LECTURE NOTES
ON
CONSTRUCTION
PROJECT MANAGEMENT

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PREFACE

In the Name of ALLAH the Most Merciful, the Most Compassionate

All praise is due to ALLAH and blessings and peace be upon His messenger and servant, Muhammad, and upon his family and companions and whoever follows his guidance until the Day of Resurrection.

Construction project management is a relatively young field. However, its impact has been quite remarkable. It has become an important practice for improving the efficiency of construction operations around the world. This book deals with some topics and tools of the large field of project management.

This book is dedicated mainly to undergraduate engineering students, especially Civil Engineering students where most of the applications are presented in the civil engineering field. It provides the reader with the main knowledge to manage a construction project from preliminary stages to handover. It includes eight chapters: Chapter 1 provides a general introduction to construction projects in terms of their types, project life cycle and the main players involved. Chapter 2 is dedicated for the contract strategy. The planning stages of a construction project are presented in chapter 3. Chapter 4 is dedicated for presenting different scheduling techniques along with the schedule representation. Chapter 5 is dedicated to discuss the scheduling methods on non-deterministic activity durations. The scheduling of linear projects is presented in chapter 6. Chapter 7 is dealing with both the resource scheduling and smoothing problems. The schedule compression is, also, presented in chapter 8. Chapter 9 is dedicated for the project finance and cash flow analysis. Finally, chapter 01 is dedicated for project control. Many solved examples have been added to enable the students to understand the material presented in this book. Also, each chapter is followed by exercises for training purposes.

Finally, May ALLAH accepts this humble work and I hope it will be beneficial to its readers.

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CHAPTER 1

INTRODUCTION

1.1 The Need for Project Management

The construction industry is the largest industry in the world. It is more of a service than a manufacturing industry. Growth in this industry in fact is an indicator of the economic conditions of a country. This is because the construction industry consumes a wide employment circle of labor. While the manufacturing industry exhibit high-quality products, timelines of service delivery, reasonable cost of service, and low failure rates, the construction industry, on the other hand, is generally the opposite. Most projects exhibit cost overruns, time extensions, and conflicts among parties. Figure 1.1 is an example of a complicated project. Table 1.1, also, exhibits some magnificent projects that suffered from huge cost overruns.

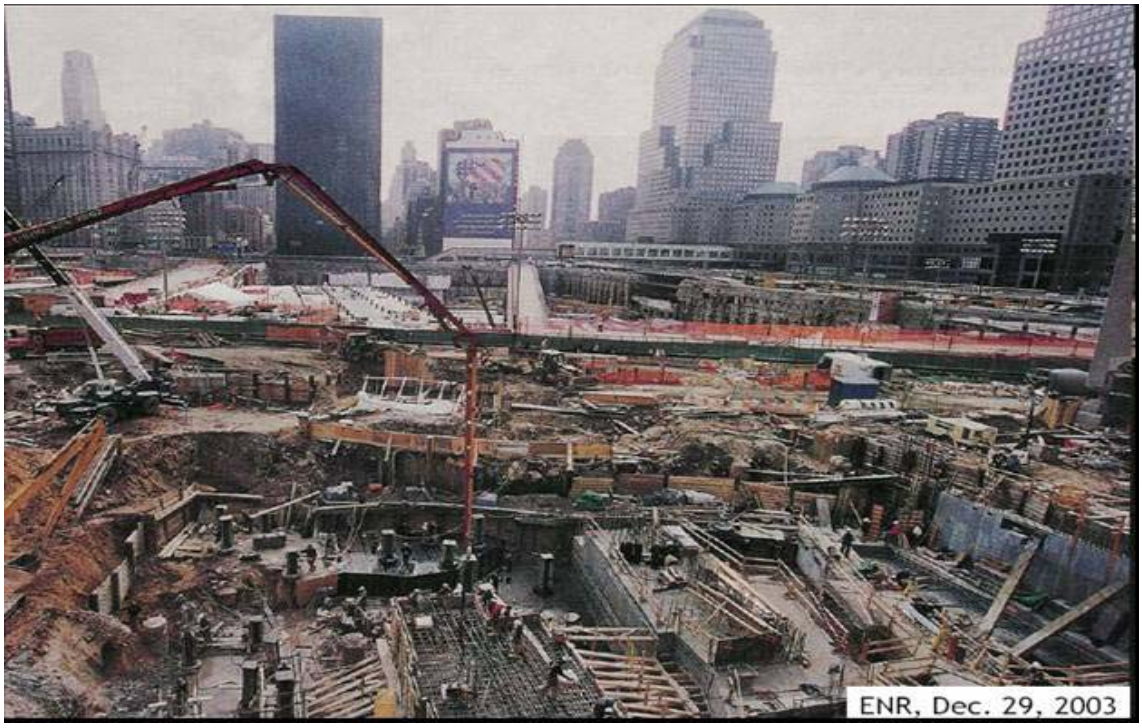

Figure 1.1: Example of a complicated project

Table 1.1: Magnificent projects with huge cost overruns

Project	Cost overruns (%)
Suez Canal	1,900
Sydney Opera House	1,400
Concorde Supersonic Aeroplane	1,100
Panama Canal	200
Brooklyn Bridge	100

(Source: Mette K. Skamris, 'Economic Appraisal of Large-Scale Transport Infrastructure Investments', Ph.D dissertation, Aalborg University, 2000).

In general, the construction industry is more challenging than other industries due to: its unique nature; every project is one-of a kind; many conflicting parties are involved; projects are constrained by time, money and quality; and high risk.

1.2 The Construction Project

A project is defined, whether it is in construction or not, by the following characteristics:

- A defined goal or objective.
- Specific tasks to be performed.
- A defined beginning and end.
- Resources being consumed.

The goal of construction project is to build something. What differentiate the construction industry from other industries is that its projects are large, built on-site, and generally unique. Time, money, labor, equipment, and, materials are all examples of the kinds of resources that are consumed by the project.

Projects begin with a stated goal established by the owner and accomplished by the project team. As the team begins to design, estimate, and plan out the project, the members learn more about the project than was known when the goal was first established. This often leads to a redefinition of the stated project goals.

1.3 The Project Scope and Goals

Project Goal Setting

You can't hit a target if you don't know what it looks like. Similarly, you can't possibly reach your project's goal if you don't know what it is. When you understand how your project fits in with the broader company direction, it's time to really pin down your goal. "But," you say, "I know exactly what my goal is, because my boss told me." However, a set of deliverables isn't necessarily a goal. On first consideration, you might say the goal of expanding the railroad westward in the United States was to enable a train to go from coast to coast. But was it? Perhaps the goal of those railroad barons was not to get a train to go cross country, but to open up opportunities for commerce in the West. It's time to put the same kind of thought to your project's goal.

Getting your goal straight

Say your project involves training new employees in a new software system. Your goal in training them on this software could be to:

- Make employees more productive in their jobs.
- Enable employees to better serve customers.
- Create a prototype program with reduced training costs that can be used to reduce overall training costs across the company.
- Increase employee retention by providing useful on-the-job skills. These goals suggest different priorities as well as different measurements for gauging the degree to which your project has succeeded in meeting its goal.

How, exactly, do you go about determining your goal? First, go back to the person who asked you to take on the project and grill him or her about what's expected of this project. Should the training have a measurable impact on job performance, customer satisfaction, employee retention, or cost of delivery? The answer you get might be that the project should do all of these things. But think about whether that's realistic and whether one of these goals should be paramount in guiding you and your project team. If overall training program cost reduction is the biggest goal factor, for example, employee productivity

might have to take a back seat when you're making choices along the way. If customer satisfaction is the real goal, training costs might have to be adjusted accordingly.

Writing a goal statement

After you get more specifics about your project's goal, it's a good idea to put your goal in writing in a goal statement. *A goal statement outlines why you're doing this project and what you hope to accomplish at the end.* You don't get down to specific deliverables and parameters in a goal statement. For now focus on the why and the desired result.

Here are a few sample goal statements:

- The goal of the project is to upgrade the shopping cart feature on our Web site to be easier to use so we can increase online sales by 25 percent.
- Our goal is to reduce human resource workload by 10 percent by offering self-service information on job benefits on the company intranet.

Using the example of a training project, consider for a moment what such a project might involve. Are you supposed to write new training materials, hire staff to deliver classes, analyze the training's effectiveness, update training materials as needed, and promote the training internally? In that case, the scope of your project involves managing the entire creation, delivery, and maintenance of a training program. Or is your goal to simply create the training materials? Or should your focus be limited to launching the new training, including promoting it to management and staff? These goals indicate very different projects, each with its own set of deliverables, tasks, resources, schedule, and costs. Writing a goal statement helps you focus on such a project from the outset.

Project scope

When you understand your goal, you can begin to define the specific parameters of the project. This is often referred to as a project's scope. ***It is necessary to know that a scope is not a goal***. Take a look again at this goal statement from the previous section: *The goal of the project is to upgrade the shopping cart feature Web site to be easier to use to increase online sales by 25 percent*. A scope statement for this project might read: *This project will involve all the steps to design and implement a new shopping cart feature (but does not include maintaining or refining it once launched)*. The cost of the project

will not exceed $25,000 and implementation must be completed before October 1 to accommodate holiday sales traffic. The new shopping cart feature should help to increase sales by allowing customers more options to review their orders, give them more frequent opportunities to shop for more items after they have added a product to the cart, and allow them to save their cart contents and come back to complete the sale at a future date. The new feature must function on our existing Web technology infrastructure.

Writing a scope statement

Scope statements define both what a project will involve and what it will not involve. In our example, the scope statement specifies that the maintenance of the shopping cart, once launched, will be handled by other project team. You typically get into specifics about the project budget, timeframe, and deliverables in a scope statement. You shouldn't include every single detail, but you should have enough information that a project team can understand the most important parameters of the project. Together, a goal statement and a scope statement are two valuable tools for focusing yourself and your team and keeping you on track as you proceed. If you take the next logical step in pinning down your project at the outset, at this point you would create what's called a project charter. This would include specifying a project name, getting authorization in writing to begin the project as of a certain date and to draw on a specified budget, creating a list of responsibilities, and having those with an interest in the project (called stakeholders) sign off giving you authority to run the project. You can use your goal and scope statements to help you obtain the various pieces of your project charter.

Breaking Your Project into Phases

How does all this goal and scope analysis relate to Project? When you start a new project schedule, one of the first things you will do is to enter individual tasks. Knowing your goal and scope helps you to identify the steps you should be performing to accomplish them. Before you create your first task, you should probably begin to think beyond the scope of your project to more detailed project parameters. These parameters help you determine what tasks to include in your project. For example, you might consider:

- **Deliverables:** These are tangible products, services, or results that you'll produce during your project. Somewhere in your project should be tasks that reflect the delivery of each deliverable.
- **Key Dates:** In addition to the project end date, do you have to meet other key dates along the way?
- **Completion Criteria:** How will you know when you're done? Do you start up the new service and that's it, or do you have to test it for a week before your job is done? Knowing your completion criteria gives your team something specific to aim for and helps you create the last phase of your project.
- **Expectations:** Knowing what you expect from your team, management, and yourself can help you identify some tasks. If you expect your team to hold a quarterly debriefing meeting and submit a progress report, you might include such a task in your project. If you expect management to sign off on a prototype, a task such as Prototype Approval is logical.
- **Potential Risks:** Identifying potential problem areas can help you build in some checks and balances to help avoid or minimize them. For example, you may create tasks that contain terms such as Q&A, Testing, Review, Debrief, and Revise to monitor or fix problems along the way.

1.4 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.

From the perspective of an owner, the project life cycle for a constructed facility may be illustrated schematically in Figure 1.2. A project is expected 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 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.

Of course, the stages of development in Figure 1.2 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. 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 beginning to end. This process is often very complex; however, it can be decomposed into several stages as indicated by the general outline in Figure 1.2. 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. Very often, the owner retains direct control of work in the planning 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.

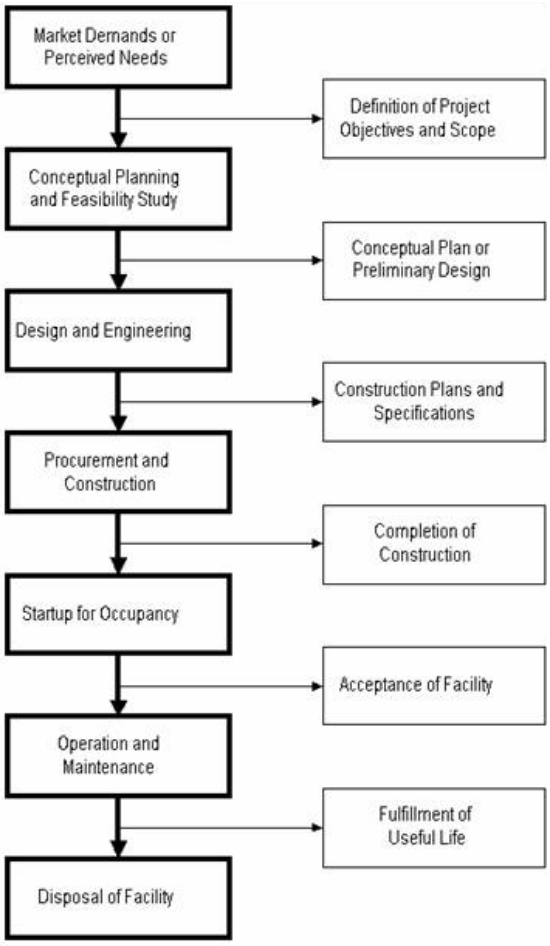

Figure 1.2: Project life cycle

There is no single best approach in organizing project 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. In summary the project phases can be summarized as follows:

1.4.1 Preconstruction phase

The preconstruction phase of a project can be broken into conceptual planning, schematic design, design development, and contract documents.

Conceptual design:

- Very important for the owner.
- During this stage the owner hires key consultants including the designer and project manager, selects the project site, and establish a conceptual estimate, schedule, and program.
- The owner must gather as much information as possible about the project.
- The most important decision is to proceed with the project or not.

Schematic design:

- During this phase, the project team investigates alternate design solutions, materials and systems.
- Completion of this stage represents about 30% of the design completion for the project.

Design development:

- Designing the main systems and components of the project.

- Good communication between owner, designer, and construction manager is critical during this stage because selections during this design stage affect project appearance, construction and cost.
- This stage takes the project from 30% design to 60% design.

Contract documents:

- Final preparation of the documents necessary for the bid package such as the drawings, specifications, general conditions, and bill of quantities.
- All documents need to be closely reviewed by the construction manager and appropriate owner personnel to decrease conflicts, and changes.
- With the contract documents are almost complete; a detailed and complete cost estimate for the project can be done.

1.4.2 Procurement phase (Bidding and award phase)

- The project formally transits from design into construction.
- This stage begins with a public advertisement for all interested bidders or an invitation for specific bidders.
- In fast-track projects, this phase overlaps with the design phase.
- If the project is phased, each work package will be advertised and bid out individually.
- It is very important stage to select highly qualified contractors. It is not wise to select the under-bid contractors.

1.4.3 Construction phase

- The actual physical construction of the project stage.
- This stage takes the project from procurement through the final completion.
- It is the time where the bulk of the owner's funds will be spent.
- It is the outcome of all previous stages (i.e., good preparation means smooth construction).

- The consultant will be deployed for contract administration and construction supervision.
- Changes during construction may hinder the progress of the project.

1.4.4 Closeout phase

- Transition from design and construction to the actual use of the constructed facility.
- In this stage, the management team must provide documentation, shop drawings, as-built drawings, and operation manuals to the owner organization.
- The as-built drawings are the original contract drawings adjusted to reflect all the changes that occurred.
- Assessment of the project team's performance is crucial in this stage for avoiding mistakes in the future.
- Actual activity costs and durations should be recorded and compared with that was planned. This updated costs and durations will serve as the basis for the estimating and scheduling of future projects.

Figure 1.3 shows the increasing cumulative cost as the projects progresses while the influence in the project cost and scope decreases.

1.5 Major Types of Construction Projects

In planning for various types of construction, the methods of procuring professional services, awarding construction contracts, and financing the constructed facility can be quite different. The broad spectrum of constructed facilities may be classified into four major categories, each with its own characteristics.

1.5.1 Residential Housing Construction

Residential housing construction includes houses and high-rise apartments. During the development and construction of such projects, the developers 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.

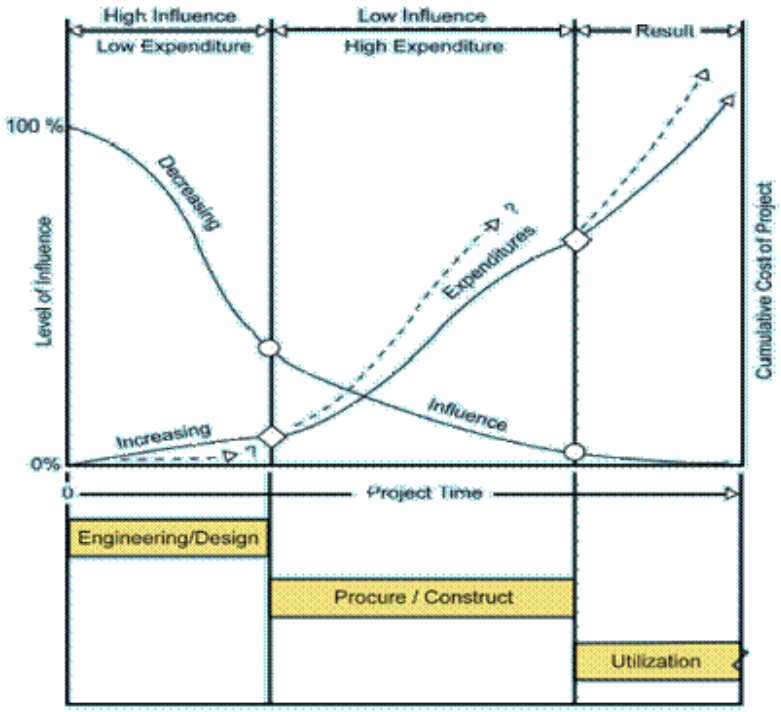

Figure 1.3: Level of influence vs. project duration

The residential housing market is heavily affected by general economic conditions. 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, 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.

1.5.2 Institutional and Commercial Building Construction

Institutional and commercial building encompasses a great variety of project types and sizes, such as schools and universities, medical centers and hospitals, sports facilities, 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.

Because of the higher costs and greater sophistication of institutional and commercial buildings in comparison with residential housing, this market segment is shared by fewer competitors. Since the construction of some of these buildings is a long process which once started will take some time to proceed until completion, the demand is less sensitive to general economic conditions than that for housing construction.

1.5.3 Specialized Industrial Construction

Specialized industrial construction usually involves very large scale projects with a high degree of technological complexity, such as oil refineries, 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.

Although the initiation of such projects is also affected by the state of the economy, long range demand forecasting is the most important factor since such projects are capital intensive and require considerable amount of planning and construction time. Governmental regulation such as environmental protection can also influence decisions on these projects.

1.5.4 Infrastructure and Heavy Construction

Infrastructure and heavy construction includes projects such as highways, 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. However, demands for different segments of infrastructure and heavy construction may shift with saturation in some segments. For example, as the available highway construction projects are declining, some heavy construction contractors quickly move their work force and equipment into the field of mining where jobs are available.

1.6 Construction Projects Participants

1.6.1 The Owner (The Client)

The owner is the individual or organization for whom a project is to be built under a contract. The owner owns and finances the project. Depending on the owners' capabilities, they may handle all or portions of planning, project management, design, engineering, procurement, and construction. The owner engages architects, engineering firms, and contractors as necessary to accomplish the desired work.

Public owners are public bodies of some kind ranging from agencies from the country level to the municipal level. Most public projects or facilities are built for public use and not sold to others. Private owners may be individuals, partnerships, corporations. Most private owners have facilities or projects built for their own use or to be sold, operated, leased, or rented to others.

In order to achieve success on a project, owners need to define accurately the projects objectives. They need to establish a reasonable and balanced scope, budget, and schedule. They need to select qualified designers, consultants, and contractors.

1.6.2 The Design Professionals

Examples of design professionals are architects, engineers, and design consultants. The major role of the design professional is to interpret or assist the owner in developing the project's scope, budget, and schedule and to prepare construction documents. Depending on the size and sophistication of the owner, the design professional can be part of the owner's group or an independent, hired for the project. In some cases design professional and construction contractor together form a design-build company.

Architect: An architect is an individual who plans and design buildings and their associated landscaping. Architects mostly rely on consulting engineers for structural, electrical, and mechanical work.

Engineer: The term engineer usually refers to an individual or a firm engaged in the design or other work associated with the design or construction. Design engineers are usually classified as civil, electrical, mechanical depending upon their specialty. There are also scheduling, estimating, cost, and construction engineers.
Engineering-Construction Firm: An engineering-construction firm is a type of organization the combines both architect/engineering and construction contracting. This type of company has the ability of executing a complete design-build sequence.

1.6.3 The Construction Professionals

The constructions Professional are the parties that responsible for constructing the project. In traditional management where the owner, design professional, and contractors are separate companies, the contractor would be termed a prime contractor. The prime contractor is responsible for delivering a complete project in accordance with the contract documents. In most cases, the prime contractor divides the work among many specialty contractors called subcontractors as shown in Figure 1.4.

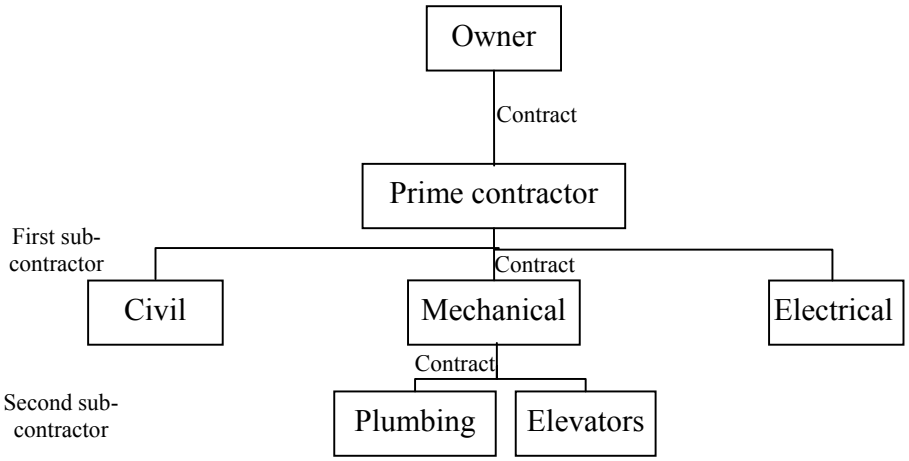

Figure 1.4: Contractor hierarchy

1.6.4 The Project Manager

The project manager is the individual charged with the overall coordination of the entire construction program for the owner. These include planning, design, procurement, and construction. Among his/her duties:

- Clear definitions of the goals of the project.
- Investigate alternative solutions for the problems.
- Develop a detailed plan to make the selected program reality.
- Implement the plan and control the project.

Construction Manager: The construction manager is a specialized firm or organization which administrates the on-site erection activities and the consulting services required by the owner from planning through design and construction to commissioning. The construction manager is responsible for design coordination, proper selection of materials and methods of construction, contracts preparation for award, cost and scheduling information and control.

1.7 Exercises

1. State if True (T) or False (F):

   a. The amount of information that a project manager must consider increases as a project moves towards completion.

   b. Dams, bridges, and highways would be classified as commercial building projects.

   c. In the construction phase of the project, the owner needs to be heavily involved.

   d. The construction project must have a defined goal or objective.

   e. The construction project must have a defined beginning and end.

   f. The main objective of the Owner is to win the job, finish it in a reasonable time, with maximum profit and reasonable quality.

2. Select the right answer:

   I. Site selection and financing would be the responsibility of which project member.

   a. Owner b. Designer

   c. Construction project manager d. Subcontractor

   II. This Category of projects is often funded by public pounds and is termed "infrastructure".

   a. Residential b. Commercial building

   c. Heavy engineering d. Industrial

   III. Which of the following is not a characteristic of a project?

   a. Having a specific goal b. Having a defined beginning and end

   c. Resources being consumed d. usually being performed only once

   e. Never being found outside the construction field

   IV. The advertising for contractors and review of contractors' bids occurs during which project phase.

   a. Procurement b. Design

   c. Construction d. Conceptual planning

V. As-built drawings, warranties, and operation manuals are all provided to the owner during which project phase.

a. Design b. Conceptual planning

c. Construction d. Project closeout

VI. As project moves on in time, the ability to change the project becomes……difficult and……expensive.

a. more, less b. less, less

c. more, more d. less, more

3. What are the main types of construction?
4. Briefly describe the project life cycle.
5. "As the project progress, the ability of the change decreases while the cost of the change increases", comment on this statement and show your answer using a schematic diagram.
6. List 10 subcontractors that can be engaged in building project.