

Project Management for Engineering and Construction

A Life-Cycle Approach

Fourth Edition

- Details all project phases—from inception to completion
- Covers the owner's team, the design engineer's team, and the construction team
- Includes an instructor and student manual as well as hands-on content for professionals

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Project Management for Engineering and Construction

A Life-Cycle Approach

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Fourth Edition



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Preface

This book presents the principles and techniques of managing engineering and construction projects from the initial conceptual phase, through design and construction, to completion. It uses a project lifecycle to emphasize the importance of project management during the early stages of project development. The project initiation stages of the project lifecycle provide the best ability to influence the quality, cost, and schedule of a project. Most books discuss project management during construction, after the scope of work is fully defined, the budget is fixed, and the completion date is firm. It is then too late to make any significant adjustments to improve the quality, cost, or schedule of the project.

Although each project is unique, there is certain information that must be identified and organized at the beginning of a project before any work is started. Numerous tables and graphs are presented and discussed throughout this book to provide guidelines for management of the three basic components of a project: scope, budget, and schedule. Throughout this book, achieving project quality to meet the owner's satisfaction is emphasized as an integral part of project management.

This fourth edition also has been reorganized into the sequence of steps a project will experience in order to emphasize the project lifecycle. A new chapter has been added to this fourth edition that addresses project document control. The topic of project document control is often overlooked, yet it is a key contributor to the success of managing a project because the project team need the information contained in project documents. This topic is covered from the perspective of the engineer who is employed with either the owner's organization or the design firm.

In preparing this fourth edition, the authors have updated example problems in all chapters and added new material and electronic content to many chapters. The chapters have been rearranged to follow the project lifecycle presented in this book.

The intended audience of this book is engineers in industry who aid the

owner in the feasibility study, coordinate the design effort, and witness construction in the field. It is also intended for students of university programs in engineering, architecture, and construction because graduates of these programs usually are involved in project management as they advance in their careers.

This book is based on the authors' experience in working with hundreds of project managers in the engineering and construction industry and on personal experiences across many years and several industries. Much of the material in this book is based on experience and formal and informal discussions with these project managers, who are actively involved in the practice of project management. Although the authors have observed that no two project managers operate exactly the same, there are common elements that apply to all projects and all project managers. The authors present these common elements of effective project management that have been successfully applied in practice.

The authors would like to thank Dan Mitchell for his careful review, helpful comments, and advice in the development of the project lifecycle approach presented in this book. Special thanks and gratitude is given to Jana Oberlender for her review and comments of copy editing and page proofs for this fourth edition. The authors would also like to thank the many project managers in industry who have shared their successes, and problems, and who have influenced the authors' thoughts in the development of this book.

For further information, please see the following website for online ancillaries:

<https://www.mhprofessional.com/9781264268443ProjMgmtEng&Constr4E>.

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CHAPTER 1

Introduction

Purpose of This Book

The purpose of this book is to present the principles and techniques of project management beginning with the conceptual phase by the owner, through coordination of design and construction, to project completion. Emphasis is placed on managing the project in its early stage of development, during the owner's study and design. It is presented from this perspective because the ability to influence the overall quality, cost, and schedule of a project can best be achieved early in the life of a project. Most books and articles discuss project management during the construction phase, after design is completed. At this time, in the life of a project, the scope of work is fully defined, the budget is fixed, and the completion date is firm. It is then too late to make any significant adjustments to improve the quality, cost, or schedule of the project.

Experienced project managers agree that the procedures used for project management vary from company to company and even among individuals within a company. Although each manager develops his or her own style of management and each project is unique, there are basic principles that apply to all projects and project managers. This book presents these principles and illustrates the basic steps, and sequencing of steps, to develop a work plan to manage a project through each phase from conceptual development to completion.

Project management requires teamwork among the three principal contracting parties: the owner, designer, and contractor. The coordination of the design and construction of a project requires planning and organizing a team of people who are dedicated to a common goal of completing the project for the owner. Even a small project involves a large number of people who work for different organizations. The key to a successful project is the

selection and coordination of people who have the ability to detect and solve problems and to complete the right project on time and within budget.

Throughout this book, the importance of management skills is emphasized to enable the user to develop his or her own style of project management. The focus is to apply project management at the beginning of the project when it is first formulated. Too often, the formal organization to manage a project is not developed until the beginning of the construction phase. This book presents the information that must be assembled and managed during the development and engineering design phase to bring a project to successful completion for use by the owner.

The intended audience of this book is new and experienced project professionals as well as students enrolled in university programs in engineering and construction. It is also intended for design professionals who aid the owner in the feasibility study, coordinate the design effort, and witness construction in the field. This book is also for personnel in the owner's organization who are involved in the design and construction process.

Arrangement of This Book

A discussion of project management is difficult because there are many ways a project can be handled. The design and/or construction of a project can be performed by one or more parties. Regardless of the method that is used to handle a project, the lifecycle of a project generally flows through the following phases and describes project management in its simplest form:

Phase 1—Determining *project feasibility* to satisfy business objectives

Phase 2—*Conceptualization* of project alternatives to accomplish phase 1 objectives

Phase 3—Developing *detailed project scope* for the selected alternative

Phase 4—Performing *detailed engineering designs* based on the project scope

Phase 5—*Construction* through start-up and hand over to owner and close out

Beginning in the earliest phases, project management practices include many activities:

- Collaborating with owner's project sponsor to clearly understand the business and facility objectives, and potential alternatives to consider
- Team selection and development
- Establishing document control requirements
- Developing the Project Charter, Project Execution Plan, and Design Basis Memorandum including project scope, budget, and completion date
- Preparing and documenting early project cost estimates for economic evaluation
- Conducting risk assessments as the project progresses toward approval and funding
- Project scheduling and tracking including detailed design work and project construction, comparing plan to actual (scope, cost, time) to ensure successful project completion
- Project close out—consisting of final completion to ensure owner satisfaction, final testing, inspection, documentation, and confirming issue resolution and handing over the project to the owner.

In practice, there is considerable overlap between the activities, because any one activity may affect one or more other activities. For example, budget preparation overlaps project definition and scope development. Similarly, project scheduling relates project scope and budget to project tracking and control.

The topic of project management is further complicated because the responsibility for these activities usually involves many parties. Thus, the above steps must all be integrated together to successfully manage a project. Subsequent chapters of this book describe each of these activities.

Chapter 1, Introduction, defines general principles related to project management. These basic principles must be fully understood because they apply to all the remaining chapters. Many of the problems associated with project management are caused by failure to apply the basic management principles that are presented in [Chapter 1](#).

Chapter 2, Project Definition, presents material that is generally performed by the owner during the Feasibility, Conceptualization, and Detailed Scope phases. However, the owner may contract the services of a

design organization to assist with the any or all aspects of these early phases. The project manager should be involved during feasibility and conceptualization phases to establish the objectives and scope. This requires input from experienced technical people that represent every aspect of the proposed project.

Chapter 3, Detailed Scope—Work Plan Development, applies to the project manager who is responsible for management of the of the entire project for the owner or for the project manager responsible for the design effort. Generally, he or she is employed by the professional design organization, which may be an agency of the owner or under contract by the owner to perform design services. The material presented in this chapter is important because it establishes the work plan that is the framework for guiding the entire project effort. The information in this chapter relates to all the project management steps and chapters of this book.

Chapter 4, Team Selection and Development, presents the human aspects of project management. The project team is a group of diverse individuals, each with a special expertise, that performs the work necessary to complete the project. Team members may be remote or colocated. As leader of the project team, the project manager acts as a hub to answer questions, coordinate the work and to make sure the team understands what is expected of them and the desired outcome of the project.

Chapter 5, Project Document Control, comprises an essential and often undervalued function for engineering projects. Document control must begin in the earliest phases and encompass all aspects ranging from electronic communication, myriad of reports, drawings, and all construction documents. This function requires dedicated staff and a disciplined project team to be effective. Well-executed document control saves enumerable hours of wasted staff time spent searching for the correct documents or drawing versions. It can be considered risk mitigation for communication issues or noncompliance with regulations, permits, or contracts.

Chapter 6, Early Estimates, presents the techniques and processes of preparing estimates in the early phases of a project. As a project proceeds through the prefunding lifecycle phases, the early estimate will reflect the additional information gained from developing the project. Preparation of early estimates is a prerequisite to project budgeting. For engineering and construction projects, the early cost estimate is used by the owner in making economic decisions to approve the project. The early cost estimate is a key

project parameter for cost control during the design process.

Chapter 7, Project Budgeting, applies to all parties in a project: the owner, designer, and contractor. The budget must be linked to the quantity, quality, risk profile, and schedule of the work to be accomplished. These parameters are established in the funding authorization for the project. A change in scope or schedule almost always affects the budget, so the project manager must continually be alert to changes in a project and to relate any changes to the budget.

Chapter 8, Risk Management, involves taking a pessimistic view of the project to identify events that can adversely affect the project. Quantifying the impact of those events and the probability of occurrence provides for contingency budgeting for cost and schedule. As the project progresses through the development phases, subsequent updates to the risk assessment help owners make informed funding decisions.

Chapter 9, Design Proposals, presents the process of preparing proposals from the design organization to the owner. After the owner has defined the goals, objectives, intended use, and desired outcome of the project, a request for proposals is solicited from the design organization. The design organization must convert the owner's expectations of the project into an engineering scope of work, budget, and schedule. Once awarded, the design organization must manage the design process to meet the stated objectives.

Chapter 10, Project Planning and Scheduling, provides the detailed base against which all activities are measured. The schedule integrates the work to be accomplished by those who will perform it, within the budget and time frame set by the owner. Project scheduling cannot be accomplished without a well-defined work plan, as described in *Chapter 3*, and it forms the basis for project tracking, as described in *Chapter 13*.

Chapter 11, Design Coordination, applies to the project manager of the design organization. The quality, cost, and schedule of a project is highly dependent on the effectiveness of the design effort. The result of the design process is to produce plans and specifications in a timely manner that meet the intended use of the project by the owner. The product of design must be within the owner's approved budget and schedule and must be constructable by the construction contractor.

Chapter 12, Construction Phase, is important because most of the cost of a project is expended in the construction phase, and the quality of the final project is highly dependent on the quality of work that is performed by the

construction contractors. Most of the books written on project management have been directed toward a project in the construction phase. This book emphasizes project management from the initial conception of the project by the owner, through coordination of design and development of the construction documents, with reduced emphasis on the construction phase, and fully details project close out.

Chapter 13, Monitoring and Reporting, cannot be effectively accomplished without a well-defined work plan, as described in [Chapter 3](#), and a detailed schedule, as described in [Chapter 10](#). This chapter is important because there is always a tendency for scope growth, cost overrun, or schedule delays. A control system must simultaneously monitor the three basic components of a project: the work accomplished, the capital spent, and the time expended. These three components must be collectively monitored, not as individual components, because a change in any one component usually will affect the other two components.

Chapter 14, Project Close Out, discusses the steps required to complete a project and turn it over to the owner. This is an important phase of a project because the owner will have expended most of the budget for the project, but will not receive any benefits from the expenditures until it is completed and ready for use. Also, it is sometimes difficult to close a project because there are always many small items that must be finished.

Chapter 15, Personal Management Skills, addresses the human or “soft” aspects of project management. Although the primary emphasis of this book is on the techniques of project management, the project manager must possess a broad range of nontechnical skills to lead, motivate, and form a cohesive project team. Project managers must overcome the challenges of remote team members, provide clear and accurate communication, and make decisions with uncertainty, among others.

Definition of a Project

A project is a time-bound endeavor that is undertaken to produce the results that are expected from the requesting party. For this book, a project may be design only, construction only, or a combination of design and construction. A project consists of three components: scope, budget, and schedule. When a project is first assigned to a project manager, it is important that all three of these components be clearly defined. Throughout this book, the term *Scope*

represents the work to be accomplished, that is, the quantity and quality of work. *Budget* refers to costs, measured in dollars and/or labor-hours of work. *Schedule* refers to the planning, logical sequencing, and timing of the work to be performed. The quality of a project must meet the owner's business and facility objectives and is an integral part of project management.

Figure 1-1 is shown as an equilateral triangle which is the most stable geometric shape. Scope is shown at the top of the triangle to highlight its importance as the first task in developing a project budget and project schedule. Scope, budget, and schedule are essential predecessors to building a good project work plan to be used during the project's execution.

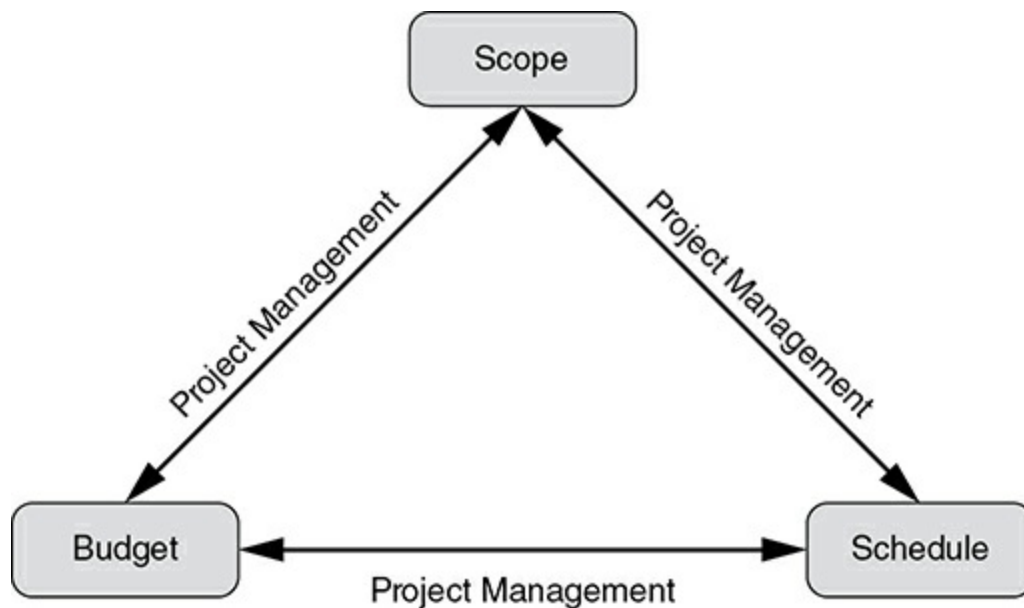


FIGURE 1-1 Principal components of a project.

All three components of the project are of equal importance in the successful completion of a project. Scope is the first component that must be developed because an accurate scope must be known before an accurate budget and schedule can be known. Just because scope should be defined first does not indicate it is more important than the budget and schedule. To illustrate, when a project with a well-defined scope is completed, but the final cost is extremely high (budget problem) and/or the completion date is extremely late (schedule problem), it is not a successful project. Any adjustment in the scope of work requires a corresponding adjustment in the budget and schedule. This principle applies between any and all of the three components of a project. This simple concept of a balance between scope,

budget, and schedule is sometimes not fully recognized during early project development as well as during design and construction. Using project management processes and principles creates a dynamic binding force to keep balance between the three essential components.

Project management (people) is the binding force for the entire system. It is people that make things happen, not things. It is the project team that develops the components (scope, budget, schedule) of a project. Project management (people) is the key component to achieve a successful project.

The source of many problems associated with a project is failure to properly define the project scope. Too often the focus is just on budget or schedule. Not only should the scope, budget, and schedule be well defined, but each must be linked together since one affects the other, both individually and collectively. The project manager must engage key stakeholders to clearly define the project objectives. They should utilize a disciplined phased approach to develop the project and select and involve the project team to deliver the project successfully.

Scope defines the work to be accomplished by the project. It should be the first task in the development of a project, prior to the development of either the budget or the schedule. Scope definition is an iterative process; it takes time to develop. Only the owner can describe the purpose and reasoning behind the project. The owner's objectives act as inputs to developing the project's scope. Experienced project managers agree that the budget and schedule are derived from the scope. Too often, top management specifies a project budget or schedule and then asks the project team to define a scope to match the budget. This is the reverse order of defining a project and is not a good project management practice. It is the duty of a project manager to ensure that the project scope, budget, and schedule are linked together. Scope definition requires involvement by the project owner.

Budgeting is important because it establishes the amount of money the owner will spend to obtain the project and the amount of money that the design and construction organizations will be compensated for performing the work. Each party is concerned about project cost overrun because it adversely affects profitability and creates adverse relationships between the parties.

Scheduling consists of two different activities. Planning is the first and most important and consists of identifying and organizing the work, detailing how the work will be performed and developing a logical sequence to

accomplish to the work. Planning includes identifying methods, contracting schemes, procurement strategies, and execution approaches. Scheduling brings together project definition, people, cost, resources, and timing. The schedule is the final product of scope definition, budgeting, and planning and forms the base against which all activities are measured. Project tracking and control cannot be accomplished without a good plan and schedule.

Quality is an element that is integrated into and between all parts of a project: scope, budget, and schedule. It should not be construed as merely creating drawings with a minimum number of errors, furnishing equipment and materials that meet specifications, or building a project to fulfill the requirements of a contract. Certainly, these factors are a part of quality, but it involves much more. Quality is meeting the needs and business (or agency) and facility objectives, and satisfaction of the ultimate end user of the project, the owner. The project team, led by the project manager, should provide the owner with no more and no less than the stated agreed to project objectives.

Quality is the responsibility of all participants in a project, including all levels of management and workers in each of the principal parties. An attitude of collaboratively achieving quality must be instilled in everyone and perpetuate throughout the work environment. The attitude should not be “what can we do to pass quality control or final inspection?” Instead, it should be “what can we do to effectively execute our work and what is the best way we can deliver a project that meets the needs and objectives of the owner?”

Lifecycle of a Project

The ongoing challenge of managing a project is defining the proper combination of scope, cost, and time to meet the owner’s requirements and keeping those components in balance. Following a project lifecycle aids in selecting the right project and develops it sufficiently to allocate the required human and financial resources. Following a lifecycle launches a quality process that runs the entire duration of the project. Lifecycle processes act as risk mitigation by helping to scope the right project to satisfy the project sponsor’s intended use of the project (business or agency objectives) when the project is completed.

For engineering and construction, the project sponsor may be a business in the private sector or an agency of a government. The private sector typically

involves companies that provide a product or service for a profit. Examples of private-sector projects include commercial buildings, processing plants, oil and gas pipelines, manufacturing plants, and other similar facilities. The public sector typically involves a governmental agency that provides services to benefit the general public. Examples of public-sector projects include public buildings, roads, highways, bridges, water systems, and similar facilities. [Table 1-1](#) compares the private sector to public sector. Although there are differences in the sectors, the lifecycle of public-sector projects is similar to the lifecycle for projects in the private sector. The following section presents an example lifecycle for the private sector.

	Private	Public
Purpose	Financial	Service, societal
Funding source	Debt and equity markets, internal funds	Taxes, tax-free bonds, low interest loans
Project durations	Shorter	Longer due to government and non-government organization (NGO) involvement and funding requirements
Labor	Can be nonunion	Davis Bacon Act, union labor, use of minority or local work forces may be required
Contractor selection	Sole source, competitive bidding, preapproved contractors	Miller Act or lowest prequalified bidder
Multipurpose	Some	Most
Project life	Shorter term	Longer term
Project benefits	Financial	Service, social, economic, aesthetic, etc.
Conflicts	Moderate to high	Common and high
Politics	Little to moderate	High
Measure of efficiency	Net Present Value (NPV), Internal Rate of Return (IRR), Return On Investment (ROI)	Exceedingly difficult to evaluate

TABLE 1-1 Private versus Public Projects

Private-Sector Project Lifecycle

Several lifecycle versions exist. Often, asset-intensive owner companies will

follow a lifecycle specific to their industry or company practices. Lifecycles can have varying numbers of phases with the most common being four or five phases. This book will use a five-phase lifecycle as shown in [Figure 1-2](#).

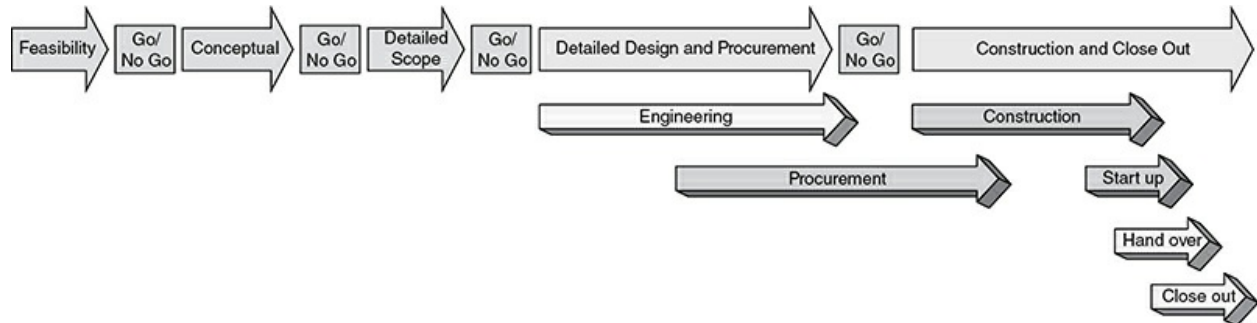


FIGURE 1-2 Example of private-sector project lifecycle.

As a project progresses from one phase to another, it passes through a stage gate. This gating process can be formal or informal, also known as hard or soft gates, respectively. For each phase, the stage gate is intended to act as a go/no go point in the project’s development. This allows the project sponsor and key decision makers an opportunity to confirm that the project continues to satisfy the business objectives and economic requirements. The project sponsor and key stakeholders have the opportunity to cancel a project that fails to meet the business objectives or fails other gate criteria. The gate between Detailed Scope and Detailed Design and Construction is a critical decision point. If a project receives a “go” decision here, capital funds are authorized, and a full project team effort can begin. The project is considered sanctioned. In practice, as the project nears a stage gate, work in the following phase will be underway. For example, if the owner has contracted with a design firm to perform alternative identification and analysis during conceptualization, the design firm may also be working on developing the detailed scope for the most promising two alternatives. As the project nears the sanctioning decision gate, the design firm may have already performed some detailed design to substantiate the budget and schedule provided to the owner for authorization. If the project is canceled at the sanction gate, the work can be archived until the owner decides to pursue the project at a later date.

The first three phases constitute what is often referred to as front end planning, front end engineering and design (FEED), or front end loading (FEL). This book emphasizes effort in these phases since concerted effort