

1.5 Owner

The owner, whether public or private, is the instigating party that gets the project financed, designed, and built. Public owners are public bodies of some kind and range from the federal government down through state, county, and municipal entities to a multiplicity of local boards, commissions, and authorities. Public projects are paid for by appropriations, bonds, or other forms of financing and are built to perform a defined public function. Public owners must proceed in accordance with applicable statutes and administrative directives pertaining to advertising for bids, bidding procedure, construction contracts, contract administration, and other matters relating to administration of the design and construction process.

Private owners may be individuals, partnerships, corporations, or various combinations thereof. Most private owners have the project built for their own use: business, habitation, or otherwise. However, some private owners do not intend to be the end users of the constructed facility; rather, they plan to sell, lease, or rent the completed structure to others. These end users may or may not be known to the owners at the time of construction.

A third classification of ownership in the form of a public-private partnership (PPP) has become popular. This tends to be subject to the rules and regulations governing public ownership since the partnership is typically used as a means to procure private financing for a public project.

1.6 Architect-Engineer

The architect-engineer, also known as the design professional, is the party or firm that designs the project. Because such design is architectural or engineering in nature, or often a combination of the two, the term *architect-engineer* is used in this book to refer to the design professional, regardless of the applicable specialty or the relationship between the architect-engineer and the owner.

The architect-engineer can occupy a variety of positions with respect to the owner for whom the design is undertaken. Many public agencies and large corporate owners maintain their own in-house design capability. In such instances, the architect-engineer is the design arm of the owner. In the traditional and most common arrangement, the architect-engineer is a private and independent design firm that accomplishes the design under contract with the owner. Where the *design-construct* mode of construction is used, the owner contracts with a single party for both design and construction. In such cases, the architect-engineer is a branch of, or is affiliated in some way with, the construction contractor.

1.7 Prime Contractor

A prime contractor, who is typically a general contractor, is a firm that contracts directly with the owner for the construction of a project, either in its entirety or for some designated portion thereof. In this regard, the owner may choose to use a single prime contract or several separate prime contracts.

Under the single-contract system, the owner awards construction of the entire project to one prime contractor. In this situation, the contractor brings together all the diverse elements and inputs of the construction process into a single, coordinated effort and assumes full, centralized responsibility for the delivery of the finished job, constructed in accordance with the contract documents. The prime contractor is fully responsible to the owner for the performance of the subcontractors and other third parties to the construction contract. The prime contractor may choose to self-perform certain parts of the work or may choose to subcontract all of the work to specialty contractors.

When multiple prime contracts are used, the project is not constructed under the centralized control of a single prime contractor. Rather, several independent contractors work on the project simultaneously, and each is responsible for a designated portion of the work. Each of the contractors is under contract with the owner, and each functions independently of the others. Responsibility for coordination of these contractors may be undertaken by the owner, the architect-engineer, a construction manager, or one of the prime contractors who is paid extra to perform certain overall job management duties.

1.8 Competitive Bidding

The owner selects a prime contractor on the basis of competitive bidding, negotiation, or some combination of the two. A large proportion of construction in the United States is done by contractors that obtain their work in bidding competition with other contractors. The competitive bidding of public projects is often required by law and is standard procedure for public

agencies. Traditionally, all public construction work has been done by this method, though recently some alternative approaches have been approved. When bidding a project, the contractor estimates how much the project will cost using the architect-engineer's drawings and specifications as a basis for the calculations. The contractor then adds a reasonable profit to this cost and guarantees to do the entire job for the stated price.

Bid prices quoted by the bidding contractors most often constitute the principal basis for selection of the successful contractor, with the low bidder usually receiving the contract award. Most bidding documents stipulate that the work shall be awarded to the "lowest responsible bidder." This gives the owner the right to reject the proposal of a bidding contractor if the contractor is judged to be unqualified for some reason. If its bid is selected, the contractor is obligated to complete the work in exchange for the contract amount.

Competitive bidding can also be used where the successful contractor is determined on a basis other than the estimated total cost of the construction. For example, where the contract involves payment of a prescribed fee to the contractor, the amount of the fee is sometimes used as a basis of competition among contractors. Construction management services are sometimes obtained by an owner using the fees proposed by the different bidders as the basis for contract award. This is often referred to as a fee-based bid.

1.9 Negotiated Contracts

At times it can be advantageous for an owner to negotiate a contract for its project with a preselected contractor or small group of contractors. It is common practice for an owner to forgo the competitive bidding process and to handpick a contractor on the basis of its reputation and overall qualifications to do the job. A contract is negotiated between the owner and the chosen contractor. Clearly, such contracts can include any terms and provisions that are mutually agreeable to the parties. Most negotiated contracts are of the cost-plus-fee type, a subject that will be developed more fully later.

1.10 Combined Bidding and Negotiation

An owner sometimes will combine elements of both competitive bidding and negotiation into an approach known as *best value*. In this approach, a portion of the decision is based on price and the rest on qualifications. In the best-value approach, the competing contractors are required to submit their qualifications along with their bids and are encouraged to tender suggestions as to how the cost of the project could be reduced. Competing contractors are often interviewed, in addition to submitting the bid and the qualifications statement. The owner then scores the bid and

the qualifications, awarding the project to the contractor with the best score. The best-value approach is now acceptable in many public-sector environments.

1.11 Subcontracting

The extent to which a general contractor will subcontract work depends greatly on the nature of the project and the contractor's own organization. There are instances where the job is entirely subcontracted, so the general contractor provides only supervision, job coordination, project billing, and perhaps general site services. At the other end of the spectrum are those projects where the general contractor does no subcontracting, choosing to do the work entirely with its own forces. Customarily, however, the prime contractor will perform the basic project operations and will subcontract the remainder to various specialty contractors. Types of work with which the prime contractor is inexperienced or for which it is not properly equipped are usually subcontracted, since qualified specialty contractors generally are able to perform their specialty faster and less expensively than the general contractor. In addition, many construction specialties have specific licensing, bonding, and insurance requirements that would be costly for the general contractor to secure for intermittent use.

When the prime contractor engages a specialty firm to accomplish a particular portion of the project, the two parties enter into a contract called a subcontract. No contractual relationship is thereby established between the owner and the subcontractor. When a general contractor sublets a portion of its work to a subcontractor, the prime contractor remains responsible under its contract with the owner for any negligent or faulty performance by the subcontractor. The prime contractor assumes complete responsibility to the owner for the direction and accomplishment of the total work. An important part of this responsibility is the coordination and supervision of the various subcontractors.

1.12 Design-Bid-Construct

Traditionally, field construction is not begun until the architect-engineer has completed and finalized the design. This sequence is still predominant in the industry and is referred to as the *design-bid-construct* procedure. While completing one step before initiating the next may be acceptable to owners on some projects, it will be unacceptably slow to other owners. A number of financial considerations dictate the earliest possible completion date for many construction projects. It is possible to reduce the total design-construction time required for some projects by starting the construction before complete design of the entire project has been accomplished.

1.13 Fast Tracking

Fast tracking refers to the overlapping accomplishment of project design and construction. As the design of progressive phases of the work is finalized, these work packages are put under contract, a process also commonly referred to as *phased construction*. Early phases of the project are under construction while later stages are still in the design process. This procedure of overlapping the design and construction can appreciably reduce the total time required to achieve project completion. For obvious reasons, fast tracking and phased construction sometimes can offer attractive advantages to the owner and also can be the source of severe coordination problems.

1.14 Construction Contract Services

A myriad of contract forms and types are available to the owner for accomplishing its construction needs, and all of them call for defined services to be provided under contract to the owner. The scope and nature of such services can be made to include almost anything the owner wishes. The selection of the proper contract form appropriate to the situation is an important decision for the owner and is one deserving of careful consideration and consultation.

The construction contract can be made to include construction, design-construct, or construction management services, each of which is discussed in the next three sections.

1.15 Construction Services

A large proportion of construction contracts provide that the general contractor have responsibility to the owner only for accomplishment of the field construction. Under such an arrangement, the contractor is completely removed from the design process and has no input into it. Its obligation to the owner is limited to constructing the project in full accordance with the contract terms.

Where the contractor provides construction services only, the usual arrangement is for a private architect-engineer firm to perform the design in contract with the owner. Under this arrangement, the design professional acts essentially as an independent design contractor during the design phase and as an agent of the owner during construction operations. The architect-engineer acts as a professional intermediary between the owner and contractor and often represents the owner in matters of construction contract administration. Under such contractual arrangements, the owner, architect-engineer, and contractor play narrowly defined roles, and the contractor is basically in an adversarial relationship with the other two.

1.16 Design-Construct

When the owner contracts with a single firm for both design and construction and possibly procurement services, this is referred to as a *design-construct* project. This form of contract is usually negotiated, although occasionally it is competitively bid. Usually, the contractor has its own design section with architects and engineers as company employees. In other cases, however, the architect-engineer can be a contractor's corporate affiliate or subsidiary, or the contractor can enter into a joint venture arrangement with an independent architect-engineer firm for a given project or contract.

The team concept is basic to design-construct. The owner, designer, and builder work cooperatively in the total development of the project. The contractor provides substantial input into the design process on matters pertaining to materials, construction methods, cost estimates, and construction time schedules. In recent years, owners have shown increasing acceptance and usage of this concept, largely due to the economies of cost and time that can be realized by melding the two functions of design and construction. Injecting contractor experience and expertise into the design process offers the possibility of achieving cost savings for the owner. Because fast tracking is possible under a design-construct contract, the owner may well have the beneficial use of the structure considerably before it would have under the more traditional design-bid-construct arrangement.

A *turnkey* contract is similar to a design-construct contract. The difference lies in the greater range of responsibilities that the contractor undertakes on behalf of the owner under a turnkey arrangement. For example, a turnkey contract often includes such services as land selection and acquisition, project financing, project equipment procurement, and leasing of the completed facility.

1.17 Construction Management

The term *construction management* is applied to the provision of professional management services to the owner of a construction project with the objective of achieving high quality at minimum cost. Such services may encompass only a defined portion of the construction program, such as field construction, or they may include total project responsibility. The objective of this approach is to treat project planning, design, and construction as integrated tasks within a construction system. Where construction management is used, a nonadversarial team is created consisting of the owner, construction manager, architect-engineer, and contractor. The project participants, by working together from project inception to project completion, attempt to serve the owner's best interests in optimum fashion. By striking a balance between construction cost, project quality,

and completion schedule, the management team strives to produce for the owner a project of maximum value within the most economical time frame. Construction management does not include design or construction services per se but involves management direction and control over defined design and construction activities.

Construction management services can be performed for the owner for a stipulated fee by a range of firms, including design firms, contractors, and professional construction managers. Such services range from merely coordinating contractors during the construction phase to broad-scale responsibilities over project planning and design, project organization, design document review, construction scheduling, value engineering, field cost monitoring, and other management services. Selection of the construction manager by the owner is sometimes accomplished by a best-value approach, including both fee and qualifications as bases for contract awards. Usually, however, the construction management arrangement is considered to be a professional services contract and is negotiated. These contracts normally provide for a fixed fee plus reimbursement of management costs.

The Construction Management approach is practiced in two distinct variations. With Agency Construction Management, the construction manager operates throughout the project as the agent of the owner to manage the entire project in the best interest of the owner and does not perform any of the construction work. With Construction Management At Risk, the construction manager will, at some relatively early stage of design, provide cost and schedule commitments to the owner and take on the responsibility of completing the job within the time frame and cost stated. At that point, the project takes on the nature of a negotiated, fixed-sum project.

1.18 Fixed-Sum Contract

A fixed-sum contract requires the contractor to complete a defined package of work in exchange for a sum of money fixed by the contract. Should the actual cost of the work exceed this figure, the contractor absorbs the loss. The owner is obligated to make only such total payment as is stipulated in the contractual agreement. A fixed-sum contract may be either lump sum or unit price.

With a lump-sum contract, the contractor agrees to complete a stipulated package of work in exchange for a single lump sum of money. Use of this form of contract is obviously limited to those construction projects where both the nature and quantity of each work type can be accurately and completely determined before the contract sum is set.

A unit-price contract requires the contractor to perform certain well-defined items of work in accordance with a schedule of fixed prices for each unit of work put into place. The total sum of money paid to the contractor for each work item is determined by multiplying the contract unit price by the number of units actually done on the job. The contractor is obligated