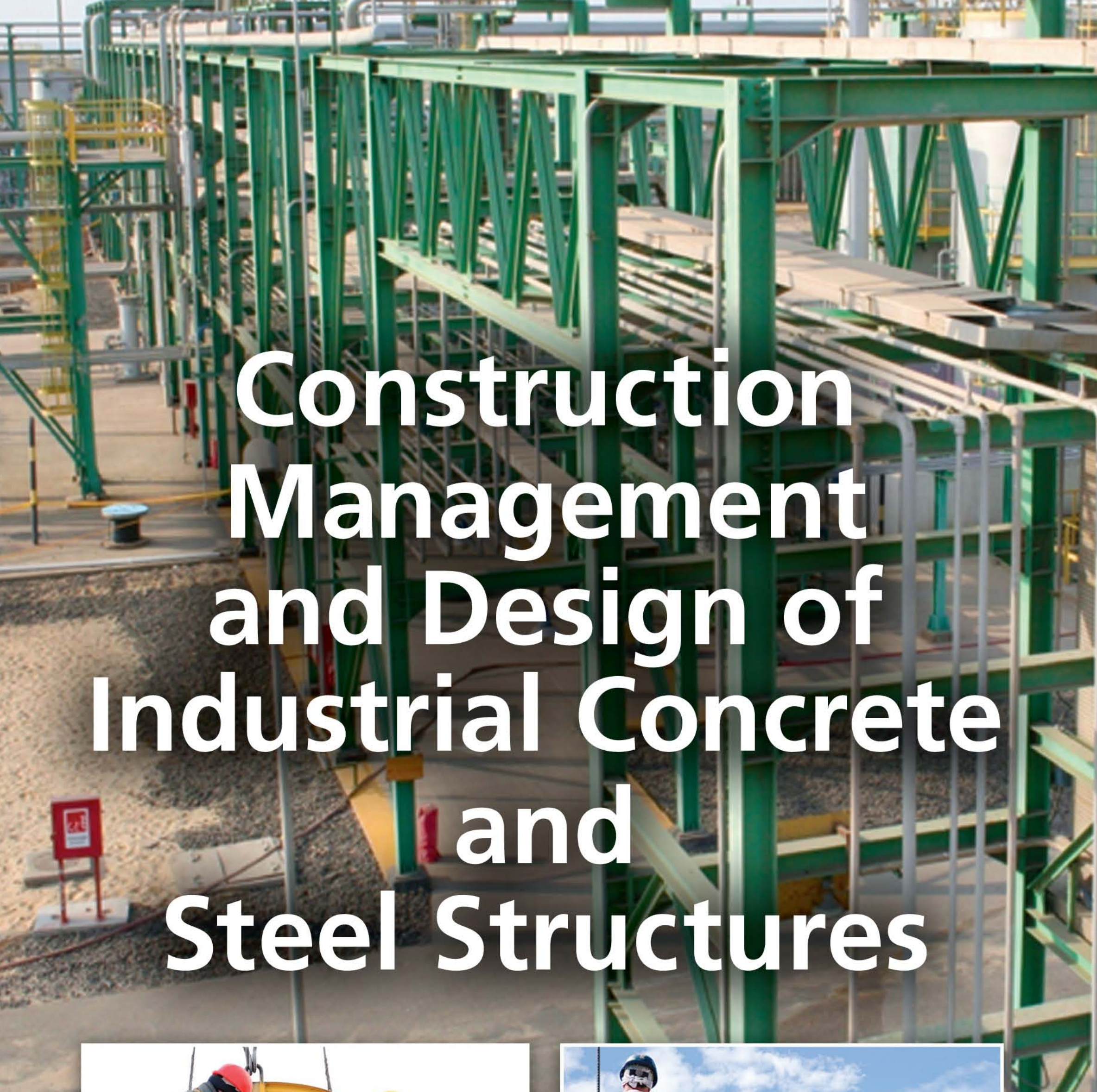

Construction Management and Design of Industrial Concrete and Steel Structures

Mohamed A. El-Reedy

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This book is dedicated to the spirits of my mother and father,

my wife, and my children Maey, Hisham, and Mayar.

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Preface

The development of any country depends on the rate of industrial growth. Currently, there is a race in industrial projects worldwide. The development of the industry depends on the development of the energy reserve by investment in projects of oil and gas exploration, onshore and offshore, which require new facilities or rehabilitation of existing facilities. At the same time, there are projects that are running in parallel to deliver electricity from electrical power stations or through nuclear power plants.

In this book, the term *industrial structures* means all the reinforced concrete and steel structures from a small factory to a nuclear plant. This book will be an overview of industrial project management, design, construction, and eventually providing a maintenance plan. Industrial projects, in most cases, are huge and can cost a billion dollars for one project, so the client, engineering firm, and contractor are in the same boat until they achieve project success through a strong management system and technical competence. Therefore, this book discusses all items that interface among these main three partners.

In these types of projects, all the engineering disciplines are working together, but, unfortunately, the structural or civil engineers are usually the last ones to obtain the exact data from the other disciplines and the first ones to start on site. Therefore it is a challenge for the structural engineers to work fast and efficiently in this type of project.

This book focuses on the structural engineering of all of these projects. The aim of this book is to provide up-to-date methodology and industry technical practice and guidelines to design, construct, and maintain the reinforced concrete and steel structures in these industrial projects. The essential processes of protection, repair, and strengthening of the industrial structures necessitated by deterioration or a change in the mode of operation are illustrated in this book. It is intended to be a guidebook to junior and senior engineers who work in design, construction, repair, and maintenance of reinforced concrete and steel structures and to assist them through all of the stages of industrial projects.

The other challenge that faces structural engineers is that most of the undergraduate courses they studied in college focused mainly on real estate projects and housing. However, the characteristics of industrial projects are different. This book provides a guide for the project and construction manager to lead the project and to successfully achieve the owner's requirements. On the other hand, from a technical point of view, this book describes the first principle of the codes and standards that are usually used in industrial projects and the most applicable methods used in the design of the steel and reinforced concrete structures that serve the static equipment, tanks, towers, and vibrating equipment. This book describes current research and development in the design, construction, repair, and maintenance philosophy.

An overview of offshore structure design and construction is very important and provides the tools to check the design and to control the project in all of its phases. Recently, there is a trend toward maintaining the reliability of the structure from both safety and economic points of view by developing the structural integrity management system, which will also be a part of this book.

The last chapter describes the soil investigation tests that are essential to the industrial projects and provides the main key to selecting the most reasonable type of test and also the main features for the pile foundation design.

This book provides a practical guide to designing the reinforced concrete and steel structures and foundations in industrial projects with the principle of repairing the concrete structures and the methodology to deliver a maintenance plan for the concrete and steel structures serving onshore and offshore facilities.

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Mohamed A. El-Reedy pursued a career in structural engineering. His main area of research is the reliability of concrete and steel structures. He has been a consultant to different engineering companies and oil and gas industries in Egypt as well as international companies such as the International Egyptian Oil Company (IEOC) and British Petroleum (BP). Moreover, he provides different concrete and steel structure design packages for residential buildings, warehouses, telecommunication towers, and electrical projects with WorleyParsons Egypt. He has participated in Liquefied Natural Gas (LNG) and Natural Gas Liquid (NGL) projects with international engineering firms. Currently, Dr. El-Reedy is responsible for reliability, inspection, and maintenance strategy for onshore concrete structures and offshore steel structure platforms. He has performed these tasks for hundreds of structures in the Gulf of Suez and in the Red Sea.

Dr. El-Reedy has consulted with and trained executives for many organizations, including the Arabian American Oil Company (ARAMCO), BP, Apache, Abu Dhabi Marine Operating Company (ADMA), the Abu Dhabi National Oil Company, King Saudi's Interior Ministry, Qatar Telecom, the Egyptian General Petroleum Corporation, Saudi Arabia Basic Industries Corporation (SAPIC), the Kuwait Petroleum Corporation, and Qatar Petrochemical Company (QAPCO). He has taught technical courses on repair and maintenance for reinforced concrete structures and advanced materials in the concrete industry worldwide, especially in the Middle East, Malaysia, and Singapore.

Dr. El-Reedy has written numerous publications and presented many papers at local and international conferences sponsored by the American Society of Civil Engineers, the American Society of Mechanical Engineers, the American Concrete Institute, the American Society for Testing and Materials, and the American Petroleum Institute. He has published many research papers in international technical journals and has authored four books about total quality management, quality management and quality assurance, economic management for engineering projects, and repair and protection of reinforced concrete structures. He received his bachelor's degree from Cairo University in 1990, his master's degree in 1995, and his PhD from Cairo University in 2000.

1

Introduction

Civilization and development in most countries depend on the sources of energy that feed all the industrial projects. At this time, the main sources of energy have been oil and gas. Therefore, oil and gas projects are critical from both safety and economic points of view. The petroleum industry is one of the richest in the world, so there is much research and development in this area to enhance the design, construction, and management of these projects.

Industrial projects have different characteristics from both management and technical points of view; for example, time is more important than cost. This principle differs from other projects. In addition, the industrial projects depend on different types of machines, cranes, vessels, tanks, and other specific equipment for each type of industry. These projects require concrete and steel structures for their equipment, which requires a special design procedure and philosophy, as these structures are at times under the effects of dynamic loading. Most industrial projects are located onshore, but many oil and gas projects have facilities and structures offshore and near-shore for activities such as exploration and loading of ships.

Management is critical to solving the interface between the different engineering disciplines that will work together in the engineering office and onsite. The electrical, mechanical, instrument, and civil engineers are focused on their concerns only, so the main challenge to management in any phase is to resolve conflict and create and maintain harmony among the team members to successfully complete the project in terms of time, cost, and quality.

Management of the projects is the main key to success. Imagine that you have very skilled team members but their objectives are not clear, there is conflict between members and a lack of cooperation. You cannot expect the project to be successful. The main tools and skills for construction management are discussed from a practical point of view in Chapter 2, as well as how to build teamwork and increase and monitor team performance in a professional manner.

In any university that graduates civil and structural engineers, most courses focus on the design of regular buildings for housing and real estate projects and their codes and standards. Industrial projects—such as oil, gas, and electrical power—have their own codes, standards, and concepts. The main differences are related to the loads that affect the structure in industrial projects. Chapter 3 defines the loads affecting the industrial project including the common codes, standards, and technical practices that are traditionally used in these types of projects. This chapter illustrates the required data from electrical and mechanical engineers and how the mode of operation influences the design load parameters. Moreover, in the case of a new plant in a new location that is outside of any major cities—as is usually true of oil and gas plant facilities—there are some data required from third parties such as MetOcean data (in the case of offshore or near-coast facilities) or information necessary to define the hazard area in case of earthquake. This chapter discusses in detail the loads affecting concrete and steel and their nature and how the designer can define the scope of the work professionally to a third party and thereby obtain useful data.

The main equipment in any industrial project is rotating equipment such as compressors, pumps, and power turbines. This type of equipment requires special precautions in the methodologies of design and construction, which will be discussed in Chapter 4.

It is traditional in these types of projects to use tanks. Chapter 5 provides the necessary guidelines and features in designing the reinforced concrete tanks that are usually used in this industry. It is common in the case of oil and gas that the steel tanks are designed by the static equipment designer. The key element are the mechanical valves with the instrumentation system that monitors and controls the levels. In minor cases, the tanks will be designed by structural engineers.

In Chapter 5, the main element of design of these steel tanks is discussed, emphasizing the essential precaution required during construction. The design of the reinforced concrete ring beam under the steel tank is discussed using a real example. In the industrial plant, there are usually retaining walls, and in most cases, these walls are located around the tanks as a safety requirement in case of a tank leak. Hence, the design of retaining walls is also presented in this chapter.

The static equipment such as the separators, steel towers, knock-out drums, and heaters are designed by static equipment specialist engineers, and they also provide the required data to design the foundations under this type of equipment. The design of these foundations will be illustrated in Chapter 6 by defining the data and the philosophy of operation of each piece of equipment.

Steel structures are usually used in industrial projects because they can be erected quickly and because of their capital cost value over time. The structures' requirements for maintenance and protection are easily met in industry as there is usually a professional crew available to conduct maintenance and ensure structural integrity over time.

In the case of the steel structures for pipe racks, some precautions are required when choosing the structure system and estimating how the loads from pipes and electrical cable trays will affect the structures. All these factors are discussed in Chapter 7. All steel structures and static equipment will be fixed to the concrete foundations by anchor bolts. The design of these anchor bolts will also be illustrated in detail in this chapter.

In general, industrial projects experienced fast growth after World War II, and after the mid-1950s, there was also fast growth in oil production worldwide. As a result, there are now many mature facilities worldwide, and therefore, it is usually required to assess the steel and concrete structures to define any problems and determine if the structures can accommodate the existing load.

In some cases, there are changes in the mode of operation or a need to install a new piece of heavy equipment, so it is necessary to evaluate and assess the existing structure to determine if it can carry the heavier load. The method for evaluating the existing structures in industrial plants will be discussed in Chapter 8.

Chapter 9 presents the method for protecting the foundations under the equipment and the main reinforced concrete structures from corrosion, as most of the facilities are near the shoreline. Factories located inside cities are subject to the effects of carbonation, so the advantages and disadvantages of each type of protection against each cause of corrosion are discussed from both technical and economic viewpoints.

The processes of repairing the reinforced concrete structures and strengthening their members to resist higher loads are presented in Chapter 10. The methods of repair are chosen based on their fast application. Aesthetics is not a main concern, as we are not working in a shopping mall or hotel building. Repair and strengthening will involve using steel sections or carbon fiber to reduce the risk as much as possible.

The integrity management system to maintain mature structures is the most recent management policy that depends on risk-based inspection and maintenance. Risk-based and underwater inspections in the case of offshore structures are discussed in Chapter 11.

Chapter 12 discusses the offshore structures used in oil and gas projects in shallow and deep water. The loads, features of design, and method for reviewing the design of a fixed offshore structure will be illustrated. The construction phase has special features as did the design phase. Therefore, the steps of construction and the loads affecting the structure during transportation, lifting, and installation are presented from a practical point of view.

Chapter 13 presents the geotechnical investigation tools and methods used to obtain the required data necessary to design the foundation for static and rotating equipment as well as the foundation for reinforced concrete and steel structures. The geotechnical investigation and the design and construction of the piles are usually performed by a third party. This chapter provides a method for preparing a precise scope of work for the third party, presenting the main concept of soil investigation and pile design, so that the required accurate data may be obtained.

2

Construction Management for Industrial Projects

2.1 Introduction

The subject of project management has become one of the most common themes in the recent past because of the increase in the number of megaprojects worldwide. The development of modern technology in all areas of knowledge requires new methods of project management to cope with the rapid advances.

The concept of the project is very different from how the daily routine operation works; therefore, project management is different from the daily activity of operation management. Most books and references that discuss project management define the project as a number of tasks and duties to be implemented during a specific period to achieve a specific objective or set of specific targets.

To clarify the difference between project management and operations management, think about what is going on in the minds of two managers. The project manager's dreams are about finishing the project on time and about where he will relocate to after the completion of the project. This is totally different from the thinking of the operation manager. He does not dream about a stop of daily production, which is contrary to the project manager's goal. Therefore, you can imagine the difference between the thinking of the two mangers.

The first difference in the definition of project management, as opposed to operation management, is that the goal is to finish the project within a certain time frame and simultaneously realize a set of objectives.

2.2 Project Characteristics

One of the most important features of the project is the selection of individuals from different locations in the same company. In some international projects, the team members are from different countries, cultures, educations, and employment backgrounds, and all of these individuals have different skills. With all of those differences, they must still work together to complete the work in a specific time and with a definite target.

The project manager has to coordinate between the members of the project to reach the project goal. As a result of the rapid development in modern technology, the specialty has become important. These days, any project contains many different disciplines. An explicit example is a construction project where there are separate teams for constructing the reinforcing concrete, finishing work, plumbing, and other activities. Every branch of the construction activity has its own technology and skills. Therefore, the project manager has to facilitate cooperation between the different disciplines to achieve the project objective.

The primary goal of the project manager is to complete the project, with high quality, and achieve the objectives.

Any project has a main driver, and it is one of the two driving forces. In other words, there are two philosophies in managing the project: one is cost-driven and the other is time-driven. This driver is considered to be the underlying philosophy in the management of the project, which must be determined by the director of the project with other parties, as well as the official sponsor of the project and the stakeholder. The project-driving philosophy should be known to both the technical and administrative department managers.

To illustrate the effect of the two driving factors, we should think about all types of projects that are running around us. We will find that, in some projects, reducing the cost is the major factor and time is the secondary factor, as the increase in project duration time will not affect the project's operation phase. Put more precisely, it will not affect the owner and his investment. Building houses, mosques, churches, museums, and other projects that have a social aspect are examples of this.

On the other hand, there are some projects where reducing time to completion is the main challenge; this is a time-driven project. A clear example of this is in the petroleum industry. For oil, gas, and petrochemical projects, any day saved will be a gain of many millions of dollars per day as the production is measured by barrels of oil per day (BOPD) or million standard cubic feet per day (MMSCFD). By multiplying that by the price of oil or gas, you can calculate the income. For example, if the gain in production from the project is 50,000 BOPD with an oil price of $40 per barrel, for every day saved, the owner gains $2,000,000.

As illustrated, the main driver of the petroleum projects is time. So, the main target of these projects is the reduction of the time to completion.

It is very important to define the basic driving force of a project, whether it is cost or time, and all the staff working on the project should know this information. This is the responsibility of the project manager. Any groups or teams at work, both in design and execution, should provide proposals, recommendations, and action steps that are in line with the project driver, whether that involves reducing time or cost.

It is necessary for the target to be clear to all involved to avoid time wasted discussing ideas and suggestions that are not feasible. Imagine that you are working on a housing project and one of the proposals from the engineers is to use a rapid-setting concrete to reduce the time of construction but with an increase in cost. Is this proposal acceptable? It certainly is not. On the other side, in the case of the construction of an oil or gas plant or new offshore platform, one of the proposals is for the use of materials that are the least expensive but that need time to be imported from abroad, which will delay the project for some days. Is this proposal accepted? Of course, this proposal is unacceptable. However, if we were to trade off each of these proposals for the other, we will find that the two proposals are excellent and acceptable.

When communication is lost between the project manager and personnel, there is a great deal of confusion; everyone works hard, but in different directions, resulting in wasted effort and lack of success. Moreover, project managers must also communicate with suppliers and contractors to ensure that their proposals regarding supply materials and construction are within the project-driven criteria. The project characteristics can be summarized as follows:

- The project has a specific target.
- The project is unique and cannot be replicated with the same task and resources giving the same results.
- The focus is on the owner's requirements and expectations from the project.
- It is not routine work, although there are some aspects that are routine.
- The project consists of a number of associated activities contributing to the project as a whole.
- There is a specific amount of time allowed to finish the project.
- The project is complex in that it involves a number of individuals from different departments.
- The project manager must be flexible to accommodate any change that might occur during the project.
- There are factors of uncertainty such as the performance of individuals, how their skills adapt to unfamiliar work, and other unknown external influences.
- The total cost is defined and has a limited budget.
- The project presents unique opportunities to acquire new skills.

- The project gives impetus to the project manager to adapt to working under changing circumstances, as the nature of the project is change.
- There are risks with each step of the project, and the project manager should manage those risks to reach the project goal.

2.3 Project Life Cycle

The project definition is a set of activities with a specific start time and end time. These activities vary from project to project depending on the nature of the project. An example of this might be a cultural or social project, such as a public education endeavor, or a civil project, such as the construction of a residential building, hospital, road, bridge, or other industrial projects. In our scope, we will focus on industrial projects.

The civil projects vary from one project to another, depending on the size and value of the project. They can range from constructing a guard room to constructing a nuclear plant; hence, the quality varies with the size of the project, especially in developing countries.

In a small project, it might be sufficient to apply a quality control only where small contracting companies or engineering offices are involved. When the target involves global competition and increasing the quality will increase the total cost of the project, quality control is often applied to the structural safety of the building only.

In the case of a major project, there are many execution companies and engineering offices working at the same time. Therefore, we must also take into account that implementing quality assurance procedures is necessary and vital as are the quality controls carried out in all phases of the project based on the project specifications. Each stage of a construction project starts with a feasibility study, followed by preliminary studies of the project, detailed studies, and, finally, execution. The operation crew will then receive the project to run.

In all of these stages, there are many types of quality control required to achieve a successful project that has benefits and appropriate return on investment for the owner and all parties and participants. Figure 2.1 shows the life cycle of any project. From this figure, it is clear that 5% of the project resources (time and cost) is expended on the feasibility study, 25% is expended on the engineering designs, and the largest percentage of project resources is expended in the execution phase.

As shown in Figure 2.1, after the feasibility study, a decision is required by senior management on the question, “Will the project continue or be terminated?” Imagine a gate and, if the results of the feasibility study are positive,

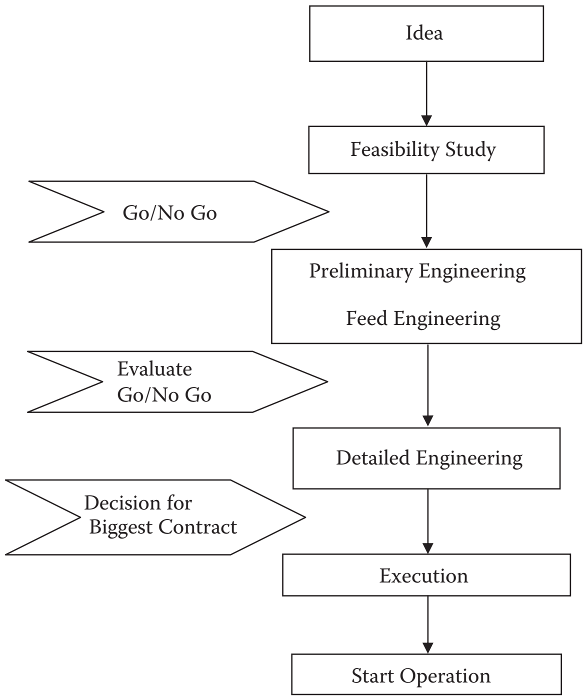

FIGURE 2.1
Project life cycle.

the project passes through to the next stage—the preliminary studies, which will provide a more accurate assessment of the project. After those studies, there is another gate and another decision required. If the answer is positive, this gate will open and the project will move forward to the detailed engineering and construction phase.

At each phase or stage of the project, there are roles for the owner, the contractor, and the consulting engineer, and each system has its own project management approach. Every stage has its own characteristics and circumstances, and each involves change in the scope of work (SOW) for each of the three involved parties and this should be clarified for each stage.

The characteristics of the project life cycle change from time to time. In each period, the number of personnel on the project can change. For example, at the beginning of the project, the number of personnel is very small. It increases with the number of activities being carried out and then gradually decreases until the end of the project. Figure 2.2 shows the changes in the number of personnel in the project and notes that the project manager should have the necessary skill to deal with the changes that occur during the life cycle of the project (Figure 2.3).

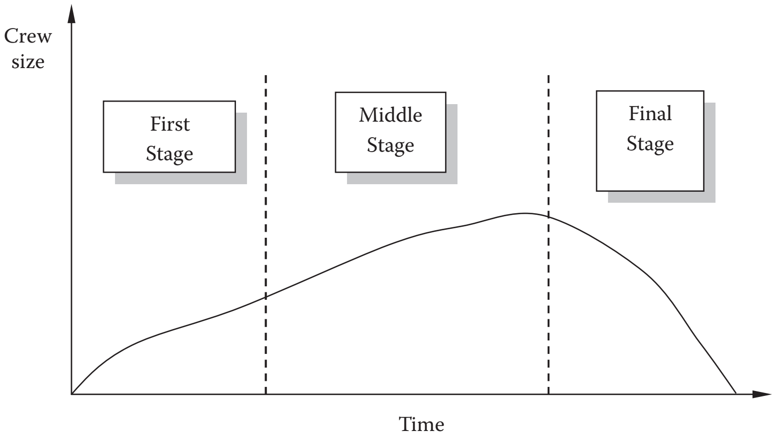

FIGURE 2.2
Change in crew size during project lifetime.

2.3.1 Feasibility Study

Each phase of the project has different importance and impact on the project as a whole and varies depending on the nature and circumstances of the project and its value and target.

The feasibility study is the second phase after the emergence of the owner's idea for the project. The owners of oil and gas projects are the geologist

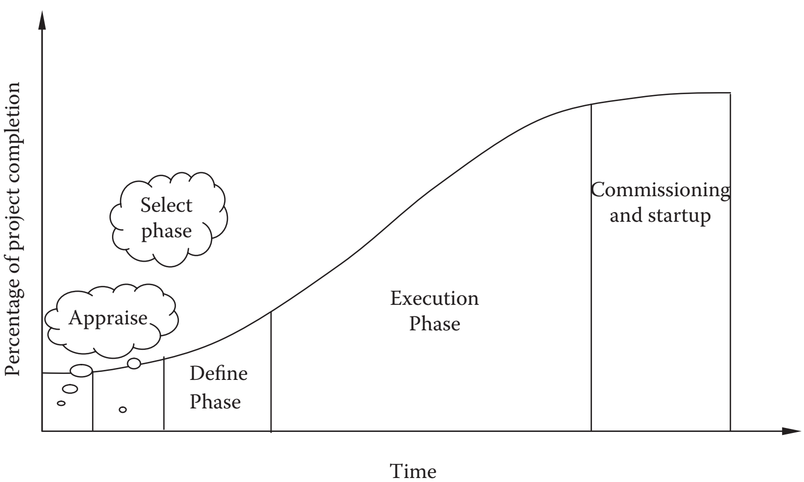

FIGURE 2.3
Project life cycle phases.

and the petroleum engineering team who base their ideas on oil and gas reservoir characteristics.

The economic study for the project will be performed by high-level and highly skilled personnel of the organization, as this study will include expected fluctuations of the price for oil and gas and other petrochemical products during the project life time. Their experience is based on what they have done on similar projects before, as well as records kept and lessons learned from previous projects.

In this initial phase, the selection of team members for the consultant's office is very important as they will perform the feasibility study for the project. In some cases, there is input from an engineering firm that performs a generic engineering study about the project and estimates the cost, based on their experience.

The feasibility study phase, which is also called the *appraise* phase, is followed by the preliminary (FEED) study phase. These two phases are essential as they set the objective of the project and identify engineering ideas through the initial studies. It is preferred to apply the Japanese proverb, "Think slowly and execute quickly," especially in the feasibility study stage. At this stage, the goal of the project is defined and the economic feasibility of any move is determined, as is the move's direction.

For these reasons, we must take full advantage of this phase and its time, effort, study, research, and discussions, with more attention to the economic data. The economic aspect is important at this stage and the engineering input is very limited.

2.3.2 FEED (Preliminary) Engineering

This stage is the second phase after the completion of the feasibility study for the project.

This phase of preliminary engineering studies, which is known as FEED engineering, is no less important than the first phase. It is one of the most important and most critical stages in the engineering of the project because the success of the project as a whole depends on the engineering study in this phase. Therefore, as this stage is vital, the engineering consultancy firm that will perform this study should have an extensive experience in these types of projects.

Specifically, liquefied natural gas (LNG) is a type of project that requires experienced personnel in this field. Another example is a project that uses floating production, storage, and offloading (FPSO). It also requires a special consulting office that has worked on this type of project before. In the case of small projects such as a residential or administrative building or a small factory, the purpose of the FEED phase of engineering is to determine the type of structure, whether it will be steel or concrete. If it is decided to use a concrete structure, the engineer should define whether it will be precast, prestress, or normal concrete and then determine if the type of slab structure system will be solid slab, flat slab, hollow blocks, or another type. This phase also defines the location of the columns and the structure system and whether the project will use a frame or shear wall for a high-rise building.

In summary, the purpose of preliminary engineering is to provide a comparison between the alternatives that vary depending on the size of the building and the requirements of the owner so that a reasonable structure system and appropriate mechanical and electrical systems may be selected. For this reason, this stage has recently been called the *select* phase.

In the case of major projects such as a petrochemical plant or new platforms, there will be other studies at this stage such as geotechnical studies, metocean studies, seismic studies, and environmental studies. The main purpose of this phase is to provide the layout depending on the road design, location of the building, and hazard area classification in the petroleum projects. Moreover, it must select the foundation type, whether it is to be a shallow foundation, or driven or rotary piles, based on the geotechnical studies. In case of oil and gas projects, we need to carefully study the mode of transfer and trade-offs of the product and select the appropriate method of transfer between the available options.

Now, it is clear that, because of the seriousness of this stage and the need for high-level experience, for large projects, the owner should have competent engineers and an administrative organization with the ability to follow-up on initial studies to achieve the goal of the project and coordination between the various project disciplines such as civil, mechanical, electrical, and chemical engineering, as all the disciplines usually intersect at this stage.

In general, regardless of the size of the project, the owner must be presented with the engineering requirements for the project through a statement of requirement (SOR) document, which must be highly accurate and contain the objective of the project and the requirement from the owner. It will also precisely identify the SOW. This document is the starting phase of the mission document quality assurance system and must contain all information requested by the owner. The preparer must be experienced because this document is relied upon to determine the outline of the whole project and to contain all particulars of the project, its objectives, proposals, and the required specifications of the owner.

This document also contains the available technical information from the owner such as the location of the land, its coordinates, and its specifications. This document will be a part of the contract document between the owner and the engineering firm, and the engineering firm will provide cost, time, and resources (CTR) sheets based on it.

In the case of projects such as gas or LNG, it is important to determine the amount of gas, type, and other specifications needed to process and transfer the gas with clarification of temperature, pressure, and all other technical data that allows for the final product to be shipped or transported. Among the most important data to be mentioned in the document is the project lifetime. Again, specifications required by the owner in the project should be defined clearly and precisely in this document.

It should be noted that there will be regular meetings among the owner, the technical team, and the consulting engineers responsible for the preparation of initial studies, and through these meetings, the SOR may be amended several times. Each time, the document must contain the date and revision number as well as all of the requirements—civil, architectural, electrical, mechanical, and others—of the project. We should note here that, for quality assurance, all parties to the project must have a current version of the document and everyone must work according to this document. It is also important to determine the number of meetings and the exact schedule of meetings required to reach the target.

An SOR document is not only required for new projects, but also for modifications to buildings or in the plant. Upon receipt of the SOR document in the engineering office, another document is prepared to respond to the SOR. This document is called the *basis of design*, and through it, the engineering firm clarifies the code and engineering specifications that will operate in the design as well as the calculation methods, theory, and computer software that will be used. This document may also state the required number of copies of the drawings that will be sent to the owner and the sizes of those drawings. The engineering firm should also request any missing data and request that a third party supplement any necessary information such as weather and environmental factors. This document will be carefully reviewed by the owner and can be amended many times until both parties are satisfied.

At this stage, it is important to make sure that both the owner and the engineering firm have the same concept and that there is complete agreement among all parties about the technical aspects. Any drawings prepared during the FEED studies should be delivered to the owner for review and comment. The owner and the engineering firm should agree on the time allotted for review of the document by the owner. If more time is taken than allowed, it indicates owner acceptance. This is very important to control the project time.

This phase may take a number of months in the case of large projects, and therefore, the technical office of the owner must have a qualified engineer with experience in controlling costs and ensuring that follow-up time conforms to the schedule agreed upon in advance. We may need an engineer specialized in planning, called the *planner engineer*. This engineer should be specialized in cost control, ensuring that the estimated cost of the project is comparable to that in the feasibility study.

By monitoring the cost at each stage precisely, at the end of the project the whole cost will be within the estimated value in the beginning of the project.

In petroleum projects, where the return of income or expense is calculated by the day, it is worth noting that any savings in time is a big return for the owner.

The project site itself and the surrounding environment must be considered to determine ways to protect it from weather and reduce the cost of maintenance over time by selecting different methods of maintenance. For example, one way to protect the reinforced concrete foundation from corrosion is by protecting the reinforcing steel with a cathodic protection system, which is expensive at the beginning of the construction but allows periodic, low-cost maintenance later. On the other hand, if we do not want to use an external protection system, we can use a low-cost alternative during construction, although this necessitates high-cost regular maintenance thereafter.

The structure, mode of operation, and maintenance plan all have an impact on the preliminary design. For example, in power stations, we must ask whether the water tank can be repaired, maintained, or cleaned. The answer to this question includes a decision on whether the station needs additional tanks as standbys for maintenance purposes.

In this phase, many other initial design decisions must be decided and, therefore, as previously noted, the parties involved must have extensive experience. An error at this stage could lead to a major problem in the future during operation, when it will cost a lot of money to resolve. Situations like that can be prevented at this stage by a low-cost solution.

2.3.3 Detail Engineering

At the end of this phase, the engineering office will deliver the full construction drawings and specifications for the whole project, which contain all the details that enable the contractor to execute his function. In this phase, there will be a huge number of engineering hours, so there must be good coordination between the different disciplines. This will happen if there is good organization in the engineering office and if the client provides a free mode of communication between the different parties through a system channel with continuous coordination.

The complexity of this phase is such that it needs a quality system. Imagine that you work in an ideal office where everyone's duties are understood, no person comes to work late, the work comes to you in an appropriate manner, and no one ever lets you down. Do you work in an atmosphere like that right now? I doubt it.

As engineers, we always believe that, in an ideal case, all of our lives depend on accuracy. Teamwork does not have this accuracy and is not precise, as all of our experiences at work tell us. Discouraging and disheartening events happen daily, which often means that the work arrives late, in a bad manner, or requires correction before you can complete your work in an efficient manner.

Sometimes there will be changes made in your company or your office without any prior notification to you. This presents obstacles and wastes time. This is the basis of a quality assurance system. When people change, some change might occur in the cooperation between departments. This varies depending on the performance of the managers and the impact they have on work. A system of quality assurance is beneficial because it ensures the basic functioning of all departments, regardless of personnel changes. These problems often occur at a stage in the studies that requires extensive and vital cooperation among the various departments of engineering (civil, architectural, mechanical, and electrical departments).

When the managers of the departments of civil and mechanical engineering have a strong relationship, the work goes well, regular meetings are held, and meetings and correspondence will be fruitful. If one of the department heads is replaced and the new relationship between the two departments is not good, you will find that the final product is also not good. There will likely be no regular meetings. We find that many of these problems do occur; we do not live in a perfect world. The main player who can solve this crisis is the project manager.

You can easily determine whether your business might benefit from a quality assurance system by taking a closer look if you have a bad experience. Does your work suffer because it depends on the work of colleagues who do not complete their tasks or who perform their work poorly? If the answer is yes, then you need a system of quality assurance.

A system of quality assurance is important at this stage because it organizes the work. The target of the project and each team member's responsibility is clear. The concept of quality is defined by supporting documents. The documents are regarded as the executive arm of the quality assurance process. For example, any amendment or correction in the drawings should be made through the agreed procedure and system. Moreover, the drawings should be sent in a specified time to the client for review and discussion, with an official transmittal letter to control the process time. If there are any comments or inquiries, they should be done through agreement between the two technical parties and then the modification should be done by the engineering firm and resent to the client through the same communication procedure.

The development of a system to avoid older copies of the drawings becoming confused with the current copies can prevent human error. The most current set of drawings may be assured by the establishment of a system for continuous amendment of the date and number of the drawings and engineering reviews until the final stage of the project and the approval of the final set of drawings is sealed with a stamp ("Approved for Construction") indicating that these are the final drawings approved for the construction.

After the completion of the detailed engineering phase, the specifications and drawings are ready to be used in the execution phase. You can imagine that in some projects the documents may reach hundreds of volumes, especially the specifications, operation manual, and volumes of maintenance and repairs.

2.3.4 Design Management

The goal of design management is to control the design stage to provide high quality at a better price.

- The design input comprises all technical information necessary for the design process. The basis of this information is the owner through the SOR document, so the engineering firm should review this document carefully, and if there is any confusion or misunderstanding, it should be clarified in the document and through meetings.
- Instructions for control of the design, whether the client controls the whole process or requests some specific action (e.g., a representative from the audit during the design phase) are often provide in the contract.
- The designer must take into account the available materials in the local market in relation to the project and its location and match these with the capabilities of the owner. The designers must have a realistic view and full and up-to-date knowledge of the best equipment, machinery, and available materials.
- The design must conform with the project specifications and the permissible deviation and tolerance should be in accordance with the specifications and requirements of the owner.
- Health, safety, and environment are the most critical subjects these days, so every design should conform to health, safety, and environmental regulations.
- The computer is one of the basic tools used now in the design process as well as in the recording and storage of information and offers the ability to change the design of the work easily. It is now easy to modify the drawings by using Computer Aided Design (CAD) software in order to obtain more precise information with the access to various tables and diagrams.
- The design output must be compatible with all design requirements, and the design should be reviewed through internal audit. The design must be compared with old designs that have been approved before for similar projects. This is a simple procedure for checking designs. Any engineering firm should have a procedural checklist for reviewing designs.

The audits of the design review are intended to be conducted on a regular basis at important stages in the design. The audit must require complete documentation and can take analytical forms such as the analysis of collapse with an assessment of the risk of failure.

2.3.5 Execution Phase

Now that everything is ready for the execution stage, it requires both quality assurance and quality control, especially in the reinforced concrete works where the concrete itself is composed of many materials such as cement, sand and coarse aggregate, water, additives, and steel bars. Therefore, it is essential to control the quality of the received materials as well as the whole mixture. The quality control should follow strict guidelines during all of the construction phase.

It is clear here that the contractor should have a strong, capable organization to achieve good quality control as well as to confirm the existence of documents that define the time and the date on which the work was carried out, who received the materials, who determined the number of samples of concrete, what has been tested by compression, and the exact time, date, and result of each test.

Often during the execution, there occurs some change in the construction drawings of the project as a result of some problems at the site during the construction or the introduction of some ideas or suggestions to reduce the time of the project. It is important that the change of work be done through the documents to manage the change. This called *management of the change document* and requires the approval of the discipline concerned and also approval from the engineering firm. Finally, all of these changes should be reflected in the final drawings.

The supervisor and the owner must both have special organizations. The owner organization in most cases has two scenarios:

- The owner establishes an internal team from the organization to manage the project.
- The owner chooses a consultant office to manage the supervision on-site; in most cases, the design office will do the supervision.

The construction phase shows the contractor's capability for local and international competition if, and only if, the concept of quality assurance for the contractor's project team is very clear and they have experience in a comprehensive quality system. All competitors on the international scene work through an integrated system whose aim is to confirm the quality of the work and control the quality in all stages of execution to achieve full customer satisfaction.

2.3.6 Commissioning and Start-Up

The importance of this stage varies depending on the nature and size of the project itself. In industrial projects such as the construction of pipelines, pumps, turbine engines, or a new plant, a new team will be assembled consisting of project members, operating personnel, and the head of the team.

This team should be competent and have previous experience in commissioning and start-up. The team will have a specific target of starting the operation. The reception is not performed until after the primary operation start-up and commissioning, which at this stage is to make sure that all the mechanical systems work efficiently and safely without any leakage or error in the operation. The length of this stage depends on the size of the project and may extend to months. It is important to have competent personnel at this stage, as it has special characteristics. The cooperation between the operation and project team is essential; communication skills must be at the highest level. The operation starts according to a specific schedule, which can be measured in hours, and all parties should agree to this schedule to provide a smooth transition zone in a safe manner. Increases in temperature or pressure to any equipment without previous study can lead to disaster.

2.4 Is This Project Successful?

When you see a huge oil or gas plant, do you ask yourself, "Is this a successful project?" Although profit and money may come to mind, the focus should be on the management of the project to determine whether it is successful. You see a high-rise building and you say that the project is successful, but is the project manager successful, too? To answer this question, you need to answer the following three questions:

1. What is the plan and actual execution time?
2. What are the actual costs and the budget?
3. Is the project performing according to required specifications?

For the last question, we can answer yes for the big project. We cannot agree or approve anything with low quality or that is beyond the specification. You may assume that quality is a red line that we cannot cross or negotiate. Therefore, the successful project manager has to achieve the goal of the project and satisfy all stakeholders while completing the project on time and within the approved budget.

2.5 Project Management Tasks

Every manager in the project organization is responsible for planning and monitoring the plan and assuring that the execution matches the plan.

To achieve this, the project manager should coordinate with and provide a report to other managers. The main items involved in the planning and monitoring process are:

- Define project objective
- Define work
- Define work period
- Define the available and required resources
- Define cost
- Review and evaluate the master plan
- Accept the master plan
- Follow-up execution
- Follow-up cost
- Compare actual work, cost, and master plan
- Evaluate performance
- Predict and change strategy

The definition of project management is illustrated in Figure 2.4. The first task of project management is to identify the target of the project management process in the planning, execution, and follow-up. There are three key factors involved: resources, time, and funding.

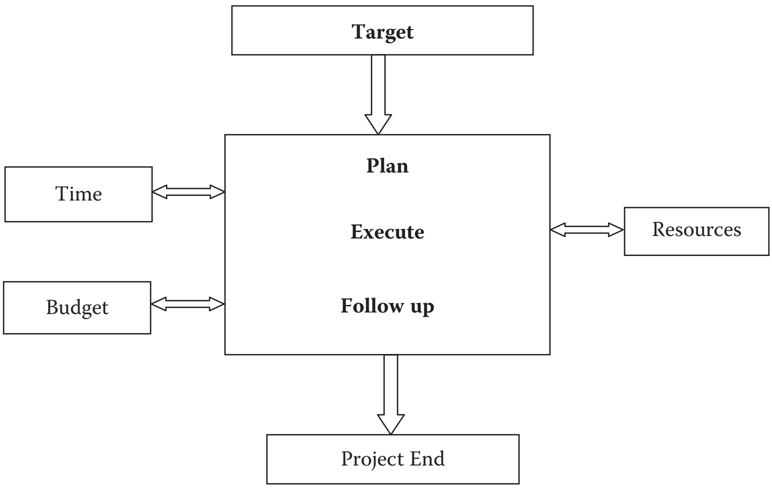

FIGURE 2.4
Project management.

2.6 Project Manager Skill

From the previous discussion, it is obvious that the main player in any project is the project manager, as he carries the biggest load. He is responsible for assembling the team.

When thinking about the selection of the project manager, we must ensure that his role is different from the operational and routine work, as the project is unique and not repetitive.

Therefore, the project manager must be flexible, because the project changes from time to time, for example, at the beginning of the project, there is a small number of individuals and the number increases with time. Then, near the end of the project, the number decreases. The behavior of the project manager must be flexible according to the variables of the project.

The project manager deals with different individuals of all levels from various departments and also with other parties dealing with the project. It is important that the project manager be a good listener and be able to offer guidance and persuasion. Previous experience on the same type of projects is important and provides the necessary technical information to manage the project in an efficient manner. The project manager must also be skilled at managing time, costs, resources, communications, and contracts.

The skill of communication is very important, as the facts do not express themselves; the best idea in the world would not be known without communication. At the lower levels, it is important to provide specific and clear instructions because a misunderstanding causes loss of time and increased costs. On the other hand, communication with the higher levels of the organization is necessary to provide summaries of the performance of the project in a way that allows senior management to understand and aid the project. Finally, the project manager must have the ability to visualize the completed project and have an accurate and broad vision for the whole project, with the capability to manage the dialogue, especially during meetings. This is regarded as the most useful means of communication to reach the goal, which is the success of the project.

2.7 Project Planning

The initial and basic principle of project management is how to read the time schedule, which is a real representation of the nature of the project, with the expectation of what could occur as a result of implementation. The next important step is to determine the purpose of the project and then answer the following question, “Is the driving force time or costs?” Then, the project manager must draw up a timetable with the project represented as a whole range of self-contained but interrelated activities.

For more than 20 years, schedules have been prepared manually. Since the developments in the field of computers, programs are now used to deliver the time schedule. In general, there is more than one method to draw up a time schedule for the project and this happens according to the nature of the project and the required presentation that will be provided to senior management.

We must recognize that the preparation of the schedule is the cornerstone of the management of projects and will follow the work schedule and the allocation of human resources and equipment, as well as the distribution of costs along the project period with the identification of ways to control costs.

In the beginning of 1900 and during World War I, Henry L. Gantt used the first method for preparing a project schedule. This is considered the first scientific method for the preparation of schedules. This simple method of representing activities with rectangles is used in project planning and work schedules at the time of production. The Gantt chart is set up by putting the plan on the magnetic blackboard and using rectangles made of iron and with length as a time unit. This was developed to be an (S) curve and is considered the first method to follow up the project with different activities by distributing the resources on the activity and monitoring the performance.

Until the mid 1950s, there had been no mention of development in project planning. In 1957, there were two different teams working on project planning using networks. The first team was prepared by using the Program Evaluation and Review Technique (PERT); this method depends on probability theory. The second team used a network and depended on the Critical Path Method (CPM). The methods of those networks have the same methodology; the difference is in the objectives. The development is done through operations research.

The first use of the PERT method was when the U.S. Navy was faced with a challenge in the POLARIS system, as they wanted to make rocket launchers in record time in 1958. The basics of the PERT method involved overcoming the lack of definition of activity duration time and used statistical methods to calculate it. This was done by defining the maximum, minimum, and most likely time for each activity, and obtaining the likely time of completion of the project, important parts of the project, and the minimum and maximum probable times to complete the project.

CPM was introduced in 1957 by two companies, Du Pont and Remington Rand Univac. The objective of the working group was to reduce the time for maintenance, overhaul of the rotating machines, and construction work.

It is noted that the calculation of the time required for different activities can easily be applied to projects other than POLARIS activities, as we need to identify one expected period only for each activity and the longer timetable for the course of the series of activities has been defined as the critical path.

CPM is the most common way of networking activities in project planning. It is used along with other methods by computer software. The process of planning is simply planning what will be done on the project in accordance with the order and manner of the execution of the project. Often there will be some changes and they should be followed up and the time schedule adjusted should be in accordance with the changes in the project as well.

To do the work with good planning, you must answer these questions clearly:

What are the activities that you want to do?

When will these activities be executed?

Who will execute the activities?

What are the equipment and tools required?

What are the activities that cannot be executed?

The answer to the previous questions is the key to arranging the work in an appropriate way.

So the project will be understandable, your goal is to transform information in a way that it can be presented to all parties in the project and be clearly understood by all. Your planning team target is to implement the project in a timely manner and in accordance with the specific cost requirements and, at the same time, achieve the required level of quality. Project planning requires the following goals:

- Reduce the risks of the project to the lowest level possible.
- Achieve the performance specifications for the project by establishing an organization for the implementation of business.
- Develop procedures to control the project.
- Achieve the best results in the shortest possible time.

The planner cannot plan for every minute of the project in detail because of the nonavailability of all information. As the work goes on, new details will require an increase in the effort and time to adjust the timetable in accordance with the new information and details.

2.7.1 Who Will Make the Plan?

In simple terms, this should be done by the project manager with the planning team. At the outset, though, it will be necessary to determine if a team will work and if you have sufficient information about their potential and their relation to the size of the project. You will also need to determine if you want to use an experienced planner from another project or contract someone to work with you for some time at the beginning of the project.

You should also know, through the collection of information, if the working group has worked in similar projects or projects that had similar activities. For example, if you are working on an oil and gas project, has the working group worked on the same type of projects before? The project will differ from the construction of housing projects, hotels, road projects, or industrial projects.

Each type of project has its own characteristics, but the working group should have worked on projects similar to your project. The draw is that you must have the human element of efficient planning and the ability to plan the project well. At the beginning of the work, the meeting of the planning group is attended by the official sponsor of the project, the director of the project, and the owner and his representative. In this meeting, the emphasis is on clarification of the main objectives of the project and identification of priorities in the implementation of the driving forces with the presentation of the project. Is it a time- or cost-driven project? What is desired from the project as a whole?

2.7.2 Where Do You Start the Plan?

Some basic definitions are as follows:

- A task is a small job done by one person.
- An activity is a part of the project that is composed of a set of tasks and performed by different individuals.
- Concurrent activities are activities developed in planning to be implemented in parallel.
- Series activities are activities put in the plan, that needs to be executed one after the other so that the second activity does not begin until the first activity is finished.

To be clear, the difference between an activity and a task is that the activity is a set of tasks or work. For example, the preparation of the report is an activity but it is carried out through a series of tasks or functions that are as follows:

1. Information collection
2. Data analysis
3. Initial report preparation
4. Graph generation
5. Final draft preparation
6. Printing of final version

You are now in a phase where it is difficult to know how to start planning. There are many ways and you have to choose among them. The first way to start is to identify the key stages of the project. The key stages of the project will be identified by holding a meeting with the experienced persons in the project team from different disciplines, the stakeholders, and the sponsor. In this meeting, use a brainstorming technique among the attendees. Every person will write his or her suggestions on paper, which will be posted on the wall, to be seen and commented on by all members at the meeting.

The collected papers will contain all the ideas and contributions, regardless of whether they are logical or illogical. An electronic blackboard may be used in some cases. It is important for the specific aim of this exercise that we follow these rules during the meeting:

- Be concerned about quantity and not quality, even if it turns out that some of the tasks and activities have been replicated.
- Avoid any idea of critical observations that would bother participants.

The list that is obtained now is not arranged in any type of order, importance, or time. When you find that all individuals have put forth all the ideas they have, stop the brainstorming. The next step of the action team is to filter the activities. This is done by removing tasks that are repetitive or duplicates and then compiling the tasks there, including the interdependence of both straight and parallel tasks. After reduction, the small number of tasks and activities is often within the range of 30–60, according to the size of the activity and the project. Compile the activities into key stages of the project. By using this method, you will reach precision in planning of up to about 90%, and this is considered the beginning in the planning of the project as a whole.

Now that you have the main stages of the project and all the key stages have been agreed on by the members of the project, you will be arranging them in a logical order. You should avoid the following:

- Avoid defining time or dates.
- Avoid the allocation of employment to those stages.

It is not easy to avoid doing these things, but they will cause problems. To avoid mistakes in the project planning logic control, the key stages must be written on the blackboard on the main wall of the office. Figure 2.5a and b shows an example of the main stages of the draft.

The advantages of this method are that everyone's ideas and opinions on the project is included, which makes them invested in the success of the project. Note that in Figure 2.5, the design phase has been divided into two stages (Figure 2.5a and b) to allow the sending of purchase orders before the end of the first phase of the design. You now have information that can be

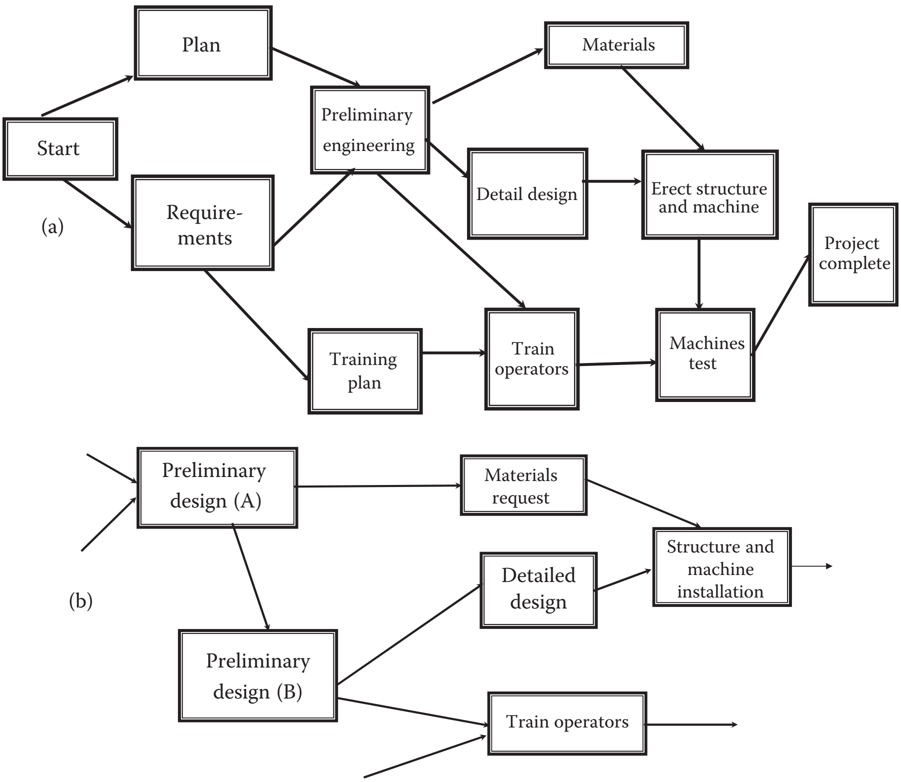

FIGURE 2.5
(a, b) Project key stages.

used in the computer software to prepare a time schedule for the agreed plan for the project.

The basic rules that must be adhered to and strictly followed in the preparation of a project schedule are as follows:

- Movement activities are from the left to the right.
- There is no measure of time.
- Start with the biggest and topmost square. Make sure there is an empty place on the page for each major stage in the project.
- Each phase is described in the present tense.
- The pages are developed in accordance with the logical arrangement.
- Communicate between the different stages of the project.
- Identify responsibilities.

- Ensure connectivity between the stages.
- Avoid the intersection of the stock as much as possible.
- Identify each key stage by professional codes.

2.7.3 Work Breakdown Structure

Figure 2.6 gives an example of a work breakdown structure (WBS). It shows a common project consisting of three pipelines: a pipeline to transport water, a pipeline to transport crude oil from the plant to storage, and a third pipeline to transport gas from the production plant to the treatment plant.

In this project, the work is divided into more than one level. The first level of the main stage in the pipe example shown in Figure 2.6 consists of

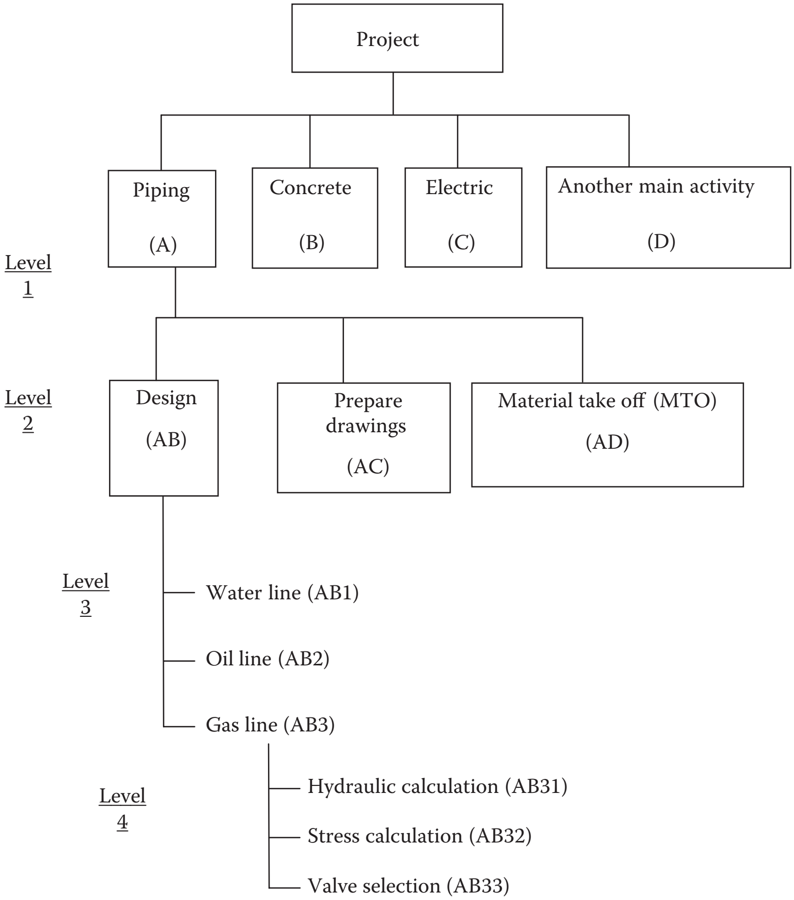

FIGURE 2.6
Work breakdown structure.

the concrete and electrical work. The second level involves more than one stage as the drawing of the designs and the calculation of materials begin. Level 3, in this example, focuses on the design phase and will be divided into stages for the design of each pipeline: gas, oil, and water. At the fourth level, we design a gas pipeline by performing a hydraulic design and pipe stress analysis to choose the thickness of the pipe and the base locations. The subsequent stage involves the selection of the required valves. There may be several stages, depending on the nature of each project.

We note each stage using the appropriate level code for ease of use later. WBS can be completed at any level of description. It does not explain the relations between the activities or show the time or length of time for any activity.

After you have selected the main stages and WBS, the next step is to develop a rough schedule of time for the project. However, you must first define the responsibilities.

2.8 Responsibilities of the Planning Team

The planning team is responsible for preparing the schedule at this stage and has the vital role of distributing the main stages of the project to the team members. Every main stage has a key stage owner (KSO) and it is that person's responsibility to reach the required target in a reasonable amount of time. This involves:

- Defining the work down to the smallest task level
- Ensuring that relations between activities and tasks are clearly defined
- Estimating time with high accuracy
- Ensuring that business is done in a timely manner in accordance with the required quality expectations
- Ensuring that work is proceeding in accordance with the procedures and requirements for quality assurance
- Maintaining the ongoing follow-up
- Ensuring that there are periodic accurate reports

There are some problems that the KSO will face during the project and they should be resolved in a timely manner. The KSO must have:

- The necessary authority to complete the work
- The necessary tools to complete the work
- The right atmosphere to achieve the required quality of work

- Direct support from the project manager or the official sponsor of the project
- Clearly understand performance expectations

When the project manager chooses the KSO for each state, the following should be considered:

- Skills
- Depth of information and knowledge
- Previous experience in the same area
- Rapid completion of work
- Accuracy in the completion of previous work
- Ability to solve problems
- Ability to manage time
- Ability to work as an individual and with a team
- Volume of work
- Ability to offer advice, be supportive, and work under stressful conditions
- Amount of current or future training required

Now that the key stages plan is available and every key stage has a defined person responsible, it is time to begin estimating the time required for each activity of the key stages.

2.9 Estimating Time Required for an Activity

To determine the time required to finish any task, you must know the resources available to perform the work at the required level of quality. To do that, you must know the following:

- The task volume, if it can be measured. For example, first, calculate the time required to prepare the wood form to pour 100 m^3 of concrete for the foundation and, from that, the task volume can be known.
- The work required to finish this activity (by hours, days, or weeks)—noting that the number of workers should be identified and the capability of each worker to perform the task alone should be considered.

The working capacity of a worker will usually be measured in days. You should take care to avoid the pitfalls that usually trap young engineers. For example, you should decrease the capacity of work per day by about 50%, as all of the hours per day do not focus on project activities. Much time is wasted in meetings or special discussions and also by routine events such as bathroom breaks, eating, etc. Moreover, there is some delay involved in the work itself.

After you define the period for each task, keep in mind the other traps when you put it on the calendar. The total time length will be different due to the following factors:

- Weekends
- Official vacations and holidays
- Annual leave for employees
- Work stoppages

It is worth noting that defining the performance rate for each activity depends on the normal rate that is found in textbooks or standard guides for contractors, but it is essential to obtain information from others with experience in the same country, the same location, or from previous projects.

From here, we cannot disregard past experiences. If an activity is the same as in similar projects—pouring concrete foundations, for example—we should use materials and procedures of the same type, preferably from the same location. This is particularly true of remote areas such as the desert because they are more challenging than cities, where there is available labor and higher efficiency of employment.

When you ask individuals and experts for information, you should keep in mind that not everyone has accurate information. It is human nature for good things to remain in memory and bad experiences are erased from the mind with time. When someone says that the expected time for an activity was 18 days, but it was finished in 10 days, that person clearly considers this to be a success story and will keep it in mind for a long time. However, as a rule of thumb, no one can work 100% of the time and that 20% to 50% of time is wasted in the following activities:

- Unnecessary meetings
- Interoffice visits
- Newspapers and mail
- Research
- Assisting or advising others
- Office equipment failure
- Regular daily activities
- Misunderstandings between team members

- Lack of specifications or SOW
- Lack of quality specifications
- Training

2.9.1 Calculating Time Required for an Activity

There is a method of calculating the time required for an activity through the use of performance rates. For example, to calculate the time required to excavate 15,000 m^3 of soil, you must first determine the method of excavation. In this example, that method has been identified as equipment, specifically two bulldozers, two loaders, and four trucks to transport the soil. The performance rate of one bulldozer is 120 m^3/h and the performance rate of one loader and two trucks is 75 m^3/h.

$$\text{Rate of excavation} = 2 \times 120 = 240\ m^3/h$$

$$\text{Time required for excavation} = 15{,}000/240 = 62.5\ h = 9\ \text{days}$$

$$\text{Rate of soil removal and disposal} = 2 \times 75 = 150\ m^3/h$$

$$\text{Time required for removal and disposal} = 15{,}000/150 = 100\ h = 15\ \text{days}$$

Therefore, the excavation time is about 9 days and the disposal of the soil takes about 15 days. Taking into consideration the number of working hours in the day, which is only 7 hours for the purposes of the timetable. For the excavation activity, take the largest period, which is 15 days. However, the excavation may be immediately followed by the pouring of plain concrete. That may begin after 9 days because there is no need to wait until the waste has been removed from the site.

2.9.2 Time Schedule Preparation

We have already discussed the most common ways to draw up a timetable and also how to map along the CPM and PERT. The most important factors in the preparation of the time schedule are to identify the activity, determine the time required for its implementation, and identify relations between the activities. We discussed how to determine the activities and the amount of time required for each activity; we must now determine how to arrange the activities around each other. The different, common relations between activities are shown in Figure 2.7.

1. Activity B cannot start until Activity A is through.
2. Activity A and Activity B start at the same time.
3. Activity A and Activity B finish at the same time.

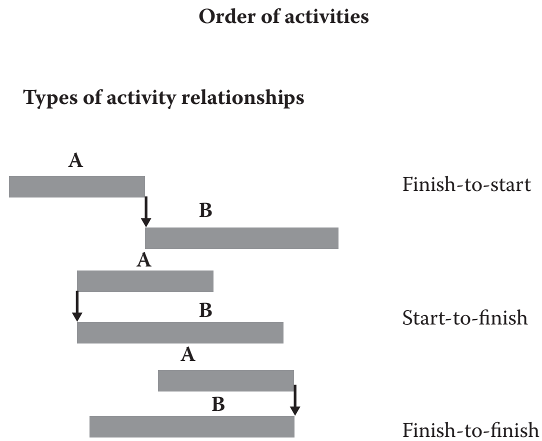

FIGURE 2.7
Order of activities.

In some cases, Activity A may start and, after a certain period, Activity B will start. This period is called "lag time." A computer can do this task easily. For manual preparation, there are two main methods: the arrow diagram and the precedence diagram, as shown in Figure 2.8.

2.9.3 Arrow Diagram

This diagram depends on defining each activity by an arrow, as in Figure 2.8. The point of connecting arrows is called a node and drawn as a circle. As in Figure 2.8, Activity A depends on Activity B. Activity C depends on Activity

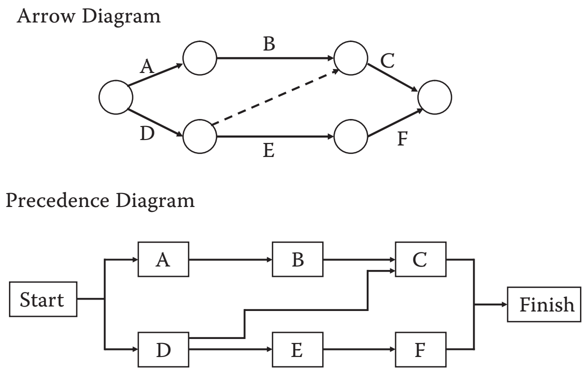

FIGURE 2.8
Tools for arranging the activities.

B and Activity D, but there is no activity line between Activity D and Activity C. So, we use a dummy arrow with time zero to solve this problem. However, using dummy arrows for large activities will present a problem, so the use of a precedence diagram is now more popular.

2.9.4 Precedence Diagram

In this method, which is the most common, every activity is represented by a rectangle, as shown in Figure 2.8. Figure 2.9 shows the rectangle in detail. From these figures, it is easy to see that Activity C starts after Activity D and Activity B.

Figure 2.9 presents the inside of a rectangle where the duration of the activity will be written, as well as early start (ES), early finish (EF), latest start (LS), and latest finish (LF) times.

2.9.5 Gantt Chart

In general, relations between activities are in series or parallel. The relation depends on the nature of the activity and this should be considered in preparing the time schedule.

The Gantt chart is an old, traditional method used until recently to present project schedules (Figure 2.10). The relations between all the activities are not well presented by this method and you cannot go through detailed activity accurately, so it is not a good presentation method for high-level management. It is detailed enough for one level of the schedule, but for more detail, there needs to be another method for scheduling (Figure 2.11).

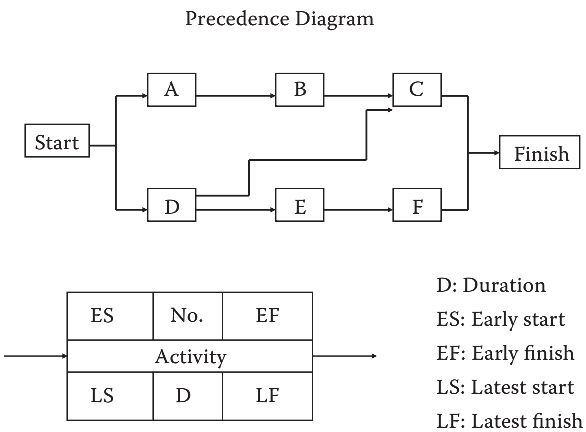

FIGURE 2.9
Method of creating a precedence diagram.

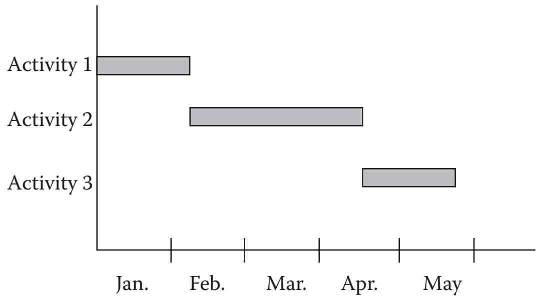

FIGURE 2.10
Example of a Gantt chart.

2.9.6 Critical Path Method

The essential technique for using CPM is to construct a model of the project that includes a list of all activities required to complete the project, the time required for each activity to be completed, and the dependencies between the activities.

Using these values, CPM calculates the longest path of planned activities to the end of the project and the earliest and latest times that each activity can start and finish without making the project longer (Figures 2.12 and 13). This process determines which activities are critical (i.e., on the longest path) and which have "total float" (i.e., can be delayed without making the project longer). Any delay of an activity on the critical path directly impacts the planned project completion date (i.e., there is no float on the critical path). A

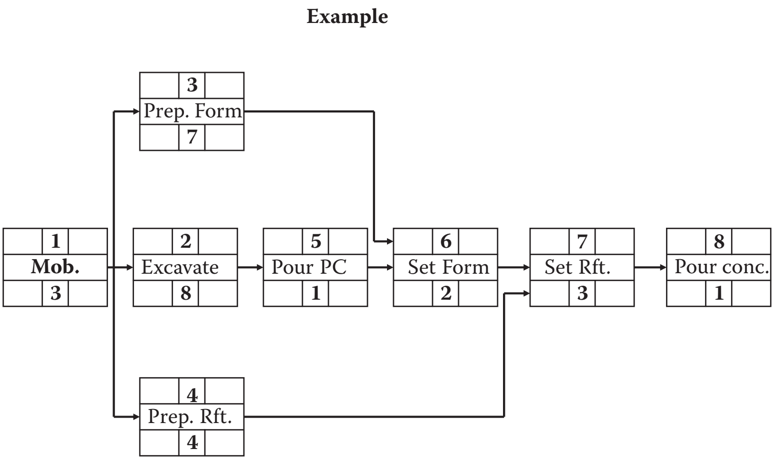

FIGURE 2.11
Precedence diagram example.

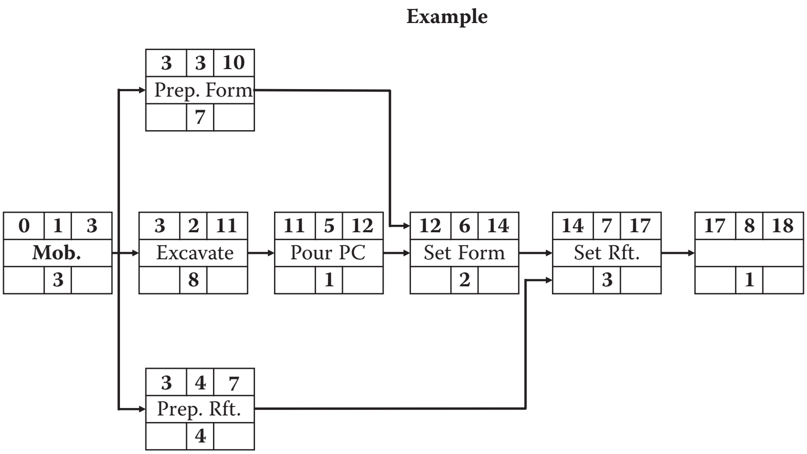

FIGURE 2.12
Calculate the early times.

project can have several critical paths. An additional parallel path through the network with total durations shorter than the critical path is called a subcritical or noncritical path.

2.9.7 Program Evaluation and Review Technique

PERT is required for the execution of special projects or large-scale deliveries with a variety of activities. These activities need to be accurately identified, as do all activities involved in the project that must be completed. The

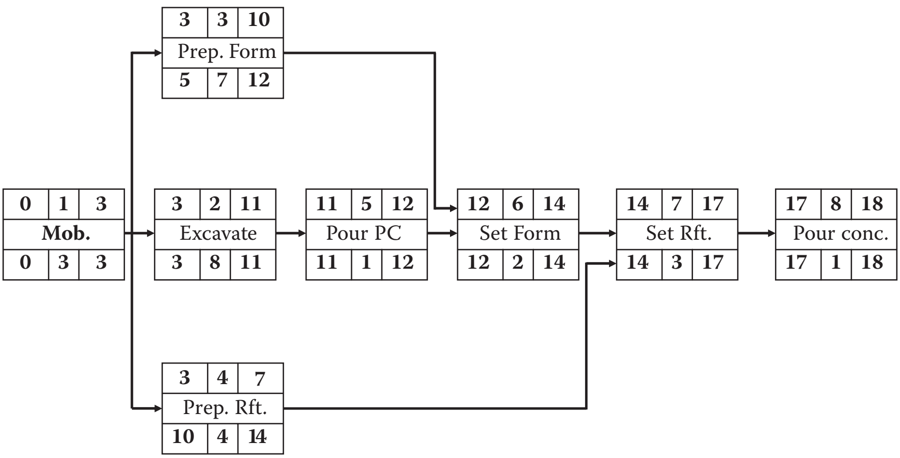

FIGURE 2.13
Calculate the latest times.

completion of these activities must be initiated and carried out in a specific sequence, particularly any activity that must be completed before the start or completion of other activities or that may occur in relay of parallel activities, meaning two or more activities could be completed at the same time.

In addition, there are specific achievements that indicate the completion of key sectors of the project. The successful implementation and management of such projects must be carefully planned to speed up the delivery during a specified period, to coordinate the multiactivity of the project, to monitor the use of various resources necessary for its implementation, and to achieve the project on time and within budget cost.

Although PERT was designed mainly for military purposes, it has been used successfully since 1959 in most large-scale projects. PERT analysis is used in a number of areas of the computer and construction industries in planning shutdowns for maintenance in refineries.

This analysis has confirmed its applicability and importance in different projects. An example of its success for contracting companies was its role in solving the problems of coordination between various activities in a large project of a considerable degree of complexity and in planning the time required for the implementation of each activity in Montreal, Canada, in 1967. This method made it possible to complete the project within the scheduled time.

PERT was developed to simplify the planning and scheduling of large and complex projects. It allowed the incorporation of uncertainty by making it possible to schedule a project even without knowing the precise details or durations of the activities.

2.9.8 Example

Table 2.1 illustrates the relation between activities and how you can create a schedule through the precedence diagram. It shows the activities required for a cast concrete foundation, which is a simple example that shows how to arrange activities and how we can account for the overall time of the project and identify the critical path.

TABLE 2.1

Example of a Foundation Project

Item	Activity	Time (days)	Precedence Activity
1	Mobilization	3	–
2	Excavation	8	1
3	Preparation of wooden form	7	1
4	Preparation of steel reinforcement	4	1
5	Pouring of plain concrete	1	2
6	Setting wooden form	2	3, 5
7	Setting reinforcement	3	4, 6
8	Pouring concrete	1	7